SHEAR FORCE IN A BEAM

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ABSTRACT

The following report describes one laboratory experiment which consisted of two parts. The first part of the experiment was to examine how shear force varies with an increasing point load. The second part was to examine how shear force varies at the cut position of the beam for various loading conditions. From our results it was concluded that for the first experiment when the load applied on the beam was increased, the Shear Force will also increase. This indicates that, Shear Force is linearly proportional (positive) to the load apply on the beam. This linear proportion can be noticed on Figure 1 of this report. However, there was a small percentage of error that occurred during the experiment which yielded slightly different experimental to theoretical values. This had an effect of the graph slightly. As for the second part of the report the shear force at the cut is equal to the algebraic sum of the forces acting to the left or right of the cut was proven to be accurate. Hence, the objective of this experiment is proven and our experiment achieved the objective.

Keywords: shear force, beam

1. Introduction

Loads on beams are common features of design. Many road bridges are constructed from beams, and as such, have to be designed to carry a knife edge load, or a string of wheel load, or a uniformly distributed load, or perhaps a combination of all three. When a beam is loaded the forces cause the beam to bend and to undergo vertical displacement (elastic deformation). These effects are due to vertical component of forces acting perpendicular to the longitudinal axis of the beam [3]. The vertical displacement tends to shear the beam. Shear means relative movement between two parts of a structural member. Any beam must be designed in such a way that it can resist shear. The purpose of this lab is to demonstrate the principles involved when determining shear force in a beam. There are two experiments involved. The purpose of the first experiment is to measure the shear force variations with an increasing point load, whereas the purpose of the second experiment is to measure the variation in shear force for various loading conditions. At the end of the lab we should arrive upon the conclusion that "The shear force at the 'cut' point is equal to the algebraic sum of the forces acting to the left or right of the cut"[2].

1.1. Procedure

<u>Laboratory 1:</u>

Part 1:

1. The teaching assistant set up the equipment in accordance with the lab manual [2].
2. The load hanger was hung at the distance 'a' from the point B.
3. The proper masses were put on the hanger according to the mass column in table 1.
4. The force displayed was noted and recorded into table 1.

Part 2:

1. The teaching assistant set up the equipment in accordance with the lab manual [2].
2. The hanger was hung according to the lab manual [2].
3. Specified masses were placed on the hanger.
4. The force displayed by the 'digital force displayer' was noted and recorded into table 2.
5. The load hanger was removed, and the hangers were placed in the position in accordance with the lab manual [2].
6. Specified masses were placed on the hangers and the values were recorded.
7. The above was repeated for row three.

2. Results

- Experimental and Theoretical values for Shear Force for experiment 1 part 1 are shown in Table 1
- Experimental and Theoretical values for Shear Force for experiment 1 part 2 are shown in Table 2
- The Load versus Shear Force for experimental and theoretical are shown in Figure 1 for part 1 and Figure 2 for part 2
- Calculated values of R_A and R_B are shown in Table 2
- All other calculations can be seen in the Appendix Section

<u>Part 1: Shear Force Variation with an Increasing Point Load</u>

Table 1. Calculations (Experiment 1, Part 1)

Mass (g)	Load (N)	Experimental Shear Force (N)	Theoretical Shear Force (N)	Percent Error (%)
0	0	0	0	0
100	0.981	0.6	0.5	20%
200	1.96	0.9	1.0	10%
300	2.94	1.4	1.5	6.7%
400	3.92	1.7	2.0	15%
500	4.9	2.2	2.5	12%

<u>Part 2: Shear Force Variation for Various Loading Conditions</u>

Table 2. Calculations (Experiment 1, Part 2)

Figure	F_1 (N)	F_2 (N)	Experimental Shear Force (N)	R_A (N)	R_B (N)	Theoretical Shear Force (N)	Percent Error (%)
5	1.96	N/A	- 0.2	2.584	-0.624	-0.623	42.3%
6	1.96	3.92	3.0	2.58	3.30	3.297	10%
7	4.9	3.92	2.2	2.81	6.01	2.1	4.5%

3. Discussion

3.1. Experiment 1, Part 1:

From Figure 1 that was plotted in this experiment, a linear graph is obtained for both Experimental Shear Force and Theoretical Shear Force values. However, for the experimental portion the graph is not 100% linear this could be due to sources of error when recording the force measurements or calibrating the equipment. Also, this may have happened due to some errors such as the sensitive apparatus easily affected by surroundings. This probably could have caused the maximum uncertainty for this experiment to be 20% for the 100g mass. However, errors can be eliminated by repeated the test at least few times in order to gain average readings. This should be implemented for future students conducting this experiment. Therefore, experimental graph should be linear. Both graphs are close to being linear and go through the origin (0,0) which tell us that, Shear Force does not exist when no load was applied on the beam. From the graph, we can notice that when the load applied on the beam was increased, the Shear Force will also increase. This indicates that, Shear Force is linearly proportional (positive) to the load apply on the beam. As well, that the equation S_c = F(L-a) / L that was used in this experiment for Theoretical Shear force calculations accurately predicts the behavior of the beam.

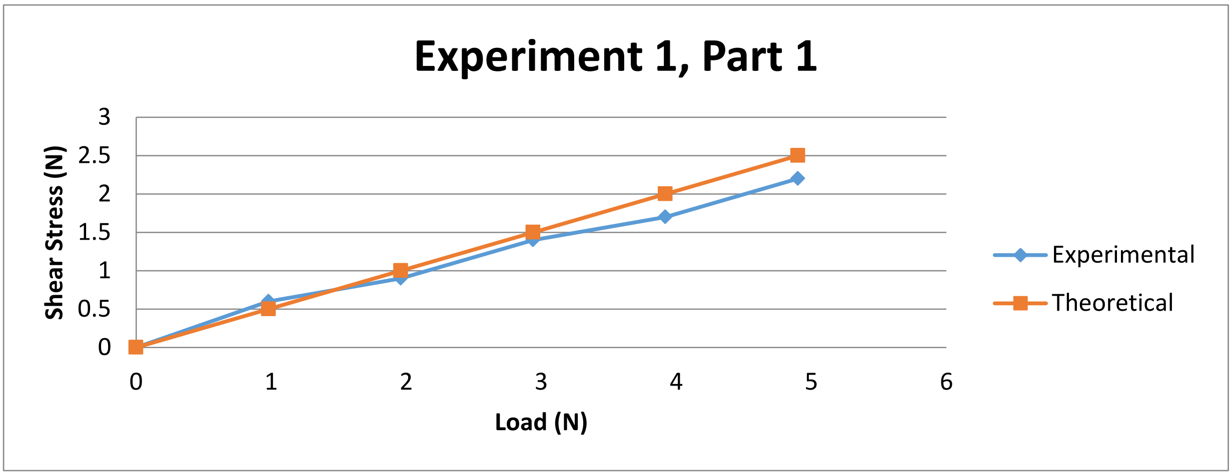

Figure 1. Experiment 1 load vs. Shear Force Comparisons for Part 1

3.2. Experiment 1, Part 2:

From Figure 2 that was plotted, it can be seen that experimental shear and the theoretical shear are very close together. There are some small deviations for figure 5 and 6. This is probably due to measurement error or sensitivity of the apparatus. As well, possibly due to the mass may not have been fully stationary when measurement was recorded and this created further uncertainty.

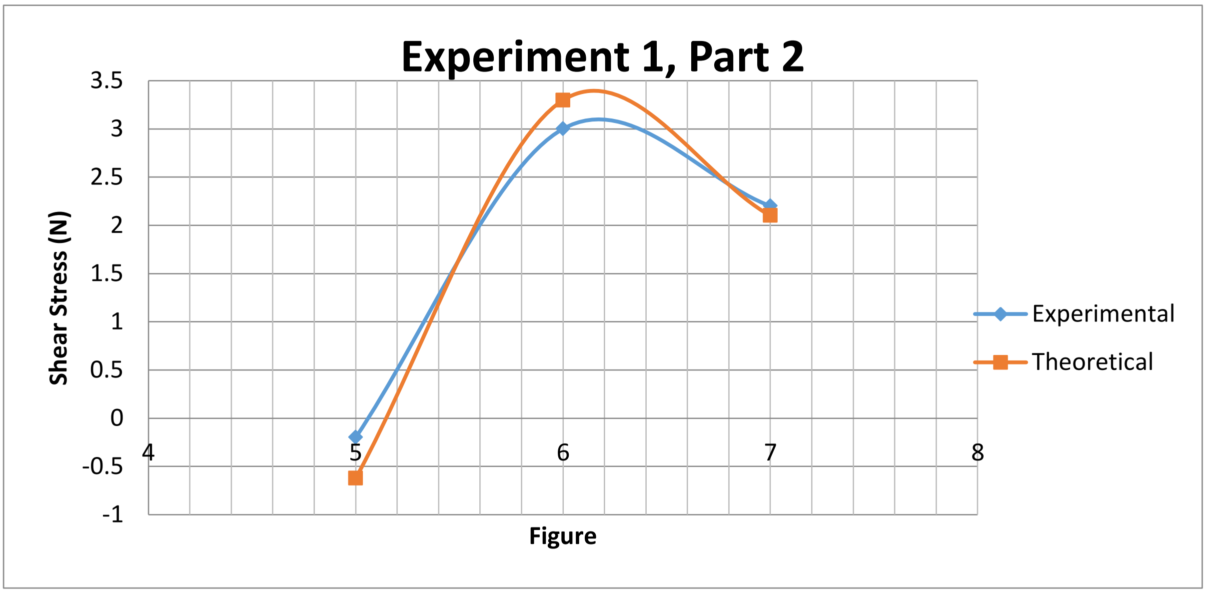

Figure 2. Experiment 1 load vs. Shear Force Comparisons for Part 2

From the experiment part 2, we found that, there is only a small difference between the values of Experimental Shear Force and the Theoretical Shear Force. For figure 6 and figure 7, the value of the Experimental Shear force is 3.0N and 2.0 N which is almost the same compared to the Theoretical Shear Force of 3.297 and 2.1N. As for figure 5 there was a small difference. The experimental was -2.0N and the theoretical was -0.623 N. Therefore, this was where the maximum uncertainty was found to be 42.3%

Also the shear force at the cut is equal to the algebraic sum of the forces acting to the left or right of the cut. The shear force can be calculated based on data distance [4]. It is proven by our experiment that the distance affects the shear force. Furthermore, this is because, from the value of F1, F2, RA and RB we can conclude that, W1 + W2 = RA + RB. The examples can be seen in Appendix B of this report for each figure.

3.3. Sources of Error for both Parts:

Possible things that caused there to be a percentage error between the experimental and theoretical values can be:

- *The beam is sensitive* when we do the experiment, the beam is moving when we try to put the load. When we want to change the holder of hanger to right side, the beam is not quite in the original position yet.
- *The load hanger is shaking*. When we are taking the reading, we put the load to the hanger. When the load is put to the hanger, the hanger is shaking and the reading of the digital indicator is changed.
- *Digital indicator is not sufficiently accurate at low values being measured.* Although the values are near each other there's still some error.
- *The digital indicator is too sensitive.* When we take the reading, the screen shows that the reading is not constant. That means the digital indicator is too sensitive and may be affected by the wind, vibration and the surrounding movement.

4. Conclusion

From this experiment, we were able to determine how shear force varies with an increasing point load. It was also seen how shear force varies at the cut position of the beam for various loading conditions. From this lab experiment, it can be concluded that when the load we placed at the beam is increasing, the Shear Force will also increase. As well it was proved that Shear force at the cut section is equal to the forces acting both right and left side of the cut section on the beam.

References

Beer, Ferdinand P.; E. Russell Johnston; John T. DeWolf, *Mechanics of Materials*. Tata McGraw-Hill Education, 2004, pp. 322–323.

Frank Durka and Hassan Al Nageim, *Structural Mechanics: loads, analysis, design and materials (6/E)*. Longman Group, United Kingdom, 2002, pp. 45-65.

Hibbeler, R., *Statics and Mechanics of Materials* (4/E). Singapore: Prentice Hall. (G. Seow, & J. Wong, Eds.), 2013.

University of Ontario Institute of Technology, *ENGR 3380U Lab 1: Shear Force Experiment.* Oshawa, Ontario. (2014).

Frank Durka and Hassan Al Nageim, *Structural Mechanics: loads, analysis, design and materials (6/E)*. Longman Group, United Kingdom, 2002, pp. 45-65.

Appendices

Appendix A: Diagram for Location of $R_{A\ and}$ R_B for the Experiment / Over All Diagram

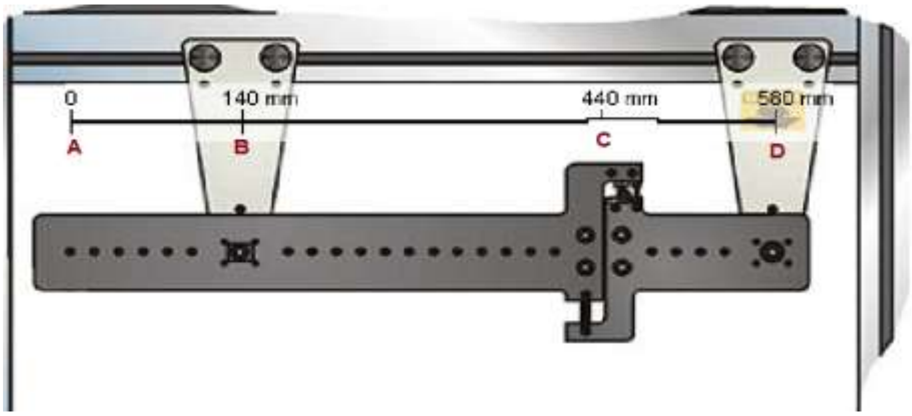

Figure 3. Over All Apparatus Diagram

Calculations were made based from this representation for part 2 of the experiment

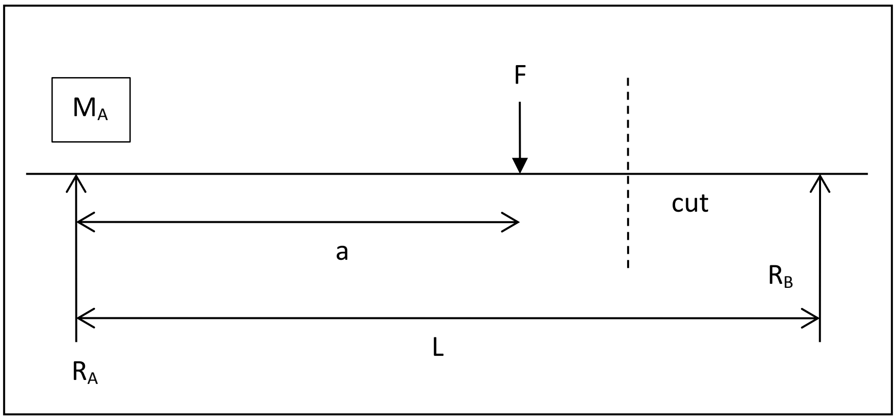

Figure 4. Part 1 Diagram for R_A and R_B Location

Appendix B: Extra Equations Used

Let; $\Sigma M_B = 0$
$(R_A * L) – F(L-a) = 0$

$R_a = F(L-a) / L$

Since the force at the cut is equal to the algebraic sum of the force acting to the left or right of the cut;

Therefore,

$Sc = R_A$

$\mathbf{S_C = F(L-a)/L}$

Let; $\Sigma M_A = 0$

$(-R_B * L) - (F*a) = 0$

$R_a = (-F*a)/ L$

$S_C = (-F*a)/L$

Appendix C: Experiment 1, Part 2 Shear Force at the Cut Proof

Figure 5:

$W_1 + W_2 = R_A + R_B$

1.96N + 0 = 2.58N + (-0.624N)

1.96N = 1.96N

Figure 6:

$W_1 + W_2 = R_A + R_B$

1.96N + 3.92N = 2.58N +3.30N

5.88N = 5.88N

Figure 7:

$W_1 + W_2 = R_A + R_B$

3.92N + 4.9N = 2.81N +6.01N

8.82N = 8.82N

Appendix D: Sample Calculations

Lab 1 Part 1:

Load:

Load = Mass**g*

Load = (0.1 kg)*(9.81 m/s^2)

Load = 0.981 N

Shear Force at Cut:

a = 22.5 cm

L = Point D –Point B = 440 mm

$S_c = R_B = (F*a)/L$

$$S_c = \frac{(0.981\ N)*(0.225m)}{0.440\ m} = 0.50\text{N}$$

Percent Error:

$$\text{Percent Error} = \left|\frac{Experimental\,Value - Theoretical\,Value}{Theoretical\,Value}\right| * 100\%$$

$$\text{Percent Error} = \left|\frac{0.6-0.5}{0.5}\right| * 100\% = 20\%$$

Lab 1 Part 2:

R_A and R_B Calculations:

Figure 5

(Moment at point B)

$$\Sigma M_A = 0$$

$$-R_B(0.44) - (1.96*0.14) = 0$$

$$R_B = \frac{1.96*0.14}{0.44} = -0.624\text{N}$$

$$\Sigma F_y = 0$$

$$R_B + R_A = W_1$$

$$R_A = 1.96\text{ N} - (-0.624) = 2.584\text{ N}$$

Figure 6

$$\Sigma M_A = 0$$

$$R_B(0.44) - 3.92(0.26) - 1.96(0.22) = 0$$

$$R_B = \frac{(1.96*0.22)+(3.92*0.26)}{0.44} = 3.30\text{ N}$$

$$\Sigma F_y = 0$$

$$R_A + R_B - W_1 - W_2 = 0$$

$$R_A + 3.30 - 1.96 - 3.92 = 2.58\text{ N}$$

Figure 7

$$\Sigma M_A = 0$$

$$R_B(0.44) - 3.92(0.4) - 4.9(0.22) = 0$$

$$R_B = 6.01$$

$$\Sigma F_y = 0$$

$$R_B + R_A = W_1 + W_2$$

$$R_A = (4.9 + 3.92) - 6.01 = 2.81\text{ N}$$

Theoretical Shear Force:

$$S_1 = -Fa/L$$

$$S_1 = \frac{1.96*0.14}{0.44\ m} = -0.623\ N$$

$$S_2 = -(-F_1a/L) - (-W_2a/L)$$

$$S_2 = -(1.96*0.22/0.44) – (-3.92*0.26/0.44) = 3.297$$

$$S_3 = (-F_2(L-a)/L) – (-W_1a/L)$$

$$S_3 = -3.92(0.44-0.4)/ 0.44 – (-4.9(0.22)/0.44) = 0.21$$