

## BENDING MOMENT 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 bending moment varies with an increasing point load. The second part was to examine how bending moment 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 bending moment will also increase. This indicates that, bending moment 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 bending moment 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.

**Key words:** *bending moment, point load, theoretically, experimentally*

### 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 [1]. The vertical displacement tends to bend the beam. Researchers tend to investigate bending characteristic

when subjected to loading [2] and [3]. Bending 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 bending moment in a beam. There are two experiments involved. The purpose of the first experiment is to measure the bending moment variations with an increasing point load, whereas the purpose of the second experiment is to measure the variation in bending moment for various loading conditions. At the end of the lab we should arrive upon the conclusion that "The bending moment at the 'cut' point is equal to the

algebraic sum of the forces acting to the left or right of the cut”[4].

**EXPERIMENT**

**Laboratory 1:**

**Part 1:**

1. The teaching assistant set up the equipment in accordance with the lab manual [4].
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 [4].
2. The hanger was hung according to the lab manual [4].
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 [4].
6. Specified masses were placed on the hangers and the values were recorded.
7. The above was repeated for row three.

**CALCULATION**

**R<sub>A</sub> and R<sub>B</sub> Calculations:**

Figure 5

(Moment at point B)

$$\Sigma M_A = 0$$

$$-R_B(0.44) - (1.96 \cdot 0.14) = 0$$

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

$$\Sigma F_y = 0$$

$$R_B + R_A = W_1$$

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

Figure 6

$$\Sigma M_A = 0$$

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

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

$$\Sigma F_y = 0$$

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

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

**RESULT AND DISCUSSION**

- Experimental and Theoretical values for Bending Moment for experiment 1 part 1 are shown in Table 1
- Experimental and Theoretical values for Bending Moment for experiment 1 part 2 are shown in Table 2
- The Load versus Bending Moment for experimental and theoretical are shown in Figure 1 for part 1 and Figure 2 for part 2
- Calculated values of M<sub>A</sub> and M<sub>B</sub> are shown in Table 2
- All other calculations can be seen in the Appendix Section

**Part 1: Bending Moment Variation with an Increasing Point Load**

Table 1: Calculations (Experiment 1, Part 1)

Mas s (g)	Loa d (N)	Experimen tal Bending Moment (N)	Theoretical Bending Moment (N)	Perce nt Error (%)
0	0	0	0	0
100	0.98 1	0.088	0.094	6%
200	1.96	0.188	0.187	0.5%
300	2.94	0.275	0.281	2%
400	3.92	0.363	0.374	3%
500	4.9	0.400	0.469	14%

**Part 2: Bending Moment Variation for Various Loading Conditions**

Table 2: Calculations (Experiment 1, Part 2)

Fig ure	F <sub>1</sub> ( N )	F <sub>2</sub> ( N )	Experi mental Bendin g Mome nt (N)	R <sub>A</sub> (N )	R <sub>B</sub> (N )	Theor etical Bendi ng Mom ent (N)	Per cent Err or (%)
4	3. 9 2	N / A	- 0.175	5. 16 7	- 1. 24 7	-0.549	37 %
5	1. 9 6	3.	0.425	2. 58	3. 30	0.592	16 %

		9 2					
6	4. 9 1	3. 9 2	0.450	2. 58 8	6. 24 2	0.621	28 %

Experiment 1, Part1:

From Figure 1 that was plotted in this experiment, a linear graph is obtained for both Experimental Bending Moment and Theoretical Bending Moment 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, Bending Moment 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 Bending Moment will also increase. This indicates that, Bending Moment 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 Bending Moment calculations accurately predicts the behavior of the beam.

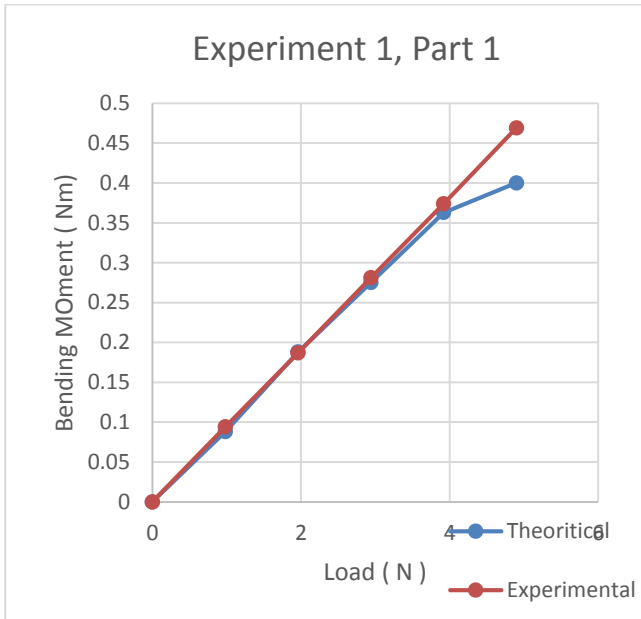


Figure 1: Experiment 1 load vs. Bending Moment Comparisons for Part 1

Experiment 1, Part 2:

From Figure 2 that was plotted, it can be seen that experimental bending moment and the theoretical bending moment 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.

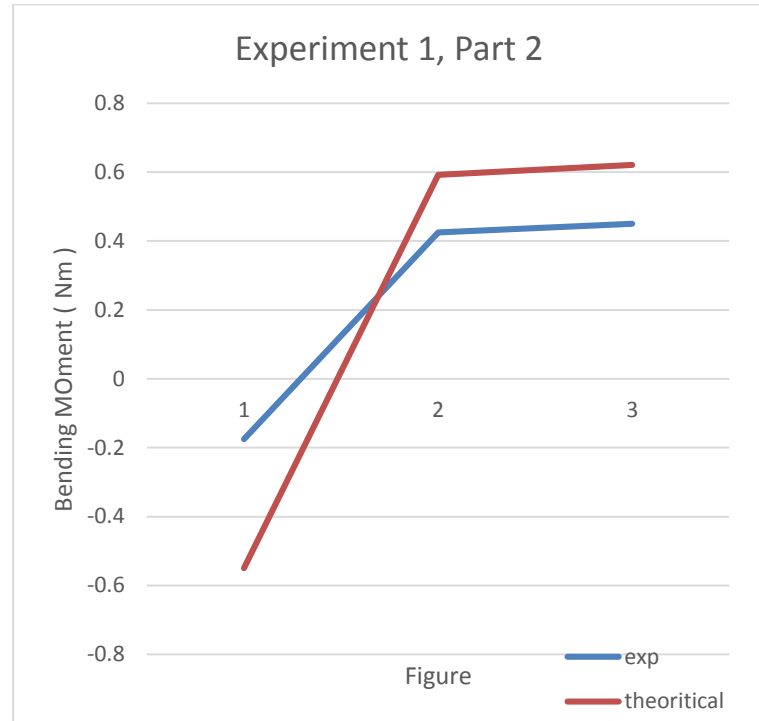


Figure 2: Experiment 1 load vs. Bending Moment Comparisons for Part 2

From the experiment part 2, we found that, there is only a small difference between the values of Experimental Bending Moment and the Theoretical Bending Moment. For figure 6 and figure 7, the value of the Experimental Bending Moment is 3.0N and 2.0 N which is almost the same compared to the Theoretical Bending Moment 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 Bending Moment at the cut is equal to the algebraic sum of the forces acting to the left or right of the cut. The Bending Moment can be calculated based on data distance [5]. It is proven by our experiment that the distance affects the Bending Moment. Furthermore, this is because, from the value of  $F_1$ ,  $F_2$ ,  $R_A$  and  $R_B$  we

can conclude that,  $W1 + W2 = RA + RB$ . The examples can be seen in Appendix B of this report for each figure.

#### 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.

#### **CONCLUSION**

From this experiment, we were able to determine how Bending Moment varies with an increasing point load. It was also seen how Bending Moment 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 Bending Moment will also increase. As well it was proved that Bending Moment

at the cut section is equal to the forces acting both right and left side of the cut section on the beam and the bending moment diagram can be determine by inversed side as stated in (Zhang, Shen, and Zhang 2014).

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