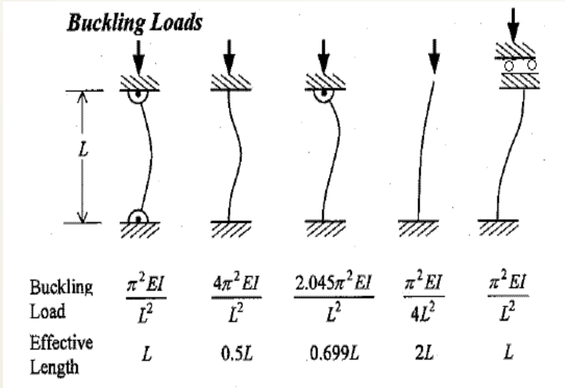
# ADVANCED STRUCTURAL ENGINEERING LABORATORY MANUAL





## Vision of the Department

To provide quality education embedded with knowledge, ethics and advanced skills and preparing students globally competitive to enrich the civil engineering research and practice.

## Mission of the Department

- To aim at imparting integrated knowledge in basic and applied areas of civil engineering to cater the needs of industry, profession and the society at large.
- To develop faculty and infrastructure making the department a centre of excellence providing knowledge base with ethical values and transforming innovative and extension services to the community and nation.
- To make the department a collaborative hub with leading industries and organizations, promote research and development and combat the challenging problems in civil engineering which leads for sustenance of its excellence.

## Program Educational Objectives (PEOs)

**PEO I:** TO prepare the students with comprehensive and in depth understanding of knowledge and research directions in structural engineering discipline

**PEO II:** To Prepare the students applying the established engineering methods and software to solve complex and challenging engineering problems

**PEO III:** To inculcate ethical practices making the students creative, innovative and pro-active demeanour and understand the significance of lifelong learning in global perspective.

## Program Outcomes (POs)

A post graduation student should able to

a. Provide technical and engineering solutions for structural engineering problems using the knowledge of science, mathematics and basic engineering concepts.
b. Analyse complex structural engineering problems critically and apply them in practice using adequate theoretical background.
c. Evaluate feasible and optimal solutions by considering safety and environmental factors.
d. Demonstrate the ability to carry out research by pursuing literature survey and conducting experimental studies in laboratories.
e. Develop and use the latest software to solve structural engineering problems.

f. Attain the capabilities to work in multi-disciplinary teams to achieve common goals.
g. Possess inbuilt social ethics and professionalism.
h. Use the modern tools for interpreting the behaviour and response of complex engineering structures.
i. Use the latest technology software to solve complex structural engineering problems.
j. Prepare detailed project reports and develop academic communication skills to present the technical data of the projects before a team.
k. Understand the responsibilities of carrying out the professional practices ethically for sustainable development of the society.
l. Develop aptitude towards learning new innovative technologies in structural engineering.

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# TWO HINGED ARCH

**EXPERIMENT NO: 1** **Date :**

# TWO HINGED ARCH

**AIM:**

1) To study experimentally a two hinged arch for the horizontal displacement of the roller and for a given system of loading and to compare the same with those obtained analytically.
2) To obtain the influence line ordinates for horizontal thrust experimentally in a two hinged arch by moving a load along the span and to compare the span with those obtained theoretically.

**APPARATUS:**

1) The model has a span of 100 cm and rise of 25 cm. here both end are hinged but of the end is free to move longitudinally.
2) A level arrangement is fitted at its end for the application of know horizontal inward force for measuring the horizontal thrust. along the horizontal span of the arch various points are marked at equidistant for the application of load .
3) This being a statically indeterminate structure of the 1 degree a dial gauge with magnetic base is supplied with the apparatus.

**PROCEDURE:**

1) Fix the dial gauge to measure the movement of the roller end and keep the lever out of contact.
2) Place a load of 0.5 kg on the central hanger of the arch at removes any slackness and taking this as initial position and set the reading on dial gauge to zero.
3) Now add 1 kg weights to hanger and tabulate the horizontal movement roller end with increase in the load in steps of 1 kg, take the reading up to 5 kg .dial gauge reading should be noted at the time of unloading also.
4) Plot a graph between the load and displacement. Theoretical values should be computed by equation 4.
5) Now move the lever in contact with 200 gm hanger on ratio 4/I position with a 1 kg load on the 1 hanger. set the initial reading of the dial gauge to zero.
6) Place additional 5 kg load on the 1 hanger without shock and observe the dial gauge reading.
7) Restore the dial gauge reading to zero by adding loads to lever hanger say the load w kg.
8) The experimental value of the influence line ordinate at the 1 hanger position shall be 4w/5.
9) Repeat the steps 5 to 8 for all the other hanger loading positions and tabulate plot the influence line ordinate.

## OBSERVATIONS AND CALCULATIONS:

ILU=5 WL $(a-2a^3+a^4)/8r$

Horizontal displacement ( $\Delta$) =5 $WL^2r/48$ EI

| Central load (kg) | Observed horizontal displacement(mm) | Calculated horizontal displacement(eq .4) |
|---|---|---|
| 0.0 | 0.0 | 0 |
| 1.0 | 0.25 | 0.53 |
| 2.0 | 0.4 | 0.106 |
| 3.0 | 0.64 | 0.159 |
| 4.0 | 1.07 | 0.212 |
| 5.0 | 1.26 | 0.265 |
| 6.0 | 1.58 | 0.378 |

| Load on 5 kg applied to hanger number | ‘W’ kg req on lever 4/I ratio to balance 20 kg load | ILO using eq.5 |
|---|---|---|
| 1 | 400 | 1.22 |
| 2 | 650 | 2.32 |
| 3 | 900 | 3.17 |
| 4 | 1000 | 3.72 |
| 5 | 1100 | 3.9 |
| 6 | 1000 | 3.72 |
| 7 | 900 | 3.17 |
| 8 | 650 | 2.32 |
| 9 | 400 | 1.22 |

## RESULTS & DISCUSSIONS:

Compare the two results obtained theoretically & analytically

# THREE HINGED ARCH APPARATUS

**EXPERIMENT NO: 2** **Date :**

# THREE HINGED ARCH

**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.

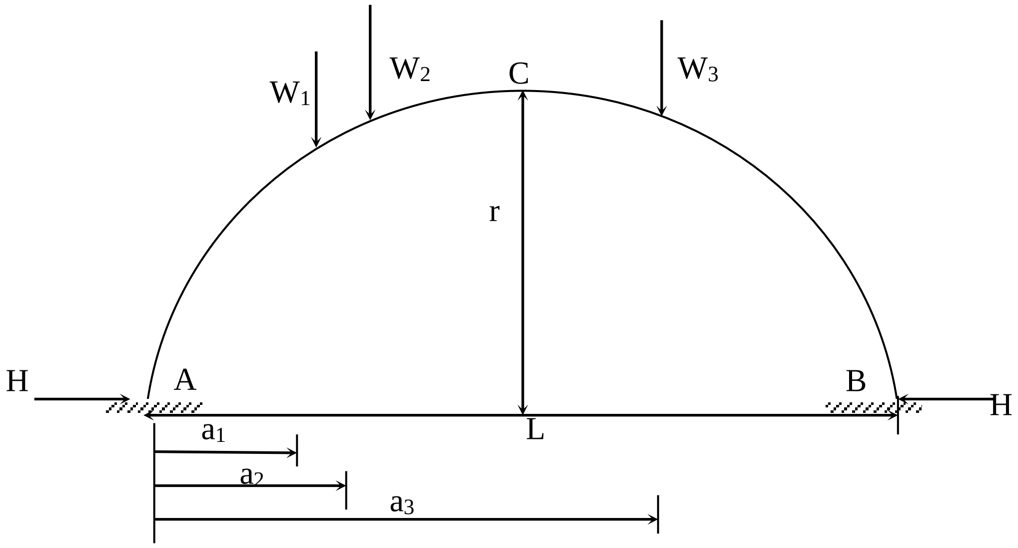
To obtain influence line diagram for horizontal thrust in a three hinged arch experimentally and to compare it with the calculated values.

**APPARATUS:**

The model has a span of 100cm and rise 25cm, with hinges at supports and crown. One of the ends rests on rollers. Along the horizontal span of the arch various points are marked at equidistant (10cm) for the application of load. A dial gauge with magnetic base is supplied with the apparatus.

**THEORY:**

A three hinged arch is a statically determinate 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 A

$$R_B \times L = W_1 a_1 + W_2 a_{2+} + W_3 a_3$$

$$R_B = \frac{W_1 a_1 + W_2 a_{2+} + W_3 a_3}{L}$$

Taking moment about B

$$R_A = \frac{W_1(L - a_1) + W_2(L - a_{2)} + W_3(L - a_3)}{L}$$

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

$$H \times r + W_1\left(\frac{L}{2} - a_1\right) + W_2\left(\frac{L}{2} - a_2\right) = R_A \times \frac{L}{2}$$

$$H = \frac{1}{r}\left[\frac{1}{2}[W_1(L-a_1) + W_2(L-a_2) + W_3(L-a_3)] - W_1\left(\frac{L}{2} - a_1\right) - W_2\left(\frac{L}{2} - a_2\right)\right]$$

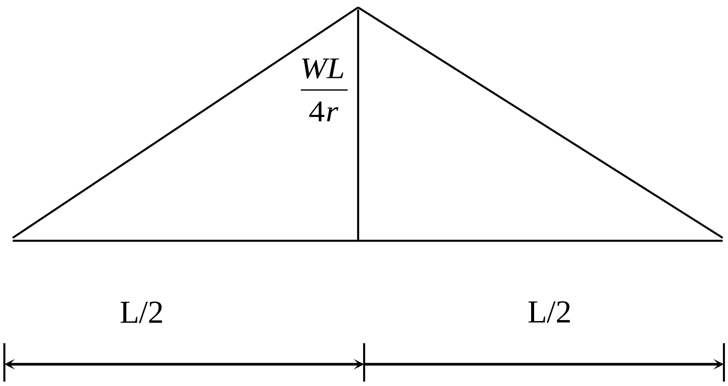
$$H = \frac{1}{r}\left(\frac{R_B L}{2} - W_3\left(a_3 - \frac{L}{2}\right)\right) \qquad (1)$$

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

The influence line of any reaction at a point is a graph showing the variation of load functions like reactions, moments, shear forces, stress or deflections at a point for various positions of moving load W. Therefore, to draw the influence line for H, a unit load of 1kg is placed at varying distance x from either of the supports.

Let a load of 1kg be placed at a distance x from A.

$R_B = \frac{x}{L}$ Then, taking moment about C for all the forces on R.H.S. of C we have




$$\frac{x}{L} \cdot \frac{WL}{2} - H \cdot r = 0$$

$$\therefore H = \frac{Wx}{2r} \qquad (2)$$

Thus, the Eq. (2) is the equation of a straight line and gives the influence line diagram for the horizontal reaction H.

**PROCEDURE:**

Step1: Use lubricating oil at 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 best equilibrium conditions are obtained. Under this condition, the roller end of the arch has a tendency to move inside on tapping the table. Note down the load in kgs.

Step2: 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.

Step3: To obtain the influence line for H, place a load of 2kg in turn on each hanger one by one and find the balancing weight required on the thrust hanger.

Step4: Plot the ordinate representing $\frac{1}{2}$ of the balancing weights on the load positions as base. This gives the influence line diagram for horizontal thrust.

**OBSERVATIONS:**

Span of the arch, L =1000mm
Central rise, h =25cm
Initial load on the thrust hanger for balancing (kg) = 2 kg

**Table-1**

| S.No. | Load on hanger member from roller end | | Total load on thrust hanger (kg) | Distance from left hand support (cm) | Additional load on thrust hanger i.e., H (kg) | Calculated value of H (kg) |
|---|---|---|---|---|---|---|
| | Set No. | Load (kg) | | | | |
| Set I | $W_1$=2kg | 3.2 | | $a_1$ =10 | 0.5 | 0.4 |
| | $W_2$ | 3.6 | | $a_2$ =20 | 0.9 | 0.8 |
| | $W_3$ | 4.0 | | $a_3$ =30 | 1.3 | 1.2 |
| | $W_4$ | 4.4 | | $a_4$ =40 | 1.7 | 1.6 |
| | $W_5$ | 4.9 | | $a_5$ =50 | 2.2 | 2.0 |
| | $W_6$ | 4.5 | | $a_6$ =60 | 1.8 | 2.4 |
| | $W_7$ | 4.1 | | $a_7$ =70 | 1.4 | 2.8 |
| | $W_8$ | 3.7 | | $a_8$ =80 | 1.0 | 3.2 |
| | $W_9$ | 3.3 | | $a_9$ =90 | 0.6 | 3.6 |

## Table-2

Initial load on the thrust hanger to balance self weight of arch = kgs.

| 2kgs load at hanger number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Balancing wt. on thrust hanger (kg) | 0.5 | 0.9 | 1.3 | 1.7 | 2.2 | 1.8 | 1.4 | 1.0 | 0.6 |
| Net weights (kg) | 3.2 | 3.6 | 4.0 | 4.4 | 4.9 | 4.5 | 4.1 | 3.7 | 3.3 |
| Influence line ordinate (net wt./2) observed | 1.6 | 1.8 | 2.0 | 2.2 | 2.45 | 2.25 | 2.05 | 1.85 | 1.65 |
| Calculated value of influence line ordinate | 0.25 | 0.45 | 0.65 | 0.85 | 1.1 | 0.9 | 0.7 | 0.5 | 0.3 |

## 2 GRAPH

1) A graph is plotted between distance from left hand support on X-axis and calculated value of influenced line ordinate on Y-axis.
2) A graph is plotted between distance from left hand support on X-axis and observed value of influenced line ordinate on Y-axis.

## 3 RESULTS AND DISCUSSIONS:

1 Find the horizontal thrust for a given set of load experimentally and theoretically..

2 Plot the observed and calculated values of influence line ordinates on the same graph and comment on the accuracy obtained in the two cases.

# VERIFICATION OF CLERK MAXWELL'S RECIPROCAL THEOREM

**EXPERIMENT NO: 3** **Date :**

# VERIFICATION OF CLERK MAXWELL'S RECIPROCAL THEOREM

## AIM :

To verify Clerk Maxwell's theorem by means of a mild steel beam.

## APPARATUS:

Mild steel over hanging beam with graduations at every 10cm along the length with 100cm long, dial gauge, weights and a magnetic base.

## THEORY:

Clerk Maxwell's theorem in its simplest form states that the deflections of any point A of any elastic structure due to a load P at any other point B is the same as the deflection of B due to the same load P applied at point 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:

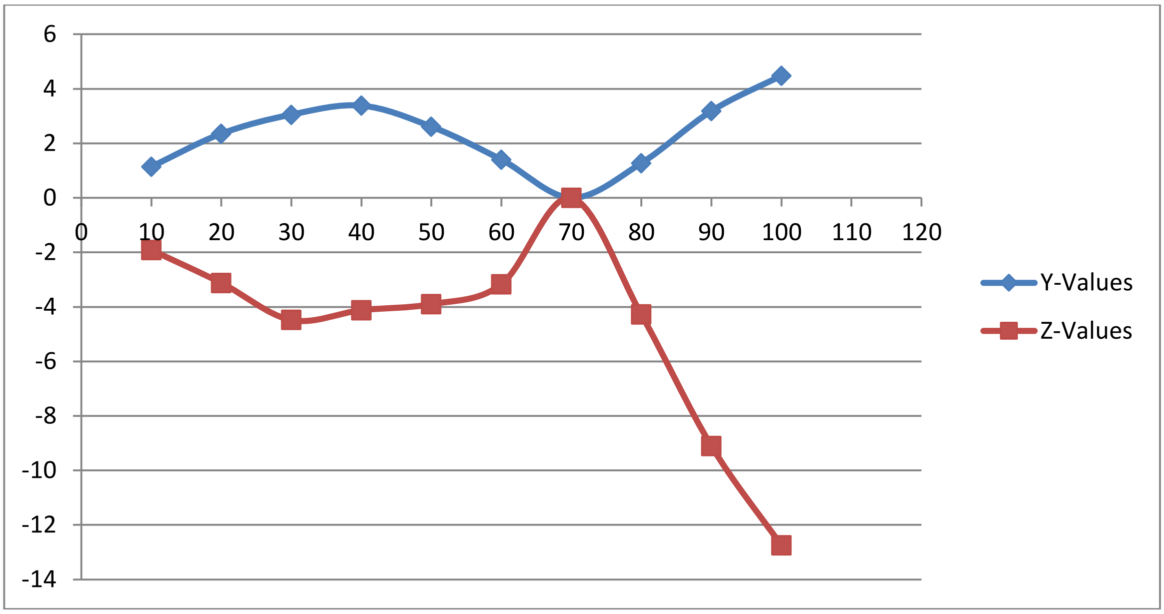
1. Apply a load of 1kg either at the centre of the simply supported span or at the free end of the beam, so that the deflected form can be obtained.
2. Measure the height of the beam at a distance of 10cm interval by means of a dial gauge before and after loading and determine the deflection before and after at each point separately.
3. Now move a load along the beam at a distance of 10cm 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.
4. Plot the graph between deflection as ordinate and position of point on abssica the plot for graph drawn in step 2 and 3. These are the influence line ordinates for deflection of the beam.

\

**TABLE AND OBSERVATIONS:**

| S.N | Distance from the Pinned end (1) | Load at central point cantilever end | | Deflection of Various points (2)-(3)mm | Loading along the beam | | Deflection of Central point (5)-(6) |
|---|---|---|---|---|---|---|---|
| | | Beam Unloaded dial gauge Reading mm (2) | Beam Loaded dial gauge Reading mm (3) | | Beam Unloaded dial gauge Reading mm (5) | Beam loaded dial gauge Reading mm (6) | |
| 1 | **10** | 0 | 2.8 | 2.8 | 0 | 1.4 | |
| **2** | **20** | 0 | 3.5 | 3.5 | 0 | 2.6 | 2.6 |
| **3** | **30** | 0 | 4.1 | 4.1 | 0 | 3.4 | 3.4 |
| **4** | **40** | 0 | 5.2 | 5.2 | 0 | 3.4 | 3.4 |
| **5** | **50** | 0 | 4.02 | 4.02 | 0 | 2.52 | 2.52 |
| **6** | **60** | 0 | 3.81 | 3.81 | 0 | 1.35 | 1.35 |
| **7** | **70** | 0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |
| **8** | **80** | 0 | 4.15 | 4.15 | 0 | 2.1 | 2.1 |
| **9** | **90** | 0 | 8.51 | 8.51 | 0 | 4.45 | 4.45 |
| **10** | **100** | 0 | 12.7 | 12.7 | 0 | 4.48 | 4.48 |

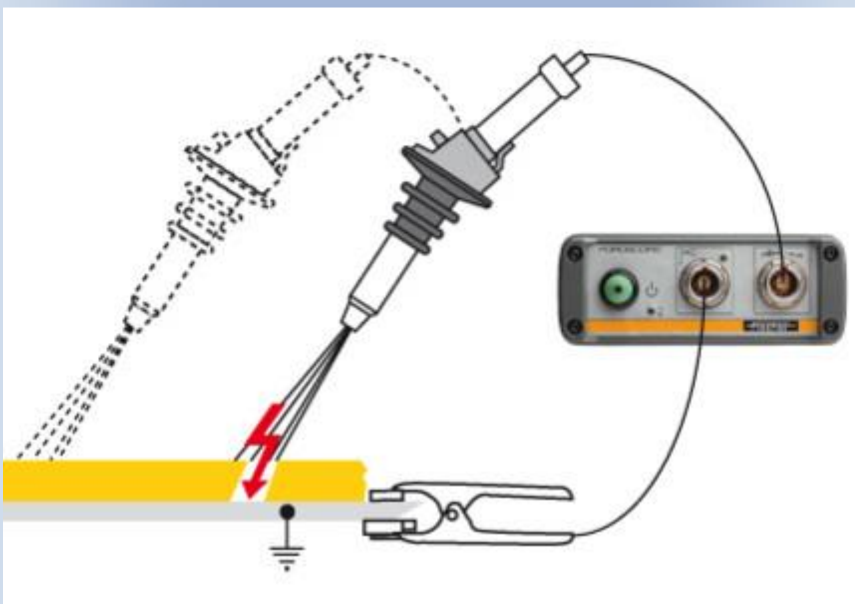
**GRAPH:**




**RESULTS:**

Compare the two curves and they are to be identical. Hence show the influence line curve for the deflection of the beam.

# METAL POTENTIAL MEASUREMENT BY USING POROSCOPE



**EXPERIMENT NO: 4** **Date :**

## METAL POTENTIAL MEASUREMENT BY USING POROSCOPE

**Aim:**

To identify probable Rebar corrosion areas.

**Apparatus:**

Cormap, high amp. Voltmeter, extension pieces, cable, meter to reel, alligator clip, wetting agent, bottle 250ml Cormap crystals, Cormap, electrode bottle with sponge.

**Procedure:**

1) Place the Cu/$CuSo_4$ agent(or) apparatus on to the concrete surface in an area protected from dust.
2) Make sure the sponge is wet and sufficient electrical contact solution is in the container. This should keep the concrete damp for the term of the test.
3) Connect the reference cell to the voltmeter and connect the voltmeter to the reel of the test wire.
4) Connect the test wire to the exposed reinforcing steel, making sure there is a good electrical connection.
5) Measure and record the potential difference values between the reference cell and the reinforcing steel as seen on the display.
6) With the reference cell assembly location unchanged, repeat steps 3 through 5 for another reinforcing steel site.
7) Repeat as necessary to obtain sufficient data.

**Tabular form:**

| Frequency | Readings | Differences |
|---|---|---|
| 10 | 0.02 | 0.02 |
| 36 | 0.07 | 0.025 |
| 86 | 0.017 | 0.01 |
| 100 | 0.021 | 0.004 |
| 160 | 0.033 | 0.012 |
| 200 | 0.044 | 0.010 |

1. Metal potential measurements with ± 0.001v { Electrical continuity probable}.
2. Metal potential measurements greater than ±0.001v but less than ±0.003v {Electrical continuity uncertain}.
3. Metal potential measurements greater than ±0.003v {Electrical discontinuity probable}.

<u>Result</u>:

# NON-DESTRUCTVE TESTING-ULTRA PULSE VELOCITY TEST

**EXPERIMENT NO: 5** **Date :**

# NON-DESTRUCTVE TESTING-ULTRA PULSE VELOCITY TEST

**AIM:**

To determine the velocity of given specimen by Non-Destructive Testing-Ultra pulse Velocity Test.

**APPARATUS:**

1) Ultra pulse velocity machine
2) calibrimeter
3) specimen

**Description:**

For assessing the quality of concrete from (UPV) measurement,it is necessary for this measurement to be higher order of accuracy. This is done by using an apparatus, which generates suitable pulses and accurately measures the time of their transmissions (i.e the transit time) through the concrete. The distance which the pluse travel in the material (i.e the path length) must also be measured to enable the user to determine the velocity as follows:

PLUSE VELOCITY = PATH LENTH/TRANSIT TIME

Path length and Transit times each Should be measured to an accuracy of about=+or-1%

**Procedure:**

1) Switch on the ultra pulse velocity machine and connect the transmitter and receiver
2) Apply the grease to the transmitter and receiver
3) Now take the calibrated specimen of cylindrical shape having transit time of 65u.sec
4) Now keep the transmitter and receiver on the two sides of cylinder and check for the calibrate value.
5) After getting the same calibrated value,we take the required testing specimen and apply the grease to any opposite face of that specimen.(concrete specimen)
6) We will keep the transmitter and receiver on the greasy faces for measuring the transit time.
7) By using the formula we will calculate the pulse velocity.

**Result:**

Pluse velocity of given specimen=5.2038mm/u.sec

# REINFORCING BAR LOCATION USING RE-BAR LOCATOR

**EXPERIMENT NO: 6** **Date :**

# REINFORCING BAR LOCATION USING RE-BAR LOCATOR

**Aim:**

To determine the reinforcing bar location and concrete cover using Rebar Locator.

Apparatus: Mini R-Meter, Rebar Locator

**Instrument Operation**:

Control Panel

1. Power switch- Turns the instrument on and off.
2. Up arrow- used to scroll through the menu and increase a displayed value.
3. Down Arrow- used to scroll through the menu and decrease a value
4. Enter Key- used to select a menu item and save displayed value
5. H key- This is a multifunctional key performs different functions depending on the mode that the instrument is in
6. Set Clock- This mode is used to set the internal real time clock
7. Configuration- from this mean language can be chosen
8. Units- The user can select the unit that he requires
9. Review- This option allows user to review saved data.

**Procedure**

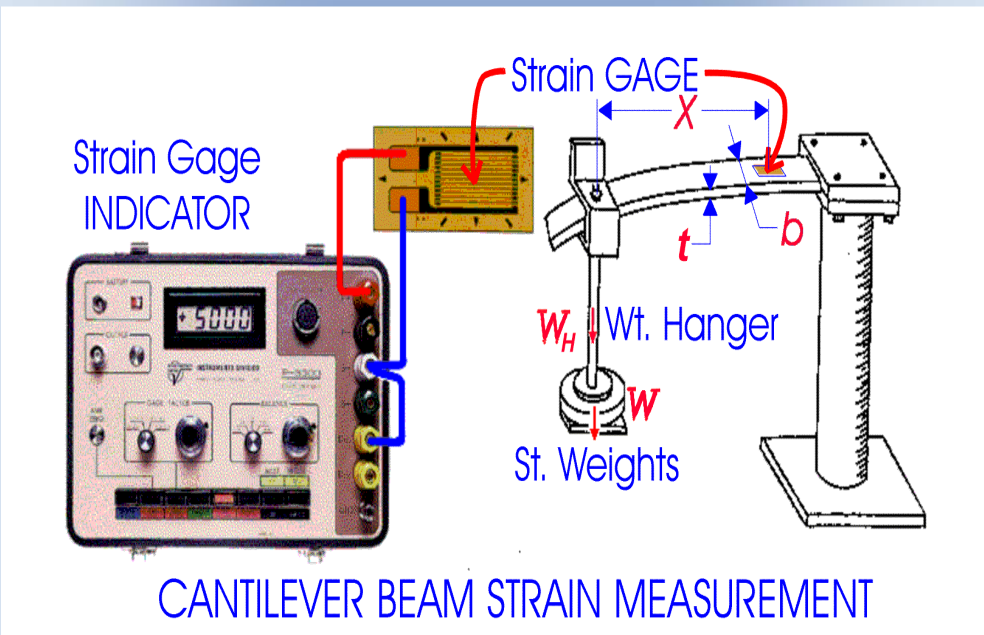
A) Reinforcing Bar Location
   1. The location of primary and secondary reinforcing bars is accomplished by moving the sensor along the surface of the concrete
   2. The user can select the---------------- until for the cover by pressing the arrows and pressing the enter key on the option UNITS(metric or imperial)
   3. On the centre of the instrument screen, the numerical output will show the rebar cover in inches or millimeters as well as the letter D or S(Deep or Short mode)
   4. The actual location of the rebar is achieved when the axis of the sensor is parallel to and directly over the axis of a reinforcing bar, or a group of bars.
   5. The software will automatically switch from short to deep according to the Rebar's depth.
   6. Short mode is used when rebar is located between 0.75-4 inches to the surface of the sensor
   7. The message "number" will appear when rebar is out of range. (too close or deep)
   8. When the rebar is very close a plastic spacer block is provided, then the result will be the instrument output minus the thickness of the shim.

B) Measurement of concrete cover

1. Place the sensor on the concrete at the chosen location.
2. Align the instrument so that the axis of it is parallel to and directly over the reinforcing bars.
3. The cover value corresponds to the distance between the bottom surface of the sensor and the top of the reinforcing bar which is closest to the surface.
4. If the exact diameter of the bar is unknown, a value may be assumed and the error will be small.
5. When the rebar is very close a non-metallic separator block is provided, then the result will be the instrument output minus the thickness of the block.

**Result**

# STRAIN MEASUREMENT USING STRAIN GUAGE



**EXPERIMENT NO: 7** **Date :**

# STRAIN MEASUREMENT USING STRAIN GUAGE

**AIM**:

Measurement of strain using strain gauge.

**APPARATUS**:

Digital panel meter, cantilever beam, weights.

**THEORY**:

Strain gauges are devices used to measure the dimensional change of components under test. These are used in many applications like force measuring devices, measurement of vibration, measurement of pressure etc., In this experiment bonded strain gauges are used . These gauges are directly bonded (that is pasted) on the surface of the structure under study. In this fine wire strain gauges are used. A fine resistance wire of diameter of 0.025mm, which is bent again and again as shown in figure. This is due to increase the length of the wire so that it permits a uniform distribution of stress. This resistance wire is placed between the two carrier bases (paper, bakelite or Teflon), which are cemented to each other. The carrier base protects the gauge from damages. Loads are provided for electrically connecting the strain gauge to a measuring instrument (wheat stone bridge).

**PROCEDURE:**

1. Ensure that the instrument is switched off.
2. Connect the flexible wires provided with the strain gauge cantilever beam between the terminals 1-1,2-2,3-3 &4-4.
3. Keep switch S1 to right position marked.
4. Turn 'ON' the main supply by gently moving the balance. Put p1 and p2 obtain initial

balance on the meter and wait for 5 minutes to allow the strain gauge temperature to stabilize.

5. Now apply a gentle pressure with hand on the end of the cantilever beam, the Digital Panel Meter (DPM) should indicate some change in reading. This indicates the strain gauge setup is ready for experiment dial.
6. Now keep p3 pot in minimum clock-wise position corresponding to position of gain =100. Check for null balance again.
7. Now apply weight of 1kg, 2kg etc., and note down the DPM reading, neglecting the decimal point.

$E_D = E_I\,(\Delta R/R)$ $(E_I=5V)$

**CALCULATIONS**:

$E_0 = E_i * \Delta R/R$ $(E_i = 5V)$

Guage Factor = $(\Delta R/R)/(\Delta l/l)$ (G=2)

E=Stress/Strain= $6Wl/bt^2$ ($E = 2 \times 10^6$)

W= Applied Load, l= Length of Cantilever Beam, b= Breadth of Cantilever Beam

t= Thickness of Cantilever Beam.

| S.NO | Load (kg) | DPM Indicator | Theoretical stress ($\sigma$) | Practical stress | % error | Theoretical strain (ε) | Practical Strain | % error |
|---|---|---|---|---|---|---|---|---|
| 1 | 1/2 | 0.48 | 11.72 | 9.2 | 21.5 | $5.86*10^{-5}$ | $4.6*10^{-5}$ | 21.6 |
| 2 | 1 | 0.95 | 23.44 | 17.26 | 26.3 | $1.172*10^{-4}$ | $0.86*10^{-4}$ | 26.7 |
| 3 | 1.5 | 1.42 | 35.15 | 25.8 | 26.6 | $1.75*10^{-4}$ | $1.29*10^{-4}$ | 26.2 |
| 4 | 2 | 1.89 | 46.89 | 34.2 | 27.06 | $2.34*10^{-4}$ | $1.171*10^{-4}$ | 26.9 |
| 5 | 2.5 | 2.35 | 58.6 | 42.6 | 27.3 | $2.93*10^{-4}$ | $2.13*10^{-4}$ | 27.3 |

Stress= wl/ ((1/6) $bt^2$)

%Error in stress= ((theoretical stress-practical stress)/theoretical stress)*100%

Theoretical value of strain=stress /E

STRAIN = (change in length)/ (original length)

%Error in strain= ((theoretical strain-practical strain)/theoretical strain) x 100%

**Precautions:**

1) Make the connection to the binding posts and terminals very carefully.
2) Provide a warm up time of about 10 to 15 minutes before taking readings.
3) Ensure that the cantilever beam arrangement is fixed to the table

**Graphs**

1) Load v/s DPM reading
2) Load v/s Practical Strain
3) Theoretical strain v/s practical strain.

**Result:**

Theoretical strain=$2.13x10^{-4}$, practical strain=$2.19\ x10^{-4}$

# BUCKLING OF COLUMNS

**EXPERIMENT NO: 8** **Date :**

# BUCKLING OF COLUMNS

**Aim**: -

To study behavior of different types of columns and find Euler's buckling load for each case.

**Apparatus:** -

Column Buckling Apparatus, Weights, Hanger, Dial Gauge, Scale, Verniar caliper.

**Theory** :-

If compressive load is applied on a column, the member may fail either by crushing or by buckling depending on its material, cross section and length. If member is considerably long in comparison to its lateral dimensions it will fail by buckling. If a member shows signs of buckling the member leads to failure with small increase in load. The load at which the member just buckles is called as crushing load. The buckling load, as given by Euler, can be found by using following expression.

$$P = \pi^2 EI/ le^2$$

Where,

E = Modulus of Elasticity = 2 x 105 N/mm2 for steel

I = Least moment of inertia of column section

Le = Effective length of column

Depending on support conditions, four cases may arise. The effective length for each of which are given as:

1. Both ends are fixed le = L/ 2
2. One end is fixed and other is pinned le = L/√ 2
3. Both ends are pinned le = L
4. One end is fixed and other is free le = 2L

**Procedure: -**

1. Pin a graph paper on the wooden board behind the column.
2. Apply the load at the top of columns increasing gradually. At certain stage of loading the columns shows abnormal deflections and gives the buckling load.
3. Not the buckling load for each of the four columns.

4. Trace the deflected shapes of the columns over the paper. Mark the points of change of curvature of the curves and measure the effective or equivalent length for each case separately.
5. Calculate the theoretical effective lengths and thus buckling loads by the expressions given above and compare them with the observed values.

Observation: -

1) Width of strip (mm) b =

2) Thickness of strip (mm) t =

3) Length of strip (mm) L =

4) Least moment of inertia $I = bt^3/12$

**Observation Table**:-

| Sr. No | End condition | Euler's Buckling load | | Effective Length (mm) | |
|---|---|---|---|---|---|
| | | Theoretical | Observed | Theoretical | Observed |
| 1 | Both ends fixed | | | | |
| 2 | One end fixed and other pinned | | | | |
| 3 | Both ends pinned | | | | |
| 4 | One end fixed and other free. | | | | |

**Sample Calculation: -**

End condition:

Both ends fixed Euler's buckling load. = $P = \pi^2 EI/ le^2$

Effective Length (mm) =.

**Result:-**The theoretical and experimental Euler's buckling load for each case is found nearly same.

# QUALIFICATION TESTS ON SELF COMPACTING CONCRETE

**EXPERIMENT NO: 9** **Date :**

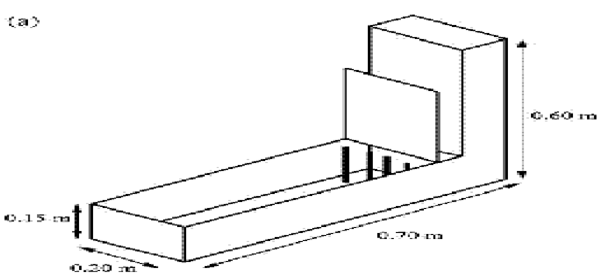
# QUALIFICATION TESTS ON SELF COMPACTING CONCRETE

## 1. L Box

Aim: To determine the passing ability.

**Equipment:**

- L box of a stiff non absorbing material
- Trowel
- Scoop
- Stopwatch




***Procedure of L Box Test:***

About 14 liter of concrete needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surface of the apparatus, remove any surplus water, fill the vertical section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Simultaneously, start the stopwatch and record the time for the concrete to reach the concrete 200 and 400 marks. When the concrete stops flowing, the distances ‘H1’ and ‘H2’ are measured. Calculate H2/H1, the blocking ratio. The whole has test is to be performed within 5 minutes**.**

**Result**

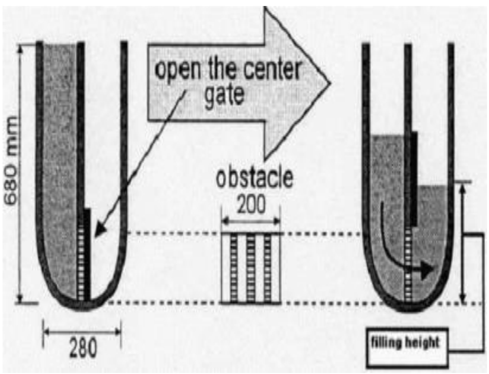
If the ratio of h2/h1 is equal to one or nearer to this value it has passing ability.

# 2. U Box

**Aim:** To determine the filling ability of the given concrete

**Equipment:**

- U box of a stiff non absorbing material
- Scoop
- Trowel
- Stopwatch




***Procedure for U Box Test on Self Compacting Concrete:***

About 20 liter of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surface of the apparatus, remove any surplus water, fill the vertical section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the other compartment. After the concrete has come to rest, measure the height of the concrete in the compartment that has been filled, in two places and calculate the mean (H1). Measure also the height in the other equipment (H2). Calculate H1-H2, the filling height. The whole test has to be performed within 5 minutes.

**Result**

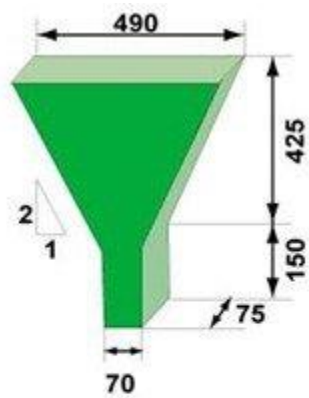
If the filling height is zero or any nearer value it has good filling ability. The acceptable filling height is 30mm.

# 3. V-FUNNEL TEST

**Aim:** To determine the flow ability of concrete

**Equipment:**

- V-funnel
- Bucket (±12 liter)
- Trowel
- Scoop
- Stopwatch




***Procedure flow time:***

About 12 liter of concrete is needed to perform the test, sampled normally. Set the V-funnel on firm ground. Moisten the inside surface of the funnel. Keep the trap door to allow any surplus water to drain. Close the trap door and place a bucket underneath. Fill the apparatus completely with the concrete without compacting or tamping; simply strike off the concrete level with the top with the trowel.

Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity. Start the stop watch when the trap door is opened, and record the time for the complete discharge (the flow time). This is taken to be when light is seen from above through the funnel. The whole test has to be performed within 5 minutes.

***Procedure flow time at T5 minutes:***

Do not clean or moisten the inside surface of the funnel gain. Close the trap door and refill the V-funnel immediately after measuring the flow time. Place a bucket underneath. Fill the apparatus completely with concrete without compacting or tapping, simply strike off the concrete level with the top with the trowel. Open the trap door 5 minutes after the second fill of the funnel and allow the concrete to flow out under gravity. Simultaneously start the stop watch when the trap door is opened and record the time discharge to complete flow (the flow time at T5 minutes). This is to be taken when light is seen from above through the funnel.

**Result**

The flow rate should be between 8-12 seconds.

# SHAKE TABLE

**EXPERIMENT NO: 10** **Date :**

## SHAKE TABLE

**(i)Aim:** Dynamics of a three storied building frame subjected to harmonic base motion.

**Apparatus:** Shake table , model.

**Experimental procedure:**

**Preliminary measurements**

a) Collect the data pertaining to geometric and material properties of the vibrating system

b) Using the three-degrees of freedom model, form the mass and stiffness matrices of the structure. Perform the eigenvalue analysis and determine the natural frequencies and modal matrix for the system.

c) Study the sensors and the charge amplifiers and note down the sensor sensitivities, sensor mass and factors to convert the measured electrical signal into mechanical units; this depends upon the amplifier settings used.

d) Run the electric motor at a few frequencies and measure the amplitude of the base motion. These amplitudes are expected to be identical and also would remain unchanged as the speed of the motor is varied. Therefore, in the subsequent experimentation, the base motion itself need not be measured.

**Studies on 3-storyed shear beam model**

e) Arrange the experimental setup. Note that the accelerometer needs to be placed on slab in such a way that displacement along *x* direction is picked up.

f) Set the frame into free vibration by applying an initial displacement. This can be achieved by gently pulling the frame at about the top slab and releasing it. Evaluate the logarithmic decrement and hence the damping ratio. One model for the damping can be obtained by assuming that the damping ration so determined would remain constant for all the modes.

g) Run the base motion test on the frame at different values of motor RPM making sure that readings at resonant frequencies are not missed. For a given motor RPM, allow the frame to oscillate for a few seconds so that the frame reaches its steady state. At this stage measure the amplitude of the frame response by using time history of displacement response acquired on the oscilloscope and records the amplitude data.

Note that the frequency of driving and the frequency of structural response can be assumed to be equal and this can be measured from the trace of displacement response on the oscilloscope. It may be noted that the test could be conducted even if only two channel measurements are possible, in which case, the above steps need to be repeated suitably.

h) The frequencies at which the structure undergoes resonance can be identified by observing the variation of response amplitudes as motor RPM is varied. At resonant conditions, in addition to noting the amplitude of slab oscillations, also note if the slabs are vibrating in phase or not.

Based on this information the modal vectors for the first three modes could be established. Compare these mode shapes with the analytical mode shapes obtained in step (b).

i) Plot *X1, X2* and *X3* versus *f*.

j) From the plots in the previous step estimate the modal damping either by half power bandwidth method or by relating the peak amplitude to the modal damping.

k) Using the modal damping ratios obtained in steps (f) or (j) determine the C matrix

using the relation $C = [\Phi^t]^{-1}[\Xi][\Phi]^{-1}$ where Ξ is a diagonal matrix with entry onthe *n*th row being $2\eta_n\omega_n$. It can be shown that $[\Phi^t]^{-1} = M\Phi$ and $[\Phi]^{-1} = \Phi^t M$, and, therefore, one gets

*C* = *M*ΦΞΦ*tM*

Using this C matrix

and equation,

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = [C]\{\Gamma\}\dot{y} + [K]\{\Gamma\}y$$

solve the mathematical model to determine analytically the amplitude of floor responses as a function of the driving frequency. Compare these analytical predictions with the measured frequency response functions.

**(ii)Aim:** Earthquake induced waves in rectangular water tanks

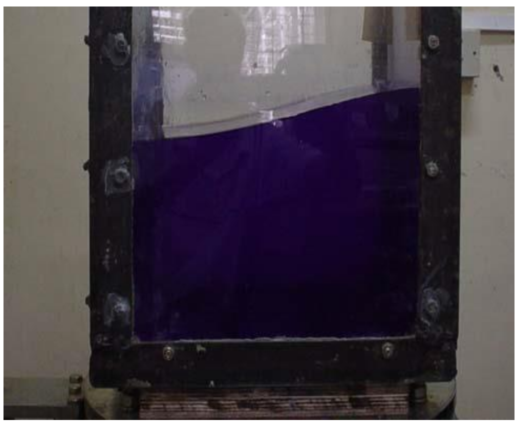
**Apparatus:** Shake table

**Procedure: Experimental procedure**

1. Mount the water tank on the shake table as shown in figure.

2. Measure the dimensions of the tank and the water level inside the tank. Add a colour dye to the water so as to facilitate visual observations of the water surface oscillations.
3. Excite the tank harmonically starting with low values of frequency. At each frequency visually observe the behavior of the water surface.
4. At every value of the frequency allow sufficient time to pass so that oscillations of water reach steady state.
5. As the frequency of driving approaches one of the natural frequencies, the water surface begin to oscillate with perceptible amplitudes (see figure).

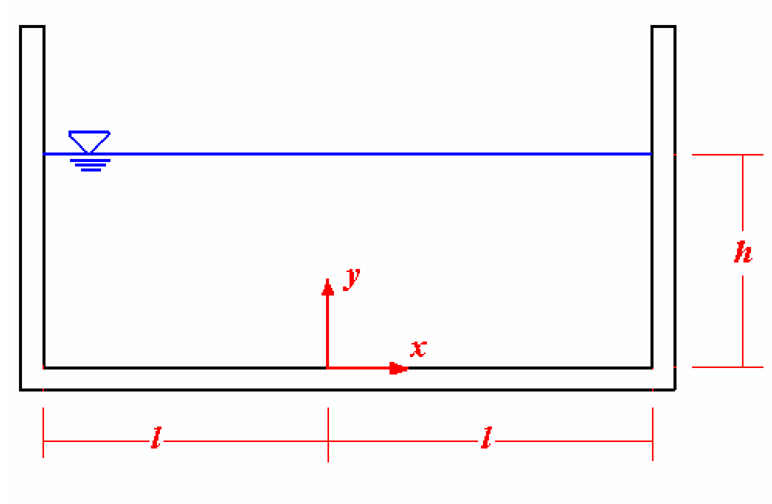





Note down the frequency at which such oscillations occur.

6. The profile of the standing waves at resonance can be measured by a simple device This consists of inserting a white sheet at the inner wall of the tank and allow the oscillating liquid surface to leave behind a tinted trace on the sheet. The shape of the standing waves could be inferred by measuring the heights from mean level of the tinted trace left on the paper by the oscillating liquid surface. Following this procedure, obtain the shape of the standing waves at the liquid surface for first few modes.

7. Predict the frequencies and shapes of the standing waves using the theoretical formulation provided.




Above figure shows a two-dimensional water tank of length *2l* containing water up to a height *h*. We assume that the liquid flow is inviscous, irrorational, and incompressible. We now consider the question as to what type of steady state waves may exist on the liquid surface. We use the notation φ (*x*, *y*,*t*),*u*(*x*, *y*,*t*),&*v*(*x*, *y*,*t*) to represent, respectively, the velocity potential, velocity components in x and y directions. The following equation is known to govern the velocity potential.

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$$

with the boundary conditions given by

$$\frac{\partial^2 \phi}{\partial t^2}(x,h,t) + g\frac{\partial \phi}{\partial y}(x,h,t) = 0$$

$$\frac{\partial \phi}{\partial y}(x,o,t) = 0$$

$$\frac{\partial \phi}{\partial x}(\pm l,y,t) = 0$$

The first of the above boundary conditions is obtained by applying the Bernoulli's equation on the free surface and the remaining set of boundary conditions reflects the fact that the normal fluid velocity components at the wall boundaries are zero. The symbol *g* in the above equation represents the acceleration due to gravity and the other notations are explained in above figure. We seek a steady state wave solution of the form

$$\phi(x,y,t) = \psi(x,y)\cos\omega t$$

This leads to the field equation

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} = 0$$

with the boundary conditions

$$-\omega^2\psi(x,h) + g\frac{\partial\psi}{\partial y}(x,h) = 0$$

$$\frac{\partial\psi}{\partial y}(x,o) = 0$$

$$\frac{\partial\psi}{\partial x}(\pm l,y) = 0$$

We seek the solution of equation 8.4 in the variable separable form $\psi(x,y) = X(x)Y(y)$. This leads to the equation

$$\frac{d^2X}{dx^2}Y + X\frac{d^2Y}{dy^2} = 0$$

Dividing both sides by *XY* one gets

$$\frac{1}{X}\frac{d^2X}{dx^2} = -\frac{1}{Y}\frac{d^2Y}{dy^2}$$

Since the left hand side is a function of *x* alone and right hand side is a function of *y* alone it turns out that each of the two terms appearing in the above equation needs to be equal to the same constant. That is,

$$\frac{1}{X}\frac{d^2X}{dx^2} = -\frac{1}{Y}\frac{d^2Y}{dy^2} = -\lambda^2$$

This leads to

$$\frac{d^2X}{dx^2} + \lambda^2 X = 0$$

$$\frac{d^2Y}{dy^2} - \lambda^2 Y = 0$$

with boundary conditions

$$\frac{dX}{dx}(\pm l) = 0; \quad \frac{dY}{dy}(0) = 0; \quad g\frac{dY}{dy}(h) - \omega^2 y(h) = 0$$

From the first equation 8.9 one gets

$$X(x) = a\cos\lambda x + b\sin\lambda x$$

Imposing the boundary conditions $\frac{dX}{dx}(\pm l) = 0$ one gets

$$\lambda\begin{bmatrix} -\sin\lambda l & \cos\lambda l \\ \sin\lambda l & \cos\lambda l \end{bmatrix}\begin{Bmatrix} a \\ b \end{Bmatrix} = 0$$

For nontrivial solution one gets the condition $\lambda\sin\lambda l\cos\lambda l = 0$. This leads to two families of solutions, namely,

$$\lambda_n = \frac{n\pi}{l}; n = 1,2,3,\ldots,\infty$$

$$\lambda_m = \frac{(2m+1)\pi}{2l}; m = 0,1,2,3,\ldots,\infty$$

The corresponding solutions for *X(x)* are obtained as

$$X(x) = a\cos\frac{n\pi x}{l}; n = 1,2,3,\ldots,\infty$$

$$X(x) = b\sin\frac{(2m+1)\pi x}{2l}; m = 0,1,2,3,\ldots,\infty$$

Considering now the second of the equation we get

$$Y(y) = c\cosh\lambda y + d\sinh\lambda y$$

Imposing the boundary conditions on $Y$ listed in we get

$$\frac{dY}{dy}(0) = 0 \Rightarrow d\lambda = 0 \Rightarrow d = 0$$

$$g\frac{dY}{dy}(h) - \omega^2 y(h) = 0 \Rightarrow g\lambda\sinh\lambda h - \omega^2\cosh\lambda h = 0$$

$$\Rightarrow \omega^2 = g\lambda\tanh\lambda h$$

with the parameter $c$ remaining arbitrary. Combining equations and one gets

$$\omega_n^2 = \frac{n\pi}{l} g\tanh\left(\frac{n\pi h}{l}\right); n = 1,2,...,\infty$$

$$\omega_m^2 = \frac{(2m+1)\pi}{2l} g\tanh\left(\frac{(2m+1)\pi h}{2l}\right); m = 0,1,2,...,\infty$$

This leads to two families of standing wave patterns given by

$$\phi_n(x,y,t) = A_n\cos\frac{n\pi x}{l}\cosh\frac{n\pi y}{l}\cos\omega_n t$$

$$\phi_m(x,y,t) = B_m\sin\frac{(2m+1)\pi x}{2l}\cosh\frac{(2m+1)\pi y}{2l}\cos\omega_m t; m = 0,1,2,...,\infty$$

The velocity components can subsequently obtained by using

$$u(x,y,t) = \frac{\partial\phi}{\partial x} \;\&\; v(x,y,t) = \frac{\partial\varphi}{\partial y}$$

In particular one gets

$$v_n(x,h,t) = \alpha_n\cos\frac{n\pi x}{l}\cos\omega_n t; n = 1,2,...,\infty$$

$$v_m(x,h,t) = \beta_m\sin\frac{(2m+1)\pi x}{2l}\cos\omega_m t; m = 0,1,2,...,\infty$$

It may be noted that the natural frequencies given by equation and the velocity profiles at $y=h$ given by equation can be observed and measured during experiments.

8. Compare the theoretical and experimental results and draw conclusions on their mutual agreement/disagreement.

9. Repeat the experiment for different values of heights of water level inside the tank.

10. Remount the tank by swiveling it through 90 degrees about the vertical axis. Repeat the experiment as described above for this configuration.