ENG10003 MECHANICS OF STRUCTURES

LAB 1: FORCES IN STATICALLY DETERMINATE TRUSS SYSTEM

AIM

To investigate the internal forces induced in a 7-bar truss (Warren Truss) and 9-bar truss (Howe Truss) from the application of a pattern of point loads applied to free joints and/or the roller support, from evaluation of the elongation/contraction of each model truss member and its nominal stiffness.

INTRODUCTION

A truss is a structure composed of slender members joined together at their end points.

Warren Truss- Type of engineering truss employing a weight-saving design based upon equilateral triangles

Howe Truss- Truss bridge consisting of chords,verticals and diagonals whose vertical members are in tension and whose diagonal members are in compression.

In this experiment we will be looking at Warren and Howe trusses and how the members behave when external force is applied to them.

EQUIPMENT/RESOURCES REQUIRED

i. Pix with the window frame in “landscape” configuration.
ii. 7-bar Truss (Figure 1) and 9-bar Truss(Figure 2).
iii. Set of chrome/stainless steel weight forces.
iv. A digital camera (phone cameras are suitable).
v. A digital scale.

EXPERIMENTAL PROCEDURES

The equipment was set up,making sure everything was in its original position(without any extra loadings).The equipment was also checked using a checklist before proceeding to the next procedure.

Starting with the Warren Truss,a close up photo of the slot of the member was taken,clearly depicting the internal pointer and its position.Measurements of distances L_0 and a_0 was taken on this photo (using a ruler to measure and capture the image on phone if using phone camera). This step was repeated for all members.

Reactions at Support A and Support E were measured and recorded using digital scales that were provided.Weight force (W) of the approximately nominated value was attached to Node D. Digital scales provided were used to accurately record the weight of the load mass being used.Reactions at Support A and Support E were measured again after the application of loading.

A close-up photo of the slot of the member that depicts the internal pointer and it's position was taken.Distances L_1 and a_1 on this photo was measured (using a ruler to measue and capture the image on phone if usingphone camera).This step was repeated for all member.

Since the actual slot length is 13.0mm in each of the truss members, the position of the internal pointer from the edge of the slot was in the proportion a/L of the slot length (irrespective of whether the photo is rectified or not). The elongation of the member, $\delta 1$, after application of the load became;

$\delta 1 = 13.0 \left(a_o / L_o - a_1 / L_1 \right) mm$ (if -ve, then contraction)

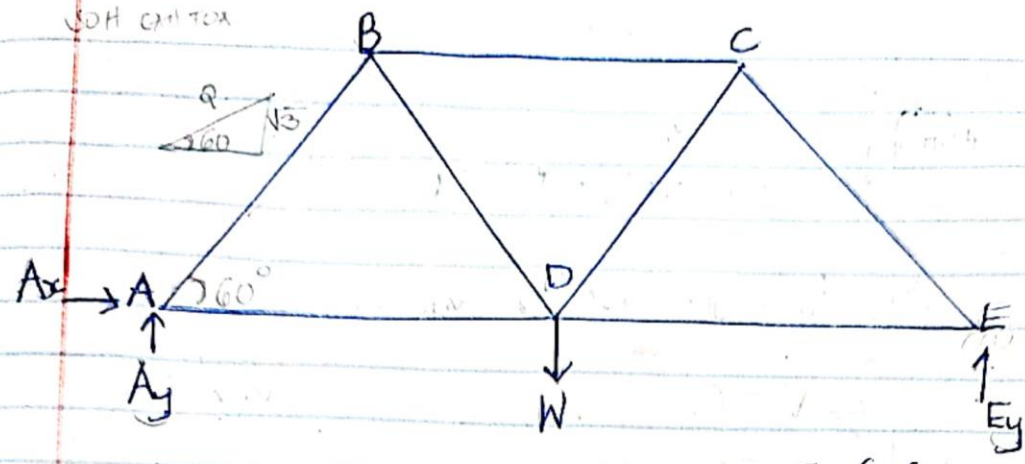
The answer was recorded and the elongation in the data sheet provided was calculated.

The procedure was repeated for 9-bar Truss (Howe Truss). All the equipment was put back to its original position and counterchecked with the checklist before leaving the laboratory.

PRE-LAB

Model Calculation

Warren Truss



$\Sigma H = 0$

$A_x = 0$

$\Sigma M_A = 0$

$-W(13) + E_y(13)(2) = 0$

$E_y(26) = 13W$

$E_y = \frac{1}{2}W$

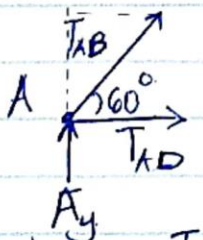
$\Sigma V = 0$

$A_y + E_y - W = 0$

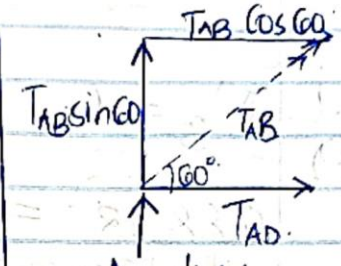
$A_y + \frac{1}{2}W - W = 0$

$A_y - \frac{1}{2}W = 0$

$A_y = \frac{1}{2}W$



Resolving T_{AB} in x and y direction;



$\Sigma F_x = 0$

$T_{AB}\cos 60 + T_{AD} = 0$

$\Sigma V = 0$

$T_{AB}\sin 60 + \frac{1}{2}W = 0$

$T_{AB} = \frac{-0.5W}{\sin 60}$

$T_{AB} = -0.5774\,W$

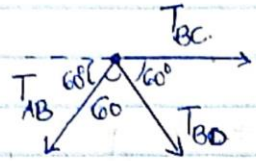
$T_{AD} = -T_{AB}\cos 60$

$= -(-0.5774W(\cos 60))$

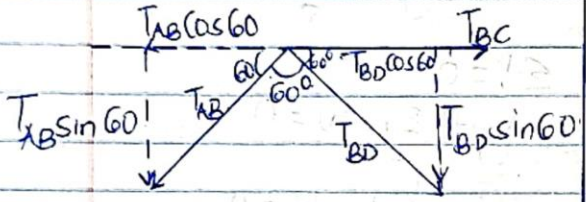
$= +0.2887\,W$

$= 0.2887\,W$

At joint B



Resolving T_{AB} and T_{BD} into x and y components.



knowing $T_{AB} = -0.5774\,W$,

$\Sigma H = 0$

$-T_{AB}\cos 60 + T_{BC} + T_{BD}\cos 60 = 0$

$\Sigma V = 0$

$-T_{AB}\sin 60 - T_{BD}\sin 60 = 0$

$-T_{AB}\sin 60 = +T_{BD}\sin 60$

$-T_{AB} = T_{BD}\dfrac{\sin 60}{\sin 60}$

$T_{AB} = -T_{BD}$

$= -(-0.5774W)$

$T_{BD} = 0.5774\,W$

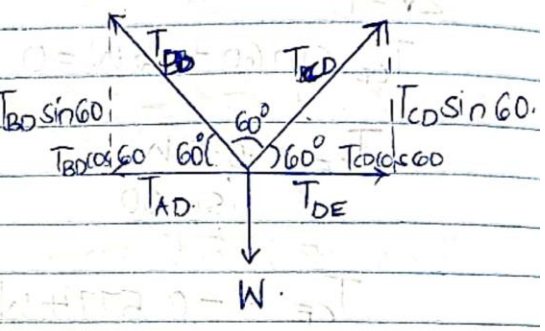
Thus; $\Sigma H = 0$

$-(-0.5774W)(0.5) + T_{BC} + 0.5774(0.5) = 0$

$T_{BC} + 0.5774W = 0$

$T_{BC} = -0.5774W$

At joint D



$\Sigma H = 0$

$-T_{BD}\cos 60 - T_{AD} + T_{CD}\cos 60 + T_{DE} = 0$

$\Sigma V = 0$

$T_{BD}\sin 60 + T_{CD}\sin 60 - W = 0$

$0.5774W(\sin 60) + T_{CD}\sin 60 - W = 0$

$-0.5W + T_{CD}\sin 60 = 0$

$T_{CD} = \dfrac{0.5\,W}{\sin 60}$

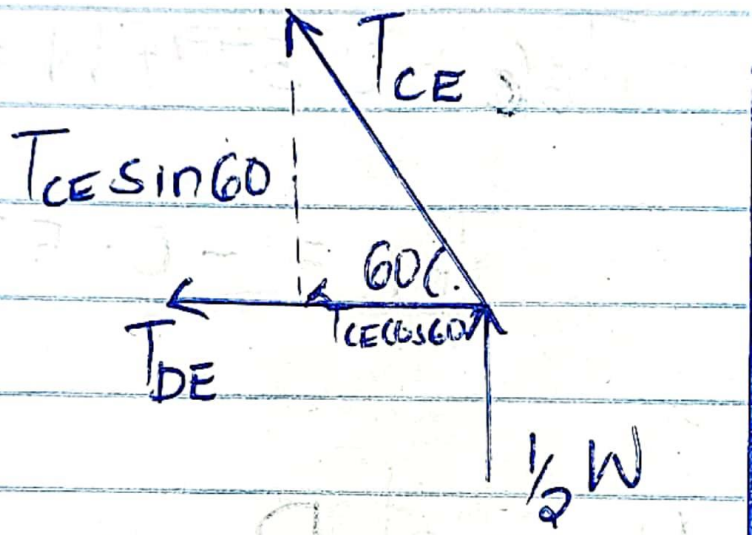
$T_{CD} = 0.5774\,W$

$0.5774W(\cos 60) - 0.2887W + 0.5774W\cos(60) + T_{DE} = 0$

$-0.2887\,W + T_{DE} = 0$

$T_{DE} = 0.2887\,W$

At joint E



$\Sigma V = 0$

$T_{CE}\sin 60 + \frac{1}{2}W = 0$

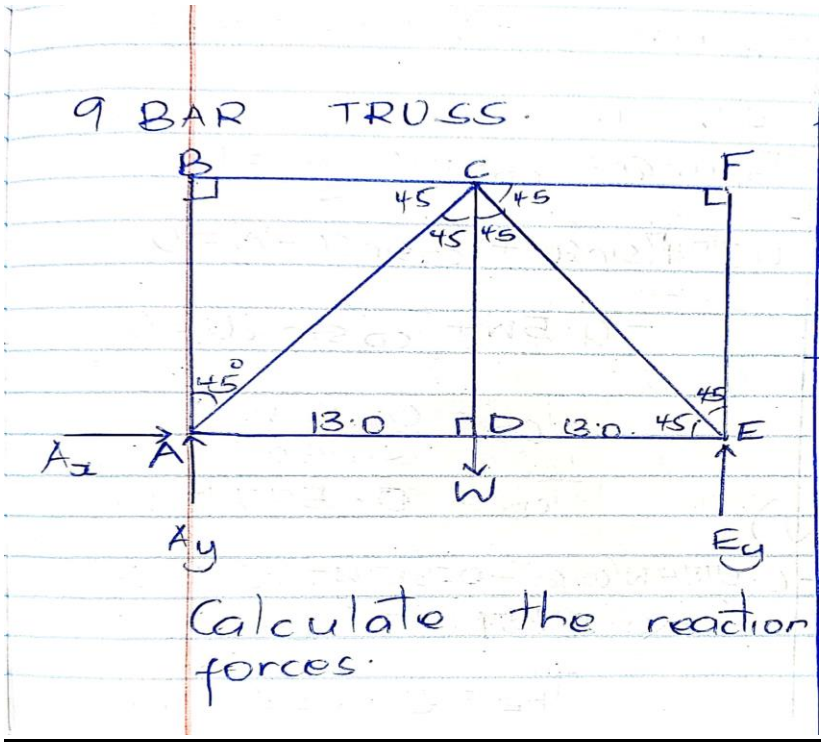
$T_{CE} = \frac{-0.5\,W}{\sin 60}$

$T_{CE} = -0.5774\,W$

Table 1:Theoretical Forces of Each Member in Term of W for Warren Truss

Member	**Force**	**Tension/Compression**
RA	0.5W	N/A
RE	0.5W	N/A
1 AB	-0.5774W	Compression
2 AD	0.2887W	Tension
3 BD	0.5774W	Tension
4 BC	-0.5774W	Compression
5 CD	0.5774W	Tension
6 DE	0.2887W	Tension
7 CE	-0.5774W	Compression

Howe Truss



$\Sigma H = 0$.

$A_x = 0$

$\Sigma M_A = 0$.

$-W(13.0) + 26 E_y = 0$.

$$E_y = \frac{13}{26} W$$

$$E_y = \frac{1}{2} W$$

$\Sigma V = 0$.

$A_y + E_y - W = 0$.

$A_y + \frac{1}{2} W - W = 0$.

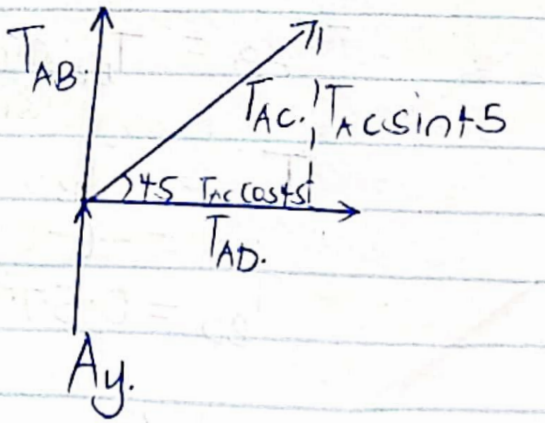
$$A_y = \frac{1}{2} W$$

By looking at the diagram, the zero force members are

AB, BC, CF, EF.

$T_{AB}, T_{BC}, T_{CF}, T_{EF} = 0$.

At joint A.



$\Sigma V = 0$

$T_{AB} + T_{AC}\sin 45 + A_y = 0.$

But $T_{AB} = 0$, zero force Member.

$0 + T_{AC}\sin 45 + \frac{1}{2}W = 0.$

$T_{AC} = \frac{-0.5W}{\sin 45}$

$T_{AC} = -0.7071\ W.$

$\Sigma H = 0$

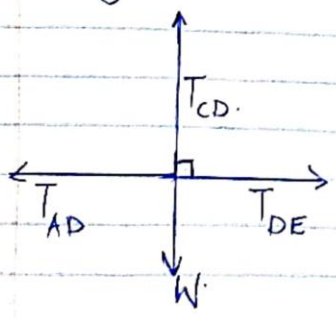
$T_{AC}\cos 45 + T_{AD} = 0.$

$T_{AD} = -T_{AC}\cos 45$

$= -(-0.7071W)(\cos 45)$

$T_{AD} = 0.5\ W$

At joint D.



$\Sigma V = 0.$

$T_{CD} - W = 0$

$T_{CD} = W$

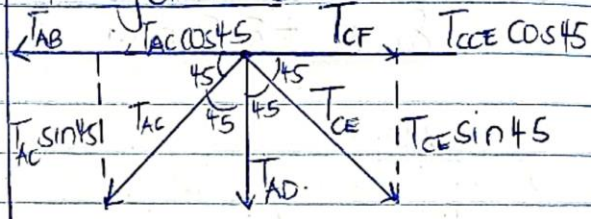
$\Sigma H = 0$

$-T_{AD} + T_{DE} = 0.$

$T_{DE} = T_{AD}.$

$T_{DE} = 0.5W.$

At joint C.



$\Sigma H = 0$

$-T_{AB} - T_{AC}\cos 45 + T_{CF} + T_{CE}\cos 45 = 0$

But, T_{AB} and T_{CF} are $= 0$, They are zero force Members

$0 - (-0.7071W\cos 45) + 0 + T_{CE}\cos 45 = 0.$

$0.5W + T_{CE}\cos 45 = 0.$

$T_{CE} = \frac{-0.5W}{\cos 45}$

$T_{CE} = -0.7071\ W$

Table 2:Theoretical Forces of Each Member in Term of W for Howe Truss

Member	**Force**	**Tension/Compression**
RA	0.5W	N/A
RE	0.5W	N/A
1 AB	0	None
2 BC	0	None
3 AC	-0.7071W	Compression
4 AD	0.5W	Tension
5 CD	W	Tension
6 CF	0	None
7 CE	-0.7071W	Compression
8 DE	0.5W	Tension
9 EF	0	None

LAB EXPERIMENT RESULTS

3.1 Data Sheet

a) Applying the assigned W≈± 300g to both set of trusses respectively(Warren Truss and Howe Truss),I recorded the data in the Table 3 .

WARREN TRUSS.

W

Experimental:

$\frac{301.2}{1000} \times 9.81 = 2.955\ N$

Theoretic:

$\frac{300}{1000} \times 9.81 = 2.943\ N$

RA

Experimental.

$\frac{150.4}{1000} \times 9.81$

$= 1.475\ N$

Theoretical

$\frac{1}{2}W = \frac{1}{2} \times 2.943$

$= 1.4715\ N$

RE

Experimental

$\frac{149.3}{1000} \times 9.81$

$= 1.465\ N$

Theoretical

$\frac{1}{2}W = \frac{1}{2} \times 2.943$

$= 1.4715\ N$

HOWE TRUSS.

W

Experimental

$\frac{295.0}{1000} \times 9.81 = 2.894\ N.$

Theoretic:

$\frac{300}{1000} \times 9.81 = 2.943\ N.$

RA

Experimental.

$\frac{124.7}{1000} \times 9.81$

$= 1.223\ N$

Theoretical

$\frac{1}{2}W = \frac{1}{2} \times 2.943$

$= 1.4715\ N$

RE

Experimental

$\frac{1.47.2}{1000} \times 9.81$

$= 1.444\ N$

Theoretical

$\frac{1}{2}W = \frac{1}{2} \times 2.943$

$= 1.4715\ N$

Table 3: Measured Records for Warren Truss and Howe Truss

Truss	Load/Reactions	Scale reading(g)			Load Reactions	
		Before Loading	After loading	Difference	Experimental	Theoretical
Warren Truss(7-bar Truss)	W			301.2	2.955	2.943
	RA	237.4	387.8	150.4	1.475	1.4715
	RE	89.3	238.6	149.3	1.465	1.4715
Howe Truss (9-bar Truss)	W			295.0	2.894	2.943
	RA	248.5	373.2	124.7	1.223	1.4715
	RE	104.8	252	147.2	1.444	1.4715

b) Based on the measurement,I recorded the data in Table 4 & Table 5.

Warren Truss

WARREN TRUSS

To Find the δ_1 of Member forces;

AB

$$\delta_1 = 13.0\left(\frac{q_0}{L_0} - \frac{q_1}{L_1}\right) \text{MM}$$

$$\delta_1 = 13.0\left(\frac{7.0}{13.0} - \frac{9.5}{13.0}\right) \text{MM}$$

$$\delta_1 = -2.5 \text{ MM}$$

AD

$$\delta_1 = 13.0\left(\frac{q_0}{L_0} - \frac{q_1}{L_1}\right)$$

$$= 13.0\left(\frac{6.0}{13.0} - \frac{4.5}{13.0}\right)$$

$$= 1.5 \text{ MM}.$$

BD

$$\delta_1 = 13.0\left(\frac{6.5}{13.0} - \frac{4.0}{13.0}\right)$$

$$= 2.5 \text{MM}.$$

BC

$$\delta_1 = 13.0\left(\frac{8.0}{13.0} - \frac{10.0}{13.0}\right)$$

$$= -2.0 \text{MM}$$

CD

$$\delta_1 = 13.0\left(\frac{6.5}{13.0} - \frac{3.5}{13.0}\right)$$

$$= 3.0 \text{MM}.$$

DE

$$\delta_1 = 13.0\left(\frac{7.0}{13.0} - \frac{6.0}{13.0}\right)$$

$$= 1.0 \text{MM}$$

CE

$$\delta_1 = 13.0\left(\frac{7.0}{13.0} - \frac{10.0}{13.0}\right)$$

$$= -3.0 \text{ MM}.$$

Table 4: Experimetally Determined Measured Member Slot for Warren Truss

Member	L_0 (mm)	L_1 (mm)	a_0 (mm)	a_1 (mm)	δ_1 (mm)	Tension/ Compression	
						Experimental	Theoretical
1 AB	13.0	13.0	7.0	9.5	-2.5	compression	Compression
2 AD	13.0	13.0	6.0	4.5	1.5	Tension	Tension
3 BD	13.0	13.0	6.5	4.0	2.5	Tension	Tension
4 BC	13.0	13.0	8.0	10.0	-2.0	Compression	Compression
5 CD	13.0	13.0	6.5	3.5	3.0	Tension	Tension
6 DE	13.0	13.0	7.0	6.0	1.0	Tension	Tension
7 CE	13.0	13.0	7.0	10.0	-3.0	Compression	Compression

HOWE TRUSS

Howe Truss

$$\delta_1 = 13.0\left(\frac{a_0}{L_0} - \frac{a_1}{L_1}\right)$$

AB

$$\delta_1 = 13.0\left(\frac{6.0}{13.0} - \frac{7.0}{13.0}\right)$$

$$= -0.5 \text{ MM}$$

BC

$$\delta_1 = 13.0\left(\frac{6.0}{13.0} - \frac{5.5}{13.0}\right)$$

$$= 0.5 \text{ MM}$$

AC

$$\delta_1 = 13.0\left(\frac{6.5}{13.0} - \frac{9.0}{13.0}\right)$$

$$= -3.5 \text{ MM}.$$

AD

$$\delta_1 = 13.0\left(\frac{5.5}{13.0} - \frac{4.0}{13.0}\right)$$

$$= 1.5 \text{ MM}.$$

CD

$$\delta_1 = 13.0\left(\frac{6.0}{13.0} - \frac{4.0}{13.0}\right)$$

$$\delta_1 = 2.0 \text{ MM}.$$

CF

$$\delta_1 = 13.0\left(\frac{6.5}{13.0} - \frac{7.0}{13.0}\right)$$

$$= -0.5 \text{ MM}$$

CE

$$\delta_1 = 13.0\left(\frac{8.0}{13.0} - \frac{11.0}{13.0}\right)$$

$$= -3.0 \text{ MM}$$

DE

$$\delta_1 = 13.0\left(\frac{6.0}{13.0} - \frac{5.0}{13.0}\right)$$

$$= 1.0 \text{ MM}.$$

EF

$$\delta_1 = 13.0\left(\frac{6.0}{13.0} - \frac{6.5}{13.0}\right).$$

$$= 0.5 \text{ MM}.$$

Table 5 : Experimetally Determined Measured Member Slot for Howe Truss

Member	L_0 (mm)	L_1 (mm)	a_0 (mm)	a_1 (mm)	δ_1 (mm)	Tension/ Compression	
						Experimental	Theoretical
1 AB	13.0	13.0	6.5	7.0	-0.5	Compression	Neither
2 BC	13.0	13.0	6.0	5.5	0.5	Tension	Neither
3 AC	13.0	13.0	6.5	9.0	-3.5	Compression	Compression
4 AD	13.0	13.0	5.5	4.0	1.5	Tension	Tension
5 CD	13.0	13.0	6.0	4.0	2.0	Tension	Tension
6 CF	13.0	13.0	6.5	7.0	-0.5	Compression	Neither
7 CE	13.0	13.0	8.0	11.0	-3.0	Compression	Compression
8 DE	13.0	13.0	6.0	5.0	1.0	Tension	Tension
9 EF	13.0	13.0	6.0	6.5	-0.5	Compression	Neither

Discussions

a) I identified all the zero force member(s) in Howe Truss.These are;

AB

BC

FC

FE.

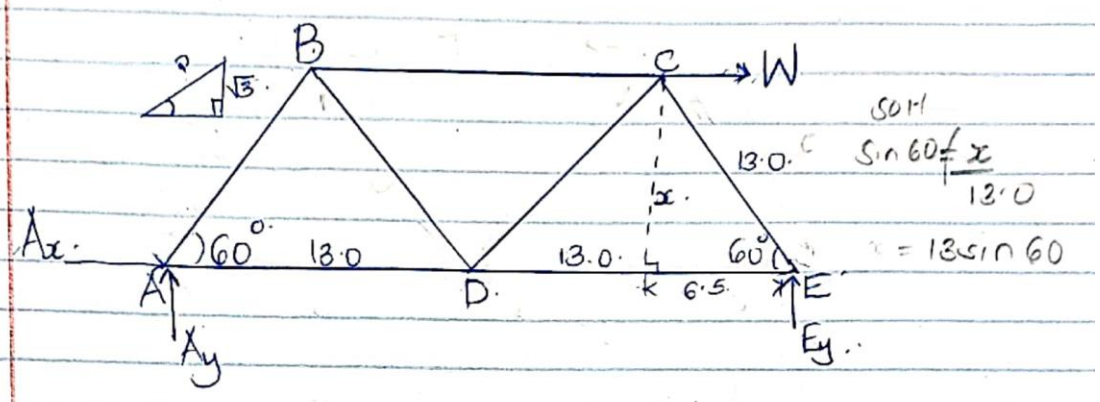
There is a difference in the magnitude of compression and tension experimentally and theoretically.One of the reasons is the self weight of the member forces included in the calculations experimentally and ignored in the theoretical calculations.

There is also parallax error when reading the values of measurements during the experiment.

b) Counterweight was required at Support A because it offers stability to the unbalanced joint.Suport A(pinned support) has a horizontal reaction force acting on it. With weight applied to the truss,there is unstability at joint A. To ensure stability and equilibrium, the counterweight is applied at joint A.

c) If the weight was acting at node C, there would be a differnce in which members would be in tension and compression to ensure equilibruim.

This is shown in the calculations and the table below which indicate the members in tension and those in compression as well as the force experienced by them.



Sin 60 = x / 13.0

x = 13 sin 60

If the weight is now acting at Node C, the expected scenario would be;

The Reaction forces would be;

$\Sigma H = 0$

$A_x + W = 0$

$A_x = -W$ (N)

$\Sigma M_A = 0$

$-W(13\sin 60) + E_y(26) = 0$

$E_y = \frac{11.258\ W}{26}$

$E_y = 0.433\ W$

$\Sigma V = 0$

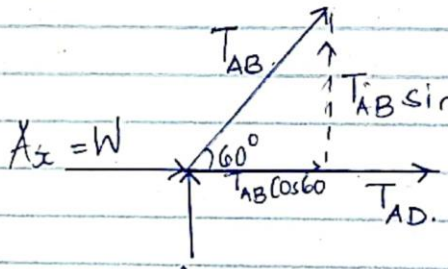
$A_y + E_y = 0$

$A_y = -E_y$

$A_y = -0.433W$

Calculating the member forces;

At Joint A.



$A_y = -0.433\ W$

$\Sigma V = 0$

$T_{AB}\sin 60 + A_y = 0$

$T_{AB}\sin 60 = -A_y$

$T_{AB}\sin 60 = -(-0.433W)$

$T_{AB} = \frac{0.433W}{\sin 60}$

$T_{AB} = 0.5\ W$ (Tension)

$\Sigma H = 0$

$A_x + T_{AD} + T_{AB}\cos 60 = 0$

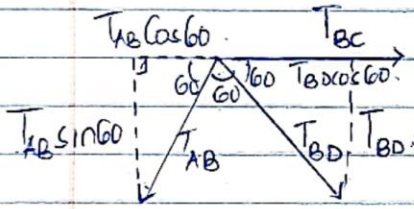
$-W + T_{AD} + 0.5W\cos 60 = 0$

$T_{AD} + 0.75W = 0$

$T_{AD} = -0.75W$ (Compression)

$T_{AD} = -0.75W$ (Compression)

At joint B.



$\Sigma V = 0$

$T_{AB}\sin 60 + T_{BD}\sin 60 = 0$

$T_{BD}\sin 60 = -T_{AB}\sin 60$

$T_{BD} = \dfrac{-0.5W\sin 60}{\sin 60}$

$T_{BD} = -0.5W$ (Compression)

$\Sigma H = 0$

$-T_{AB}\cos 60 + T_{BD}\cos 60 + T_{BC} = 0$

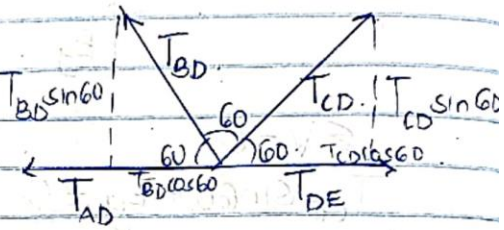
$-0.5W(\cos 60) + (-0.5W\cos 60) + T_{BC} = 0$

$-0.25W - 0.25W + T_{BC} = 0$

$-0.5W + T_{BC} = 0$

$T_{BC} = 0.5W$ (Tension)

At joint D.



$\Sigma V = 0$

$T_{BD}\sin 60 \; T_{BD}\sin 60 + T_{CD}\sin 60 = 0$

$T_{BD} = T_{CD}$

$-0.5W(\sin 60) + T_{BD}\sin 60 = 0$

$T_{BD} = \dfrac{0.5W\sin 60}{\sin 60}$

$T_{BD} = 0.5W$ (Tension)

$T_{CD} = 0.5W$ (Tension)

$\Sigma H = 0$

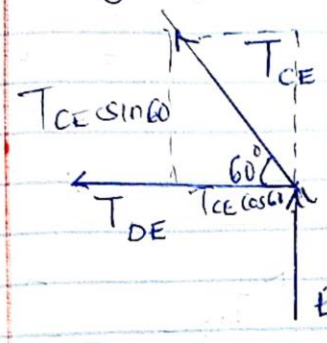
$-T_{AD} - T_{BD}\cos 60 + T_{CD}\cos 60 + T_{DE} = 0$

$-(-0.75W) - (-0.5W(\cos 60)) + 0.5W\cos 60 + T_{DE} = 0$

$1.25W + T_{DE} = 0$

$T_{DE} = -1.25W$ (Compression)

At joint E



$\Sigma V = 0$.

$T_{CE}\sin 60 + E_y = 0$.

$$T_{CE} = \frac{-E_y}{\sin 60}$$

$$T_{CE} = \frac{-0.433W}{\sin 60}$$

$T_{CE} = -0.5W$

(compression)

Table 6: Expected scenario if W is applied at Node C

Member	**Force(N)**	**Tension/Compression**
RA	-1.433	N/A
RE	0.433	N/A
1 AB	0.5W	Tension
2 AD	-0.75W	Compression
3 BD	-0.5W	Compression
4 BC	0.5W	Tension
5 CD	0.5W	Tension
6 DE	-1.25W	Compression
7 CE	-0.5W	Compression

d) The differences between theoretical and experimental reactions at support A and Support E is due to additional load of member forces which is included in the experimental calculations but are ignored during the theoretical calculation.

Below shows the calculation for experimental error wih reference to theoretical calculations.

Means Warren Truss:

% error
= R.A

$$\frac{1.475 - 1.4715}{1.4715} \times 100\%$$

$$= 0.2379\ \%$$

RE

$$\frac{1.465 - 1.4715}{1.4715} \times 100\%$$

$$= -0.4417\ \%$$

Howe Truss

RA

$$\frac{1.293 - 1.4715}{1.4715} \times 100\%$$

$$= -10.89\ \%$$

RE

$$\frac{1.444 - 1.4715}{1.4715} \times 100\%$$

$$= -1.869\%$$

W - Warren Truss

$$\frac{2.955 - 2.943}{2.943} \times 100\%$$

$$= 0.407\ \%$$

W - Howe Truss

$$\frac{2.894 - 2.943}{2.943} \times 100\%$$

$$= -1.665\ \%$$

Conclusion

Experimental reading for members of the truss in terms of tension/compression correspond to the theoretical reading.

Magnitude is however different due to human error as well as inclusion of the self weight of the members of the truss.

References

Warren truss - Wikipedia

Howe truss - Wikipedia