TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

DEPARTMENT OF CIVIL ENGINEERING

Theory of Structures-II

SUBMITTED BY

SURENDRA SHARMA (078BCE178)

SUBMITTED TO

DEPARTMENT OF CIVIL ENGINEERING

PULCHOWK CAMPUS

PULCHOWK,LALITPUR

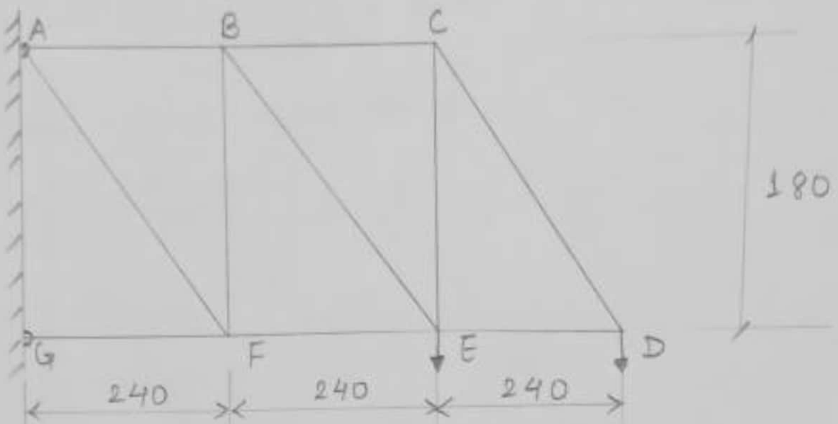
TITLE: DEFLECTION BY VIRTUAL WORK

OBJECTIVES:

TO measure experimentally the force in a plane truss and to use the results to obtain by the method of virtual work, the vertical deflection due to the vertical loads acting at the structure.

DETAILS OF APPARATUS

Details of truss and loading



Details of Members

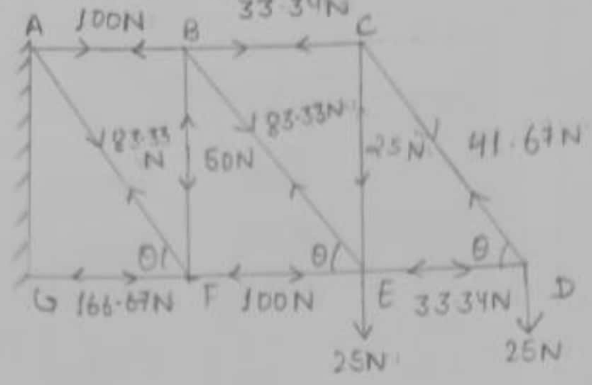
Young's Modulus, E = 200 KN/mm^2

Member	L (mm)	Area (mm^2)
AB, BC	240	4.3
AF, BE, CD	300	4.3
GF, FE, ED	240	.21
BF, CE	180	2 1

A load indicator is available for direct reading of force values; a calibration chart is also available. A dial gauge is provided for the measurement of deflection.

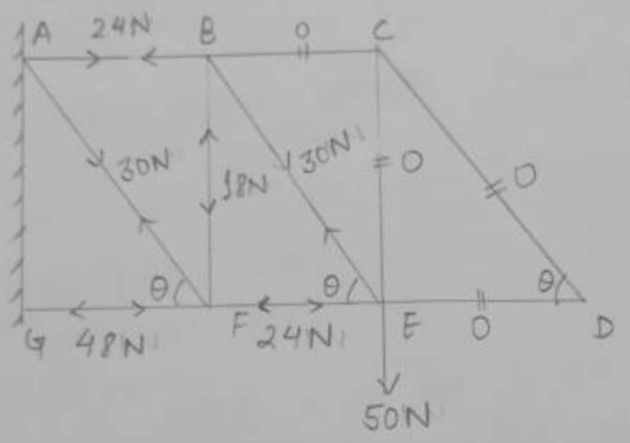
Theoretical calculation

I. When 25N load at D and E:



$$\theta = \tan^{-1}\left(\frac{180}{240}\right) = 36.87^\circ$$

II. When 50N load at E



When unit vertical load kept at E

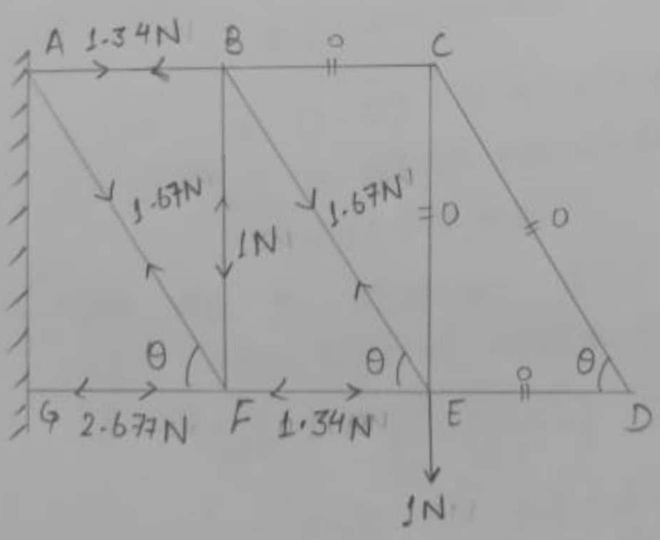


Table for calculation of deflection

Members	Length, L (mm)	Area, A (mm^2)	P (N)	Q (N)	P_i (N)	Remarks
AB	240	4.3	100	24	1.34	
BC	240	4.3	33.34	0	0	
CD	300	4.3	41.67	0	0	
DE	240	21	-33.34	0	0	
EF	240	21	-100	-24	-1.34	
FG	240	21	-166.67	-48	-2.677	
AF	300	4.3	83.33	30	1.67	
BE	300	4.3	83.33	30	1.67	
BF	180	21	-50	-18	-1	
CE	180	21	-25	0	0	

P → Member forces when loading with 25N load at E and D

Q → Member forces when loading with 50N at E

P_i → Member forces when loading with unit vertual load at E.

- Deflection at E due to load at E and D of 25N

$$(\Delta_E)_v = \left(\Sigma \frac{P P_i L}{AE}\right)$$

$$E = 200 kN/mm^2 = 2 \times 10^5 N/mm^2$$

$$= 0.0374 + 0 + 0 + 0 + 0.00766 + 0.0255 + 0.0485 + 0.0485 + 0.00214 + 0$$

$$= 0.16978 \text{ mm.}$$

- Deflection at E due to 50N load at E,

By virtual work theorem,

$$1 \cdot (\Delta_E)_v = \left(\Sigma \frac{Q P_i L}{AE}\right)$$

$$= 0.00897 + 0 + 0 + 0 + 0.00184 + 0.00734 + 0.0175 + 0.0175 + 0.00077 + 0$$

$$= 0.16978 \text{ mm.}$$

078BCE178

LAB NO. 2: Deflection By virtual Work

Case I: 25N at E and 25 N at D

Member	Indicator Reading	Force	$P = F/100$	Indicator reading	Deflection
AB	90 + 5	95	0.95	95	(60×0.01)
GF	260−10	250	2.5	250	0.6mm
BF	65+25	90	0.9	90	
AF	65−5	60	0.6	60	
BE	55+30	85	0.85	85	
FE	165+5	170	0.170	170	
CE	0	0	0	0	

Case II 50N at E

Member	Indicator Reading	Force	$P = F/100$	Indicator Reading	Deflection
AB	70	70	0.7		
GF	220−10	~~210~~ 210		210	(49×0.01)
BF	90	90			(0.49mm)
AF	60	60			
BE	80	80			
FE	130−10	120		120	
CE	0	0		0	

080-9-18

OBSERVATIONS AND CALCULATIONS

Deflection measured by Dial gauge for 25N load at D & E

(ΔE) = ~~0.35~~ 0.6mm

Deflection measured by Dial gauge for 50N load at E

$\Delta E = 0.49$mm.

Member	Length (mm)	Area (mm²)	50N at E		25N at E & D P(N)	$\Delta E = \frac{pPL}{AE}$ (mm)
			Force F	p = F/50		
AB	240	4.3	70	1.4	95	0.01856 × 2
GF	240	21	-210	-4.2	-250	0.06
BF	180	21	-90	-1.8	-90	0.0069
AF	300	4.3	60	-1.2	60	0.02512
BE	300	4.3	80	-1.6	85	0.0474
FE	240	21	-120	-2.4	-170	0.023314
CE	180	21	0	0	0	0
						Σ=0.18604

Thus,

~~Observed~~ theoretical deflection, $(\Delta E)_T = 0.16978$mm

Observed deflection, $(\Delta E)_O = 0.18604$ mm.

$$\%\ \text{Error} = \left|\frac{0.16978 - 0.18604}{0.16978}\right| \times 100\%$$

$$= 9.58\%$$

RESULT

The observed deflection at point E was found to be 0.29048 mm which deviated from theoretical value of 0.16978mm. The errors might be due to observation error, defect in instrument, ~~and~~ calibration error and other external factors.

CONCLUSION:

Thus, deflection at a point of plane truss was measured & calculated using measured force and by theoretically. Also, the value obtained experimentally and theoretically was computed by virtual work method.

TITLE: DEFLECTION OF BEAM

OBJECTIVES

(1) To determine the modulus of elasticity of a beam.

(2) To obtain experimentally the slope of the support of a simply supported beam when it is subjected to a concentrated load.

(3) To obtain experimentally, the deflection at mid-span of a beam built in at both ends when it is subjected to a concentrated load.

APPARATUS

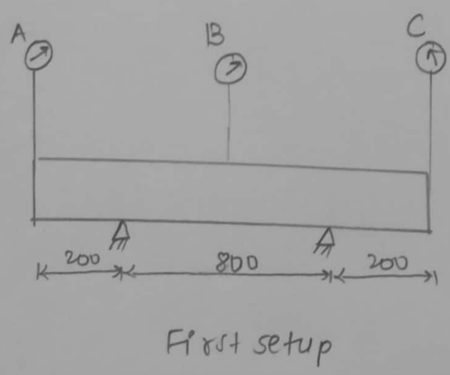
→ The apparatus consists of a steel beam (30mm x 5mm) (in cross-section) dial gauge for recording deflections & various type of supports.

Knife-edge support:

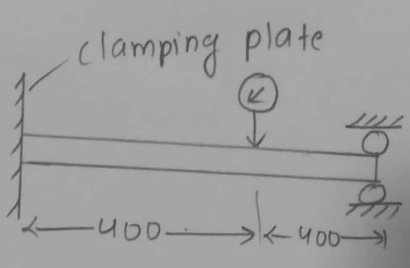
(CHST1304) for simply supported clamping plates ~~(CHST 1303)~~ ~~for providing fix~~ (CHST-1303) for providing fixfly & at the same time providing horizontal movement only.

With the fixture the knearled thumb screws are tightened evenly all round but not excessively. The effective length of the beam is measured from inner edge at clamping plates to the centre line of the inner part knerned screws.

To acheive this the objective above, two different arrangements are required.



First setup



Second setup

PROCEDURE

(A) Using the 1st setup apply a stabilizing load of 10N to the hangers was applied. The dial gauge was A,B, C were read. These readings should be regarded as datum readings for calculating deflections. Loading in increments of 10N was applied until the total applied load is 40N (excluding the hanger and 10N stabilizing load). The gauges were read at each loading stage. The reading were recorded in tabular form.

(B) The apparatus were rearranged as shown in second step. A stabilising load of 10N to the hanger was applied & the dial gauge was read. This will be datum reading for the deflection, loading is increments of 10N until load of 40N was applied. The gauge at each stage was read and reading were recorded in a table.

078BCE178

TITLE: DEFLECTION OF BEAMS

Case I:

D.G.R → Dial Gauge Reading.

Load (N)	D.G.R at A	Defl^n at A (mm)	D.G.R at B	Defl^n at B (mm)	D.G.R at C	Defl^n at C (mm)
0	5.23	0	5.19	0	5.27	0
5	6.02	0.79	4.12	1.07	6.06	0.79
10	6.78	1.55	3.10	2.09	6.85	1.58
15	7.51	2.28	2.10	3.09	7.57	2.30
20	8.26	3.03	1.10	4.09	8.31	3.04

D.G.R = Dial Gauge Reading.

Case II:

Load (N)	D.G.R.	Deflection
0	4.54	0
5	4.09	0.45
10	3.64	0.9
15	3.18	1.36
20	2.74	1.80

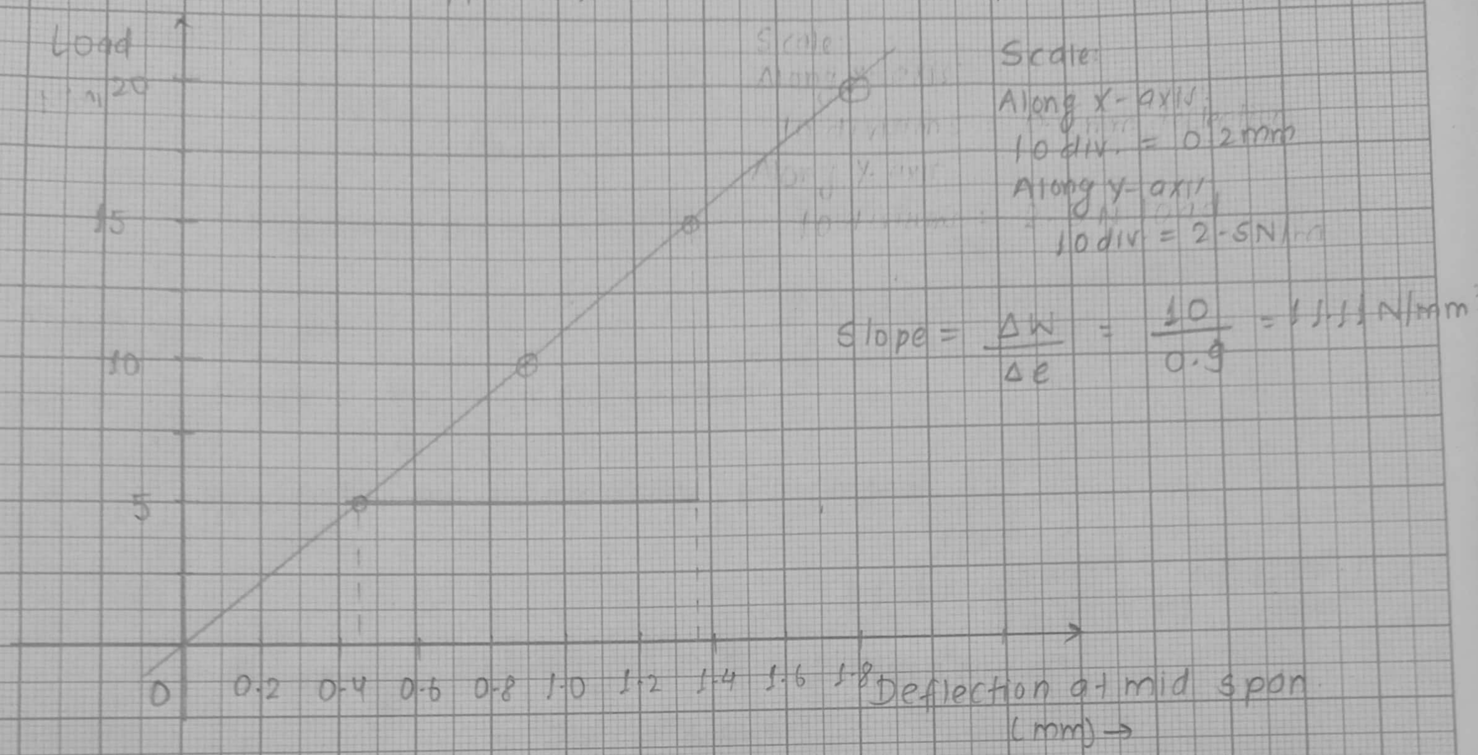
080710-24

SUB/REF

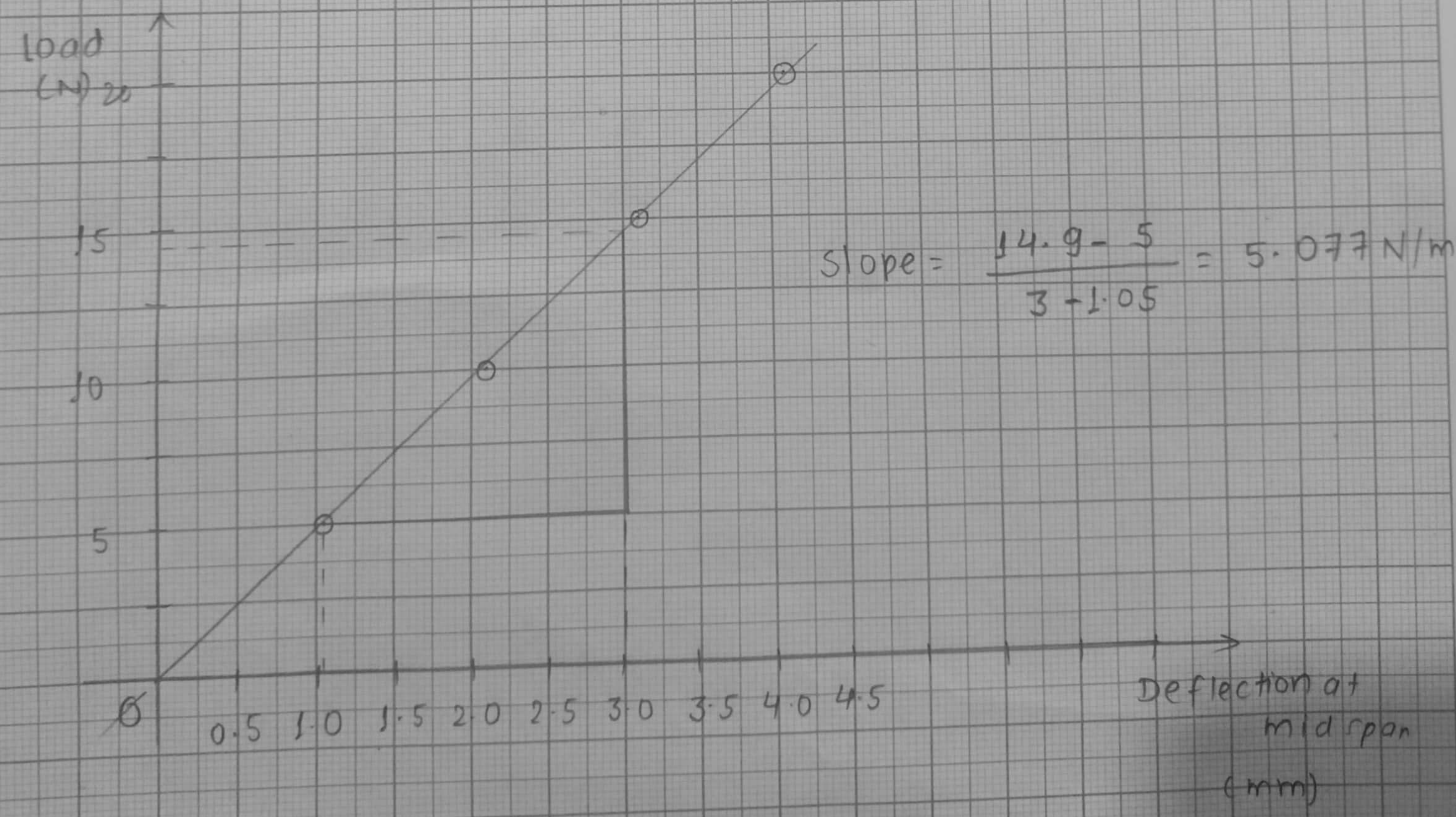
NO

DATE

(b) For one support fixed and other roller fixture



(a) For simply supported beam with both sides overhanging



Calculation,

Here, $b = 25mm$, $h = 5mm$, $L_1 = 800mm = 0.8m$, $L_2 = 1m$

Moment of inertia, $I = \frac{bh^3}{12} = 260.417 \, mm^4$

From graph (a),

Slope, $\frac{W}{\Delta_{mid}} = 5.077 \, N/mm$

Modulus of elasticity, $= \text{Slope} \times \frac{L_1^3}{48I}$

$= 207953.654 \, N/mm^2$

$= 2.08 \times 10^{11} \, N/m^2$

From graph (b)

Slope $= \frac{W}{\Delta} = 11.11 \, N/mm$

Modulus of elasticity, $E = \text{slope} \times \frac{L_2^3}{192I}$

$= \frac{11.1 \times (1000)^3}{192 \times 260.417} = 2.22 \times 10^{11} \, N/m^2$

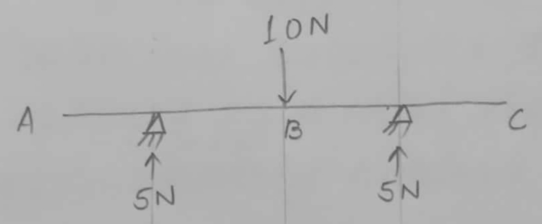
$E_{average} = \left(\frac{2.08 + 2.22}{2}\right) \times 10^{11} = 2.14 \times 10^{11} \, N/mm^2$

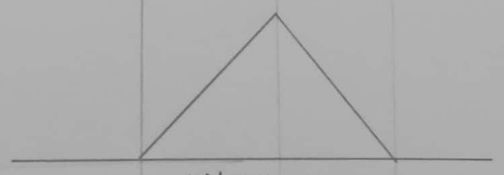
$E_{theoretical} = 2 \times 10^{11} \, N/m^2$

Error $= \left| \frac{2.14 \times 10^{11} - 2 \times 10^{11}}{2 \times 10^{11}} \right| \times 100\%$

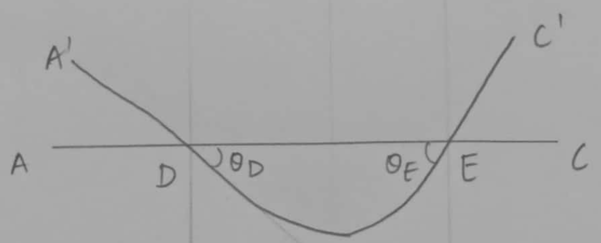
$= 7\%$

For load, $W = 10N$





M/EI Diagram



Elastic curve

Tangential deflection at E, $t_{ED} = \frac{1}{2} \times \frac{2}{EI} \times 0.8 \times 0.4$

$= \frac{0.32}{EI}$

Slope at D, $\theta_D = \frac{0.32}{8EI} = \frac{0.4}{EI}$

$\theta_D = 8.2 \times 10^{-3}$ radians (↷) Theoretical.

~~For theoretical value,~~

Experimental, θ_D = Deflection at A due to 10N/200

$= \frac{1.55}{200}$

$= 7.75 \times 10^{-3}$ radians (↷)

$$\text{Error} = \left| \frac{8.2 \times 10^{-3} - 7.75 \times 10^{-3}}{8.2 \times 10^{-3}} \right| \times 100\%$$

$= 5.488\%$

DISCUSSION AND CONCLUSION

Thus, the modulus of elasticity of given beam was calculated. The deflection at different point under given load was calculated. Theoretical deflection and slope obtained by moment area theorem slightly varied from experimentally obtained value.

THREE HINGED ARCH

OBJECTIVES

(i) To maintain the horizontal reaction of a symmetrical arch when it is subjected to vertical concentrated load.

(ii) To measure the horizontal reaction of a unsymmetrical arch when it is subjected to UDL

DETAILS OF ARCHES

Symmetrical arch

- Span = 1000mm
- Rise = 200mm

Unsymmetrical arch

- Span of left-hand section = 250mm
- Rise of left section = 125mm
- Span of right section = 200mm

PROCEDURE

(A) Symmetrical Arch

(1) The span was measured from left to mark on track plate for right hand bearing. The span was checked if it is 1 m.

(2) The load was added to horizontal direction reaction load, hanger to balance the self weight of the arch so that the roller axis is in the line with span marker.

(3) 50N was placed on arch with centre vertically above the bridge of the crown. 25N load was placed. 50N load with the link provided the timber wedges were used to prevent load from moving.

(B) Unsymmetrical arch

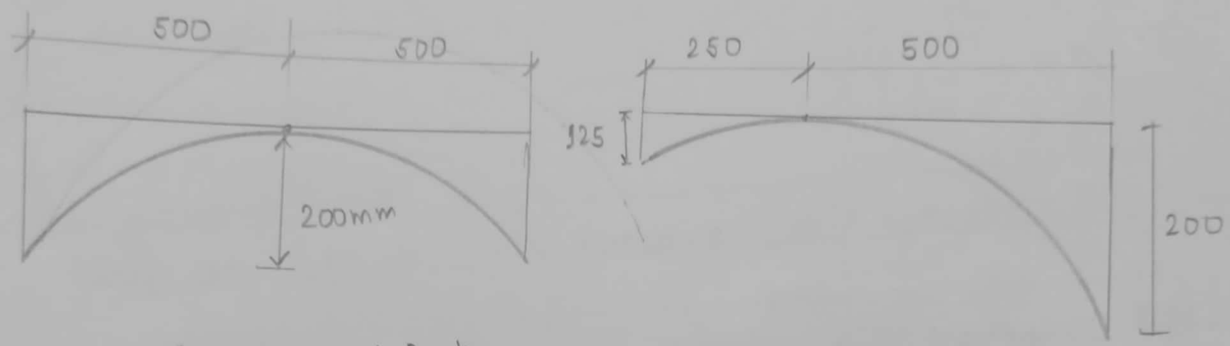
(1) The pin was carefully drawn from left hinge to the crown & removed the left hand span.

(2) It was replaced with alternative left hand span. The left hand springing was required to

move up until it is approximately 117mm above the bottom member of supporting frame.

As in part A, load required to be balanced the self weight & remove the load.

For UDL (T = 25N/m) to right hand span were applied & horizontal reaction was obtained as part A.



Symmetrical Arch

Unsymmetrical Arch.

OBSERVATION

Symmetrical Arch load (N)	Horizontal (B+A) Reaction (N)	Applied Load (B) at hanger (N)
50N at center and 25N at left	88.5	94.2
50N at center and 25N at Right	88.8	94.2

Load on hanger to balance self weight =A=5.7N

Roll no → 078BCE178

Date / /
Page No.

Three Hinged Arch

Symmetrical arch

Load on hanger to balance self weight = 5.7N (A)

Load	Load on hanger (B)	Horizontal Reaction (B-A) N
50N center	94.2N	88.5
25N left		
50N center	94.5N	88.8
25N right		

Unsymmetrical arch

Load on hanger to balance self weight = A = 5.4N

Load	Load on Hanger (B)(N)	Horizontal Reaction
25N/m X0.5	12.6	7.2
50N/m X0.5	19.8	14.4
75N/m X0.5	27.1	21.7
100N/m X0.5	34.4	29

080 [signature]

Unsymmetrical arch

Load on hanger to balance self weight = 5.4N (A)

Load (l=0.5m)	Load on hanger (N) (B)	Horizontal reaction (B-A) (N)
25N/m	12.6	7.2
50N/m	19.16	14.4
75N/m	27.1	21.7
100N/m	34.4	29

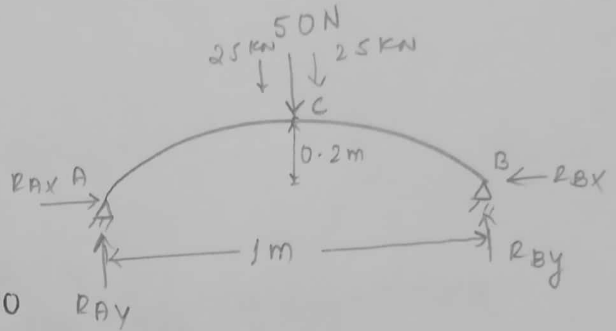
Calculating Reactions.

Symmetrical arches.

$\Sigma M_A = 0$ (↻ +ve)

or, $R_{By} \times 1 - 0.75 \times 0.5 = 0$

or, $[R_{By} = 37.5KN (\uparrow)]$



$\Sigma M_C = 0$ (right ↻ +ve)

or, $R_{Bx} \times 0.2 - R_{By} \times 0.5 = 0$

or, $[R_{Bx} = 93.75KN (\leftarrow)]$

$[R_{By} = 93.75KN (\rightarrow)]$

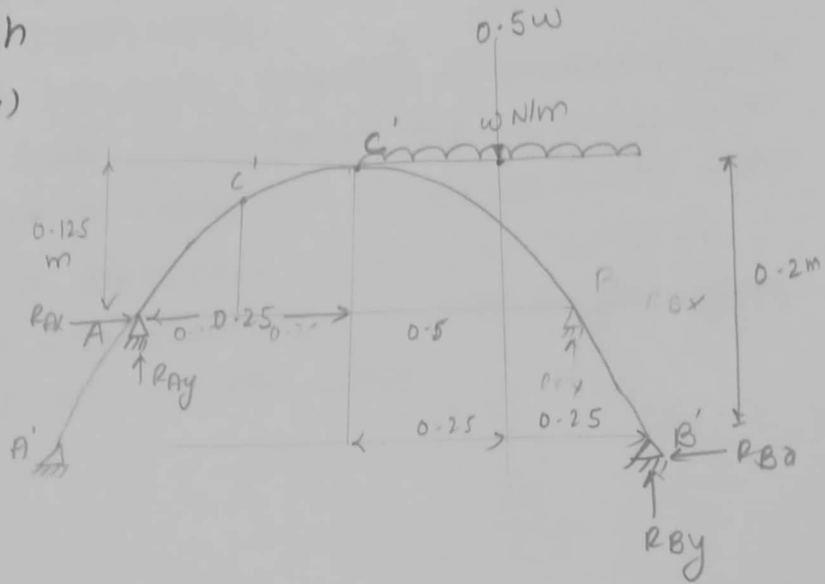
$[R_{Ay} = 50 + 25 - 37.5 = 37.5KN (\uparrow)]$

Theoretical $(R_{Bx}) = 93.75KN$

Observed $(R_{Bx}) = \dfrac{88.5 + 88.8}{2} = 88.65$ KN $(\leftarrow)$

$$\text{Error} = \left| \frac{88.65 - 93.75}{93.75} \right| \times 100\% = 5.44\%$$

Unsymmetrical arch



$(\Sigma M_C)_{left} = 0$ (↺+ve)

or, $R_{Ax} \times 0.125 - R_{Ay} \times 0.25 = 0$

$\therefore R_{Ax} = 2R_{Ay}$ — (I)

↻+ : $\Sigma M_B = 0$

or, $R_{Ay} \times 0.75 + R_{Ax} \times (0.2 - 0.125) - 0.5w \times 0.25 = 0$

or, $R_{Ay} = 0.139w$ — (II)

→+ $\Sigma F_x = 0$

or, $R_{Ax} = R_{Ay}$ — (III)

↑+ $\Sigma F_y = 0$

or, $R_{Ay} + R_{By} = 0.5w$

or, $R_{By} = 0.5w - R_{Ay} = 0.5w - 0.139w$

$[R_{By} = 0.361w]$ — (IV).

(a) Case a when w = 25 N/m

Then using (I), (II), (III), (IV)

$R_{Ay} = 3.472$ N (↑)

$R_{Ax} = 6.944$ N (→)

$R_{Bx} = 6.944$ N (←)

$R_{By} = 9.028$ N (↑)

Here, experimental value of $(R_{Bx}') = 7.2$ N

Theoretical value $(R_{Bx}) = 6.944$ N

Error % = 3.58%.

UDL (N/m)	Observed Hz. Reaction (N)	Actual Horizontal Reaction (N)	Error (N)	Error %
25	7.2	6.944	0.256	3.687 %
50	14.4	13.9	0.5	3.597 %
75	21.7	20.85	0.85	4.077 %
100	29	27.8	1.2	4.317 %

DISCUSSION AND CONCLUSION

We calculated the horizontal reaction experimentally of three hinged arch both symmetrical and unsymmetrical under various loading conditions. The experimental value slightly varies from theoretical value. This is due to instrumental error, miscallibration of load hanger, aging of instruments and observation error.

TITLE: SUSPENSION BRIDGE (RIGID DECK)

OBJECTIVES:

To compare the theoretical value of cable tension with the experimental data.

THEORY:

A suspension bridge consists of two cables, one on either side of the road way stretched over the span to be bridged. The cables which passover supporting towers are anchored by back stays to a firm foundation. The deck loads are transmitted to the cables through closely spaced hangers.

In suspension bridge, cables force an important structural component. It has been known that cables are frequently used to support loads over long spans such as in suspension bridge and roofs of open large buildings. The only force in cable is direct tension, since cables are too flexible to carry moment. The analysis of cables involves the straight forward application of equilibrium equations to various free bodies.

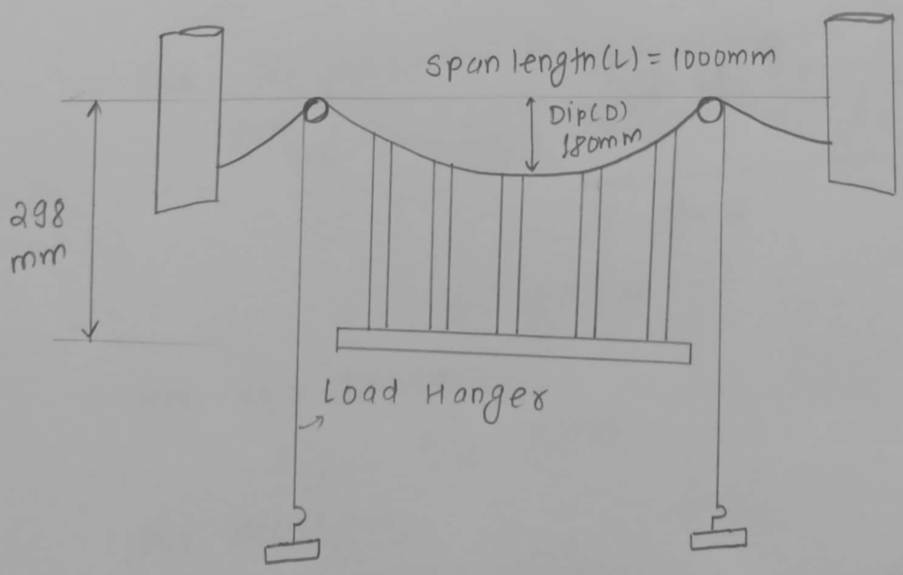


Fig: Suspension Bridge

PROCEDURE

(1) Add equal loads (H) to each load hanger until the hanger just come from the adjustable stops.

(2) The self load of bridge is now being suspended by the suspension cables

(3) Remove those loads and add uniform distributed loading to bridge deck in four increment of 25 N/m.

(4) Similarly for each loading case add equal loads at each of the two loads hangers until the hangers move down from the stops.

OBSERVATION :-

Applied Load	Load applied to hanger (W), N	Cable Tension (W − H), N
Self-Balancing weight (H)	18.7N	
25	42.5	22.8
50	66.6	47.9

The theoretical expression for cable tension

$$T = \frac{WL}{2} \frac{\sqrt{D^2 + L^2/16}}{D}$$

For, W = 25 N/m

$$T_{25} = \frac{25 \times 1}{2} \frac{\sqrt{(0.18)^2 + \frac{1}{16}}}{0.18}$$

$$= 21.393\,N$$

For, W = 50 N/m

$$T_{50} = 42.79\,N.$$

For W = 60 N/m

$$T_{60} = 54.343\,N$$

078BCE178

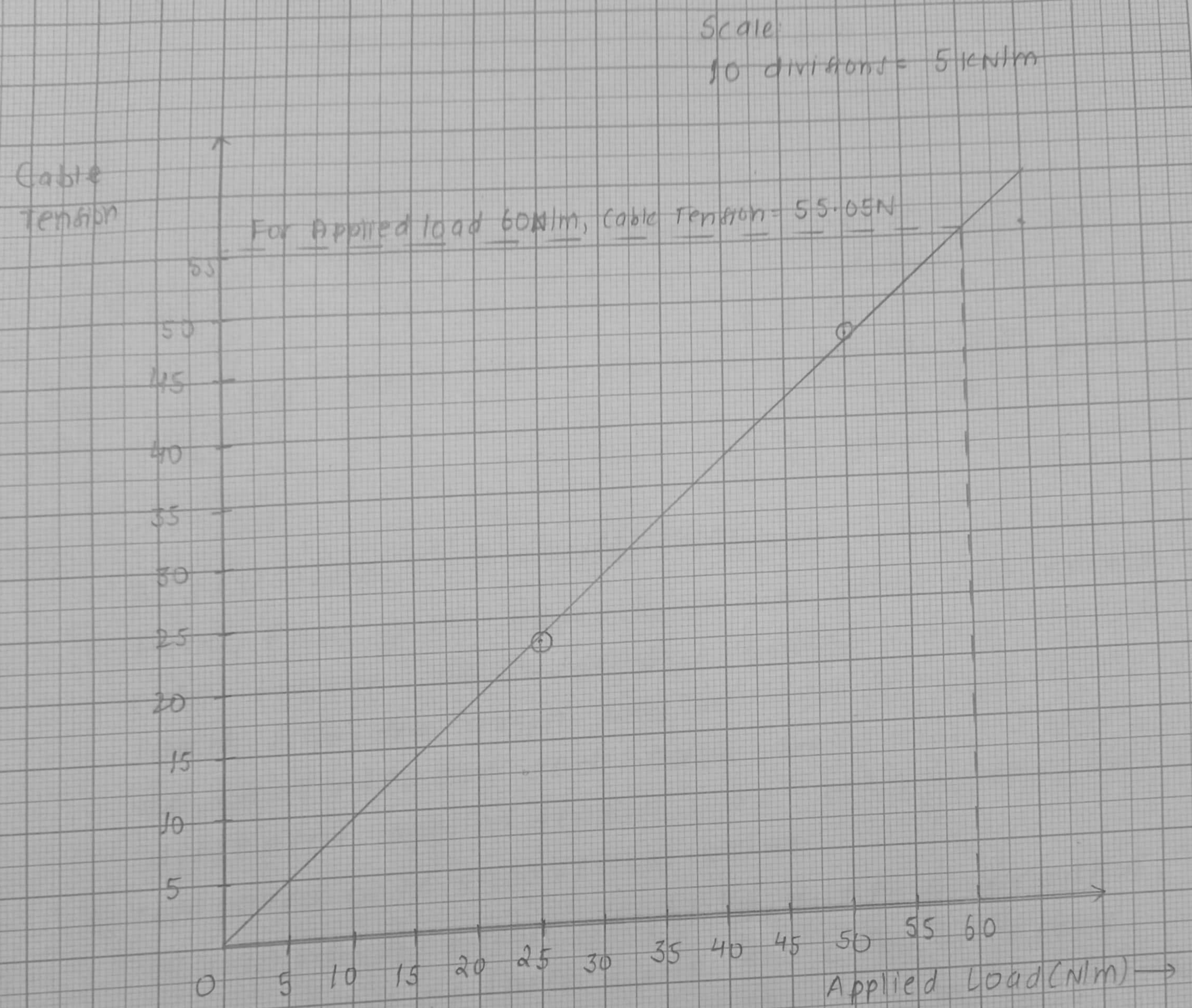
SUSPENSION BRIDGE (RIGID DECK)

Self balancing weight (H) = 18.7

Applied load (N/m)	Load applied to Hanger (H)(N)	Cable Tension (W−H)(N)
25	42.5	22.8
50	66.6	47.9

080-10-3

Graph for Applied load V/s Cable tension



From graph,

For applied load of 60N/m,

Cable tension, $T_{60}' = 55.05 KN$

Thus,

$$\text{Error \%} = \left| \frac{55.05 - 54.343}{54.343} \right| \times 100\%$$

$$= 1.3\%$$

Similarly,

For 25N/m load, $\text{Error \%} = \left| \frac{22.8 - 21.393}{21.393} \right| \times 100\%$

$$= 6.58\%$$

For 50N/m load, $\text{Error \%} = \left| \frac{42.79 - 47.9}{42.79} \right| \times 100\%$

$$= 11.94\%$$

DISCUSSION AND CONCLUSION

Hence, from given experiment we could determine cable tension on suspension bridge due to applied load. Also, the graph was plotted for Applied load v/s cable-tension and cable-tension value for different applied tension was interpolated and compared with theoretical value.

The sources of error might be due to observation, due to aging of instrument the cable lost some ~~qua~~ amount of of its elasticity and room temperature might have affected the measurement.