ENGR 1181 | Lab 4: Beam Bending

- Lab Memo
- Team N

Accountability Acknowledgement:

I declare and acknowledge that I have offered a significant contribution to this team writing assignment and that the work I have submitted to the group is my own.

Name (typed)	Role	Signature	Date
Justin Lewis		Justin Lewis	10/5/23
Nick Schwalm		Nick Schwalm	10/5/23
Joey Silvaggio		Joseph M Silvaggio	10/5/23
Marquez Minor		Marquez Minor	10/5/23

Memorandum

Date: October 5, 2023

To: Supervisor

From: Team Letter – Nick Schwalm, Justin Lewis, Marquez Minor, and Joey Silvaggio

Subject: Beam Bending Lab

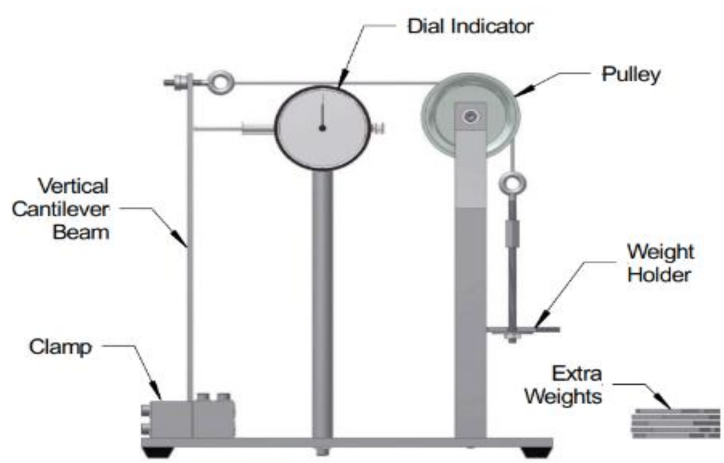
Introduction:

The goal of the Beam Bending Lab was to provide a large commercial real estate firm with guidance on the possible reuse of materials based on our evaluation of all aspects of their reclamation project. Our specific task was to identify several unknown materials within large structural beams within the properties on the old industrial end of the town where the project was taking place, and to provide precise suggestions on what materials could be re-used in the future. To demonstrate the precision of our techniques used to find our data, we tested known beams to secure precision in our field study on the unknown beams. This memo will provide a brief overview of our procedure, our results, and discuss suggestions based on our results. ~ [1]

Results:

Description of Experiment:

The equipment for this experiment was: a clamp, four types of vertical cantilever beams (aluminum, copper rectangular, copper square, and an unknown), dial indicator, a pulley weight holder, and weights. The beam apparatus was prebuilt (picture below). Put the weights in the weight holder and read the dial indicator to find the measured deflection. ~ [2]



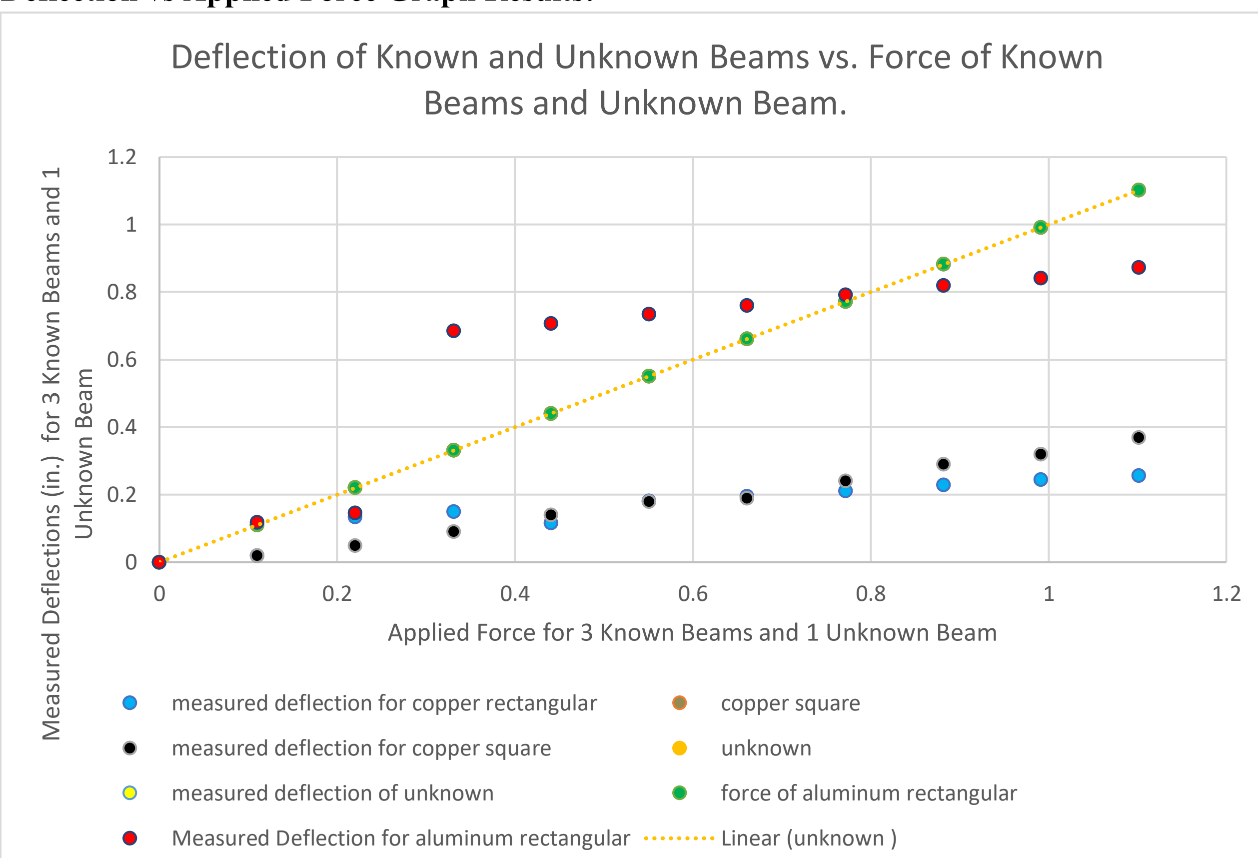
Description of Observations:

One of the most important observations made throughout all the experiments is that the force on the beams is consistent throughout each trial. This is because the force is caused by the weights pulling on the beams, and the weights used are the same for each and the same increments are used throughout. This is an important observation for our results because this is our control variable. This variable will help us determine the deflection of each beam given the same force for every beam. The beams with the smaller deflection for the same weight will correspond with larger Youngs Modulus'. This was important in determining the material of the unknown beam. Since the measured deflection was lower for the unknown beam than the three known beams, it can be assumed that the Youngs Modulus of the unknown beam would be greater than the known beams' Youngs Modulus'. ~ [3]

Youngs Modulus results:

Using the same techniques performed with the known beams, we determined the Youngs Modulus of the unknown beam to be 13,714,651. Our average percent error when getting our measured deflection was 296.97% with a standard deviation of 146.56%. This Young's Modulus was calculated in excel and determines the distance a beam will bend when a certain force is applied to it. Given this Young's Modulus and the chart provided, we were able to determine the unknown beam's material to be titanium. ~ [4]

Deflection vs Applied Force Graph Results:



Discussion:

Trends in this Study:

There were many trends in this study. First, the larger the Youngs Modulus value, the lower your deflection (measured and theoretical) values come out to be. Shapes and sizes were a common trend, if the beam had the normal thin rectangular shape, then the dial indicator value was low, but if the beam was thick and squared the dial indicator value was larger. Lastly, if the moment of inertia value was lower, the Youngs Modulus was larger. ~ [5]

Comparison to Theory:

For every beam except the rectangular copper beam, the percentage error is increasingly larger than expected. These results do not make sense for the fact that if they did, our results would not have had a percentage error that was as big as the one we reported. In a perfect world, the percentage error of all the beams would have been zero or close to zero. ~ [6]

Potential Error:

We calculated our average percent error when comparing our measured deflection to theoretical deflection to be 296.97% with a standard deviation of 146.56%. This is a very high percentage error and could affect the results and predictions greatly. This large error could be the effect of several different factors. The main factor being human/random error. This could have occurred during the set-up of the experiment. For example, the clamps holding the beam could have been tightened too much or too little, which in turn would affect the measured deflection. Our dial indicator could have been set up incorrectly, which would also affect our measured deflection results. Human/random error could also have occurred during the experiment itself. This could have happened when we were reading the dial caliper for measurements of the beams, which would in turn affect the moment of inertia, which was used to calculate theoretical deflection. These potential human/random errors could have greatly affected our results and possibly account for our large average percent error. Another cause of error could be systematic error. This could be caused by faulty or uncalibrated equipment. Systematic errors could have occurred such as the dial indicator being uncalibrated causing all the measured deflections to be slightly off by the same increment. Another possible systematic error would be if one of our beam's structural integrity was compromised causing the measured deflection to be greater than the theoretical deflection. This is unlikely to be the cause of the average error because the standard deviation would most likely be very low in this case because uncalibrated equipment would still be precise, just less accurate. ~ [7]

Shape/Material:

Shapes and materials played a role in our results for sure. The materials all had their own specific Young's Modulus values, those values tell you how stiff a material is. Regarding our study if a material had a higher Young's Modulus value, then the material was stiffer which means a lower deflection value and vice versa. Also, the shape played a factor because depending on the shape you could find how thick the beam was and the width of the beam. The thickness and the width played a role in the dial indicator value. If the beam was thin and wide then the dial indicator value was low, if the beam was thicker and less wide then the dial indicator value was higher. ~ [8]

Appendices:

Figure 1: Tables of Data

Table 1.1: Material properties of the aluminum beam

Property	Variable	Value	Units
Young's Modulus	E =	10,000,000	lbf/in^2 (psi)
Distance to Force	L =	8.750	in
Distance to Dial Ind	S =	7.500	in
Width of beam	w =	0.479	in
Thickness of beam	t =	0.115	in

Table 1.2: Calculation of moment of inertia, theoretical deflection, and experimental error (Task 1)

Calculation	Variable	Equation	Value	Units
Moment of Inertia	I =	$w \cdot t^3 / 12$	6.071E-05	in^4
Theoretical Deflection	δ =	$F \cdot S^2 \cdot (3L-S) / (6 E I)$	Varies with Force See Table 1.3	in
Experimental Error	Error =	$(\delta_{measured} - \delta_{theoretical}) / \delta_{theoretical}$	"	%

Moment of Intertia Equation =	(F16*F17^3)/12

Table 1.3: Measured and theoretical deflection according to various weights for rectangular aluminum beam (Task 1)

Number of Weights	Total Weight	Dial Indicator Reading	Incremental Deflection, ΔX (verify!)	Measured Deflection	Force	Theoretical Deflection	Error
(50g each)	(gmf)	(in)	~ constant ?	(in)	(lbf)	(in)	%
None	0	0.101	0.000	0.000	0.000	0.000	0.00%
1	50	0.220	0.119	0.119	0.110	0.032	272.84%
2	100	0.246	0.026	0.145	0.220	0.064	127.15%
3	150	0.786	0.540	0.685	0.331	0.096	615.39%
4	200	0.809	0.023	0.708	0.441	0.128	454.55%
5	250	0.836	0.027	0.735	0.551	0.160	360.56%
6	300	0.862	0.026	0.761	0.661	0.192	297.38%
7	350	0.893	0.031	0.792	0.772	0.223	254.49%
8	400	0.920	0.027	0.819	0.882	0.255	220.75%
9	450	0.942	0.022	0.841	0.992	0.287	192.77%
10	500	0.975	0.033	0.874	1.102	0.319	173.83%

Error Analysis	
Average	296.97%
Standard Deviation	146.56%

Force Equation	D28/G6
Measured Deflection Equation	E29-F28
Theoretical Deflection Equation	(G29*F15^2*(3*F14-F15))/(6*F13*H21)
Error Equation	(G29-I29)/I29

Table 2.1: Material properties of copper rectangular beam

Property	Variable	Value	Units
Young's Modulus	E =	17,000,000	lbf/in^2 (psi)
Length of beam	L =	8.750	in
Distance to Dial Ind	S =	7.500	in
Width of beam	w =	0.498	in
Thickness of beam	t =	0.125	in

Table 1.2: Calculation of moment of inertia and theoretical deflection (Task 1)

Property	Variable	Equation	Value	Units
Moment of Inertia	I =	$w \cdot t^3 / 12 =$	8.11E-05	in^4
Theoretical Deflection	δ =	$F \cdot S^2 \cdot (3L-S) / (6 E I) =$	see Table 2.3	in
Experimental Error	Error =	$(\delta_{measured} - \delta_{theoretical}) / \delta_{theoretical}$	"	%

Table 2.3: Measured and theoretical deflection according to various weights for rectangular copper beam (Task 2)

Number of Weights	Total Weight	Dial Indicator Reading	Incremental Deflection, ΔX (verify!)	Force	Measured Deflection	Theoretical Deflection	Error
(50g each)	(gmf)	(in)	~ constant ?	(lbf)	(in)	(in)	%
None	0	0.101	0.000	0.000	0.000	0.000	0.00%
1	50	0.120	0.019	0.110	0.019	0.014	35.12%
2	100	0.235	0.115	0.220	0.134	0.028	376.46%
3	150	0.251	0.016	0.331	0.150	0.042	255.57%
4	200	0.267	0.016	0.441	0.166	0.056	195.12%
5	250	0.282	0.015	0.551	0.181	0.070	157.43%
6	300	0.297	0.015	0.661	0.196	0.084	132.30%
7	350	0.312	0.015	0.772	0.211	0.098	114.36%
8	400	0.329	0.017	0.882	0.228	0.112	102.67%
9	450	0.345	0.016	0.992	0.244	0.127	92.80%
10	500	0.358	0.013	1.102	0.257	0.141	82.76%

Error Analysis	
Average	154.46%
Standard Deviation	99.52%

Table 3.1: Material Properties of Copper Square Beam

Property	Variable	Value	Units
Young's Modulus	E =	17,000,000	lbf/in^2 (psi)
Distance to Force	L =	8.750	in
Distance to Dial Ind	S =	7.500	in
Width of beam	w =	0.251	in
Thickness of beam	t =	0.251	in

Table 3.2: Calculation of moment of inertia and theoretical deflection (Task 3)

Property	Variable	Equation	Value	Units
Moment of Inertia	I =	$w \cdot t^3 / 12$ =	3.3076E-04	in^4
Theoretical Deflection	δ =	$F \cdot S^2 \cdot (3L-S) / (6 E I)$=	see Table 3.3	in
Experimental Error	Error =	$(\delta_{measured} - \delta_{theoretical}) / \delta_{theoretical}$	"	%

Table 3.3: Measured and theoretical deflection according to various weights for copper square beam (Task 3)

Number of Weights	Total Weight	Dial Indicator Reading	Incremental Deflection, ΔX (verify!)	Force	Measured Deflection	Theoretical Deflection	Error
(50g each)	(gmf)	(in)	~ constant ?	(lbf)	(in)	(in)	%
None	0	2.220	0.000	0.000	0.000	0.000	0.00%
1	50	2.240	0.020	0.110	0.020	0.003	480.38%
2	100	2.270	0.030	0.220	0.050	0.007	625.48%
3	150	2.310	0.040	0.331	0.090	0.010	770.58%
4	200	2.360	0.050	0.441	0.140	0.014	915.67%
5	250	2.400	0.040	0.551	0.180	0.017	944.69%
6	300	2.410	0.010	0.661	0.190	0.021	818.94%
7	350	2.460	0.050	0.772	0.240	0.024	894.94%
8	400	2.510	0.050	0.882	0.290	0.028	951.95%
9	450	2.540	0.030	0.992	0.320	0.031	931.79%
10	500	2.590	0.050	1.102	0.370	0.034	973.71%

Error Analysis	
Average	830.81%
Standard Deviation	164.17%

Table 4.1: Material Properties of Unknown Beam

Property	Variable	Value	Units
Young's Modulus	E =	13,714,651	lbf/in^2 (psi)
Distance to Force	L =	8.750	in
Distance to Dial Ind	S =	7.500	in
Width of beam	w =	0.539	in
Thickness of beam	t =	0.125	in

Table 4.2: Calculation of moment of inertia and theoretical deflection (Task 4)

Property	Variable	Equation	Value	Units
Moment of Inertia	I =	$w \cdot t^3 / 12$ =	8.7728E-05	in^4
Theoretical Deflection	δ =	$F \cdot S^2 \cdot (3L-S) / (6 E I)$=	see Table 4.3	in

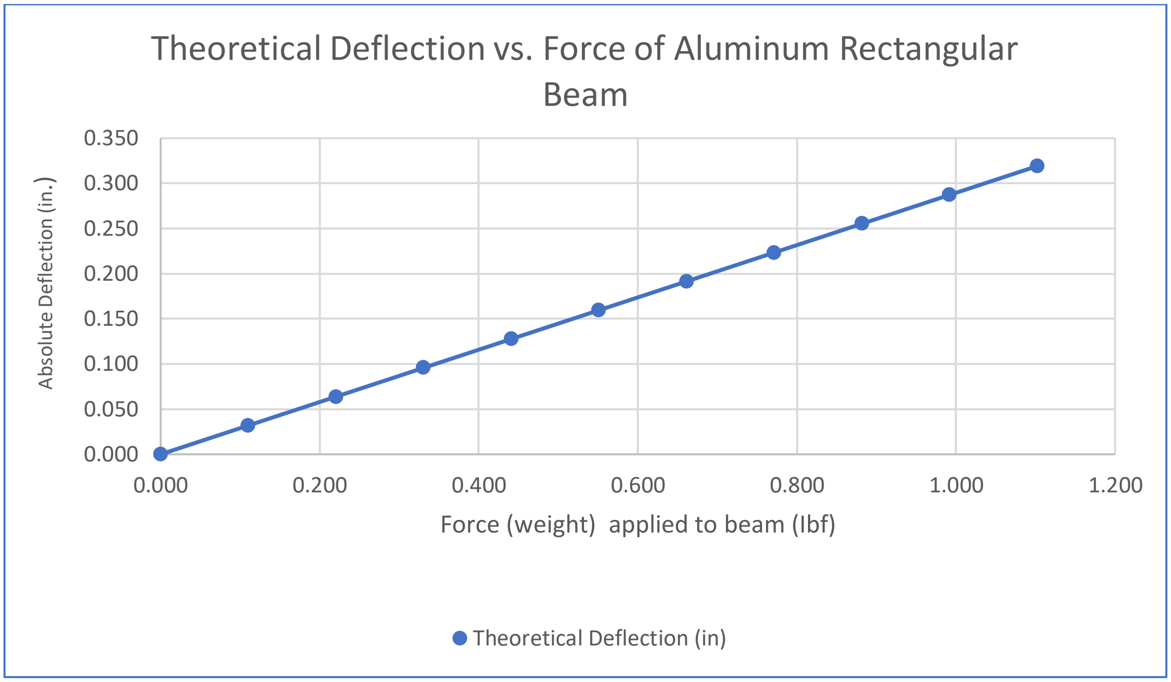
Table 4.3: Measured and theoretical deflection according to various weights for unknown beam (Task 4)

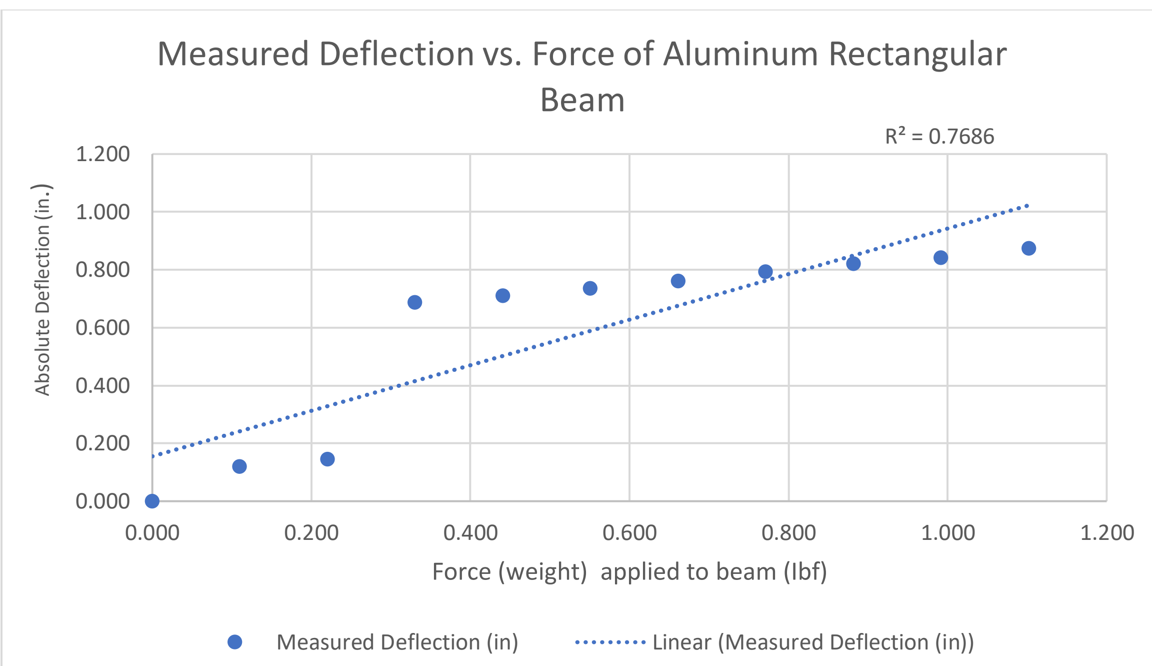
Number of Weights	Total Weight	Dial Indicator Reading	Incremental Deflection, ΔX (verify!)	Force	Measured Deflection
(50g each)	(gmf)	(in)	~ constant ?	(lbf)	(in)
None	0	0.272	0.000	0.000	0.000
1	50	0.288	0.016	0.110	0.016
2	100	0.296	0.008	0.220	0.024
3	150	0.309	0.013	0.331	0.037
4	200	0.331	0.022	0.441	0.059
5	250	0.346	0.015	0.551	0.074
6	300	0.365	0.019	0.661	0.093
7	350	0.378	0.013	0.772	0.106
8	400	0.398	0.020	0.882	0.126
9	450	0.415	0.017	0.992	0.143
10	500	0.429	0.014	1.102	0.157

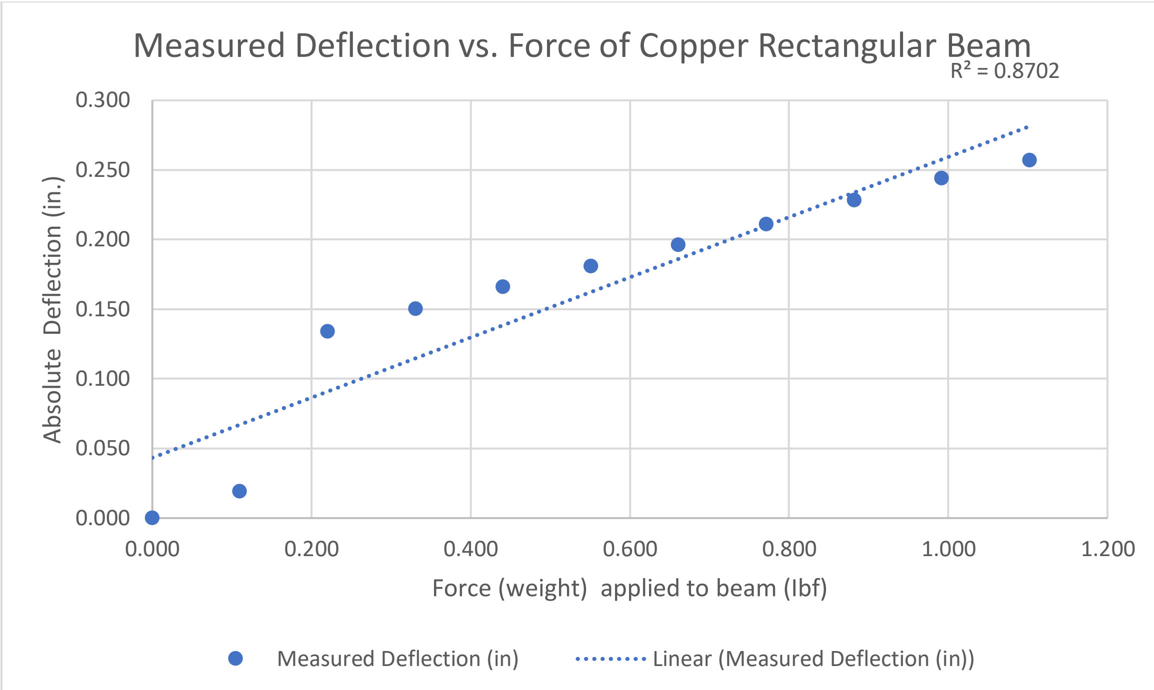
Error Analysis	
Average Error Task 1	296.97%
Average Error Task 2	154.46%
Average Error Task 3	830.81%
Estimated Error Task 4 (Average of Average Errors from Tasks 1, 2 and 3)	427.41%

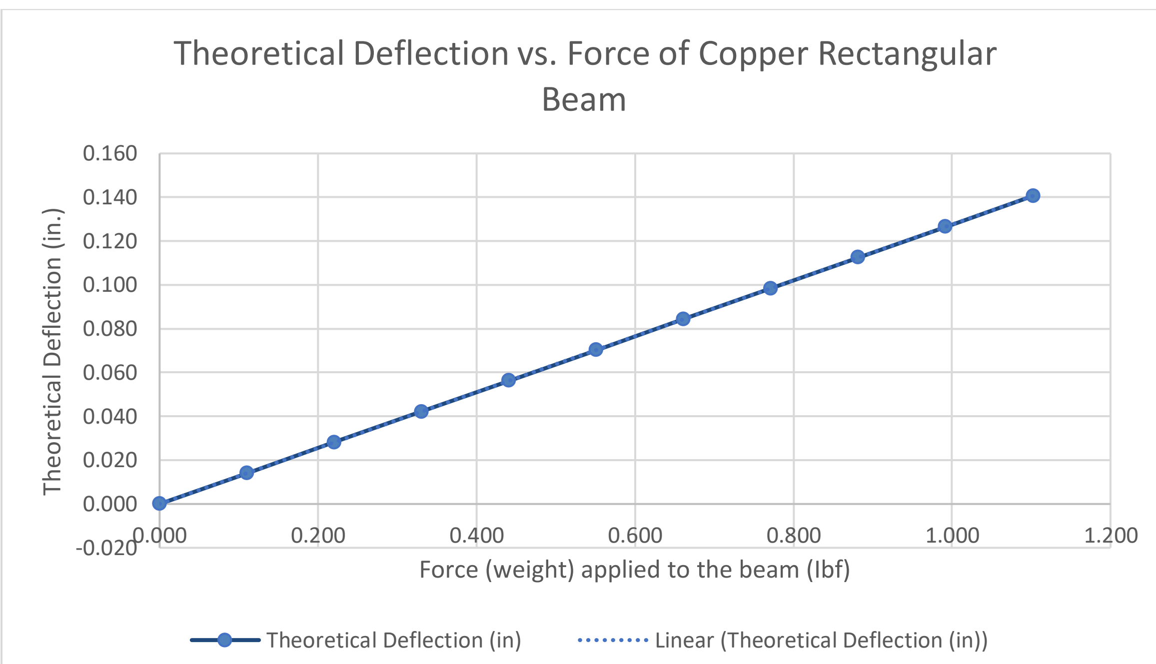
Observed Slope From Trendline Equation =	0.1461
Calculated Young's Modulus, E=	13714651.44
Youngs Moduls Equation =	((\$F\$174^2*(3*\$F\$173-\$F\$174))/(6*\$H\$180))*(1/\$M\$201)
Young's Modulus Lower Limit	-44903693.78
Youngs Modulus Upper Limit	72332996.66
Unknown Beam is	Titanium

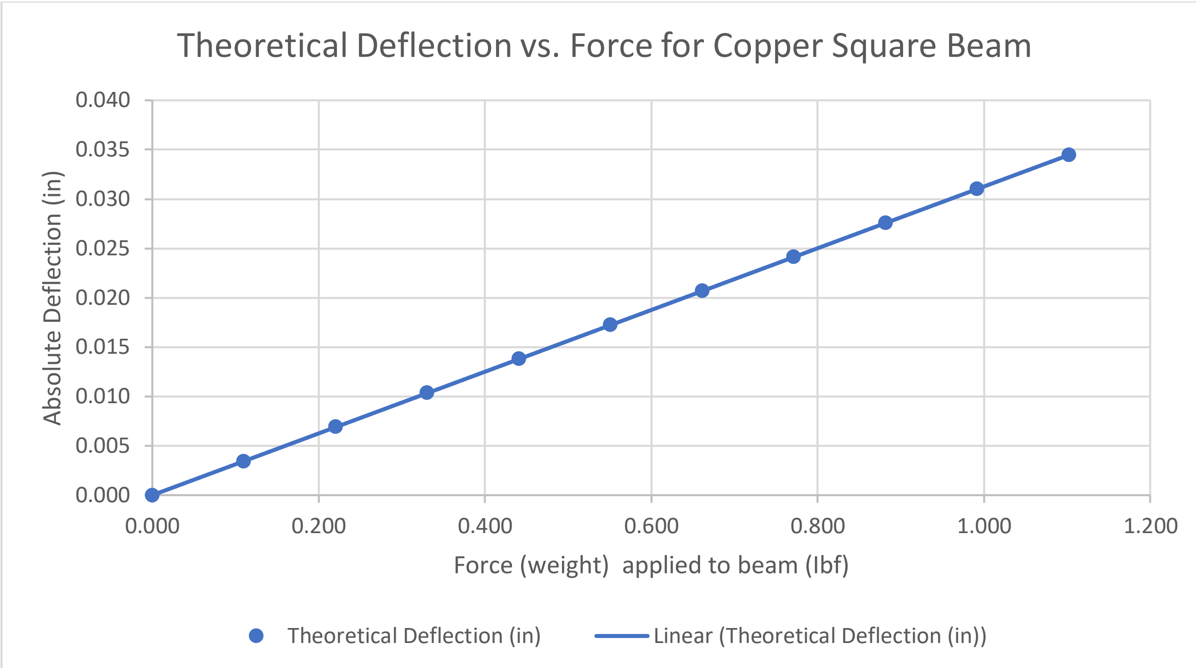
Figure 2: Graphs of Results

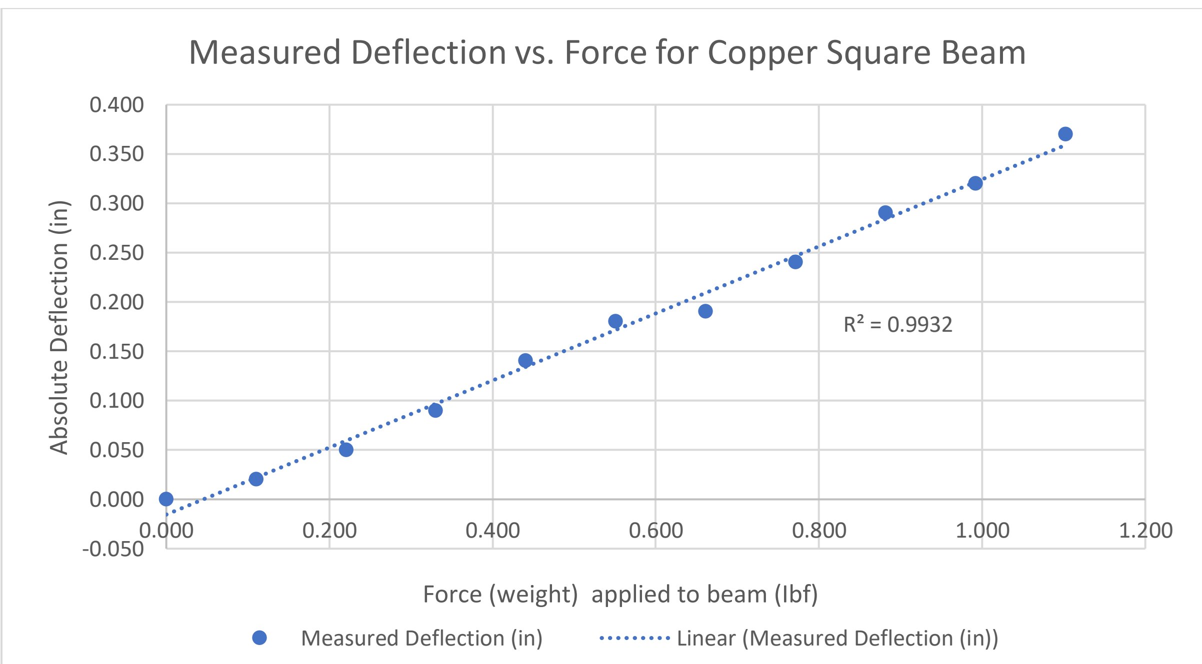


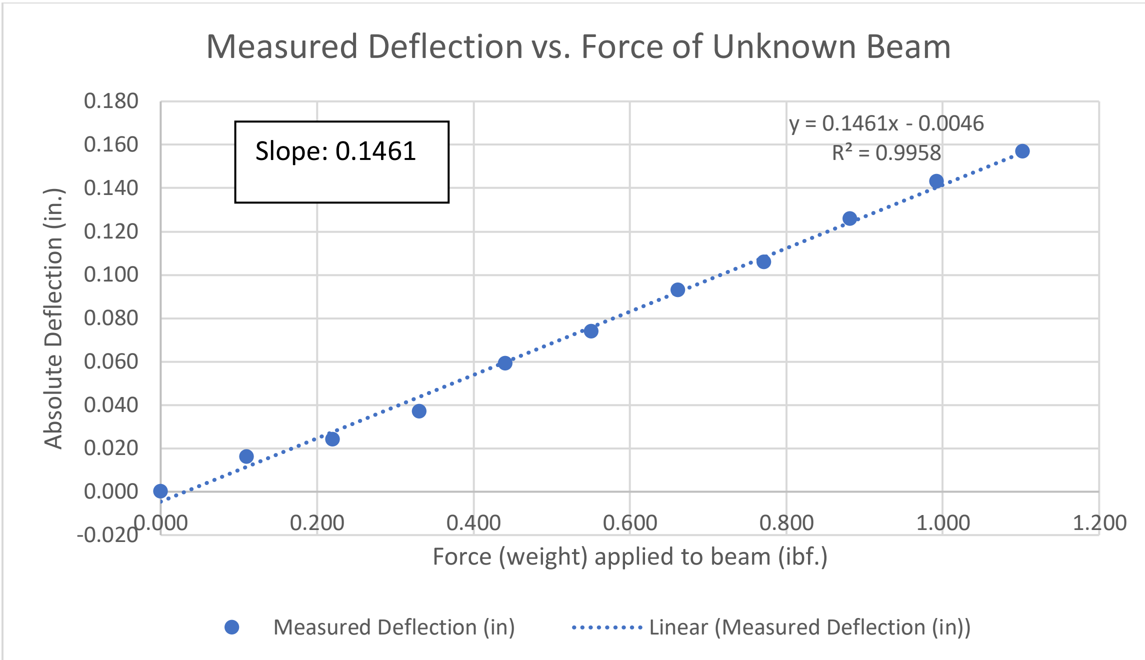



Measured Deflection vs. Force of Copper Rectangular Beam
R² = 0.8702
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Absolute Deflection (in.)
0.000
0.200
0.400
0.600
0.800
1.000
1.200
Force (weight) applied to beam (lbf)
Measured Deflection (in)
Linear (Measured Deflection (in))

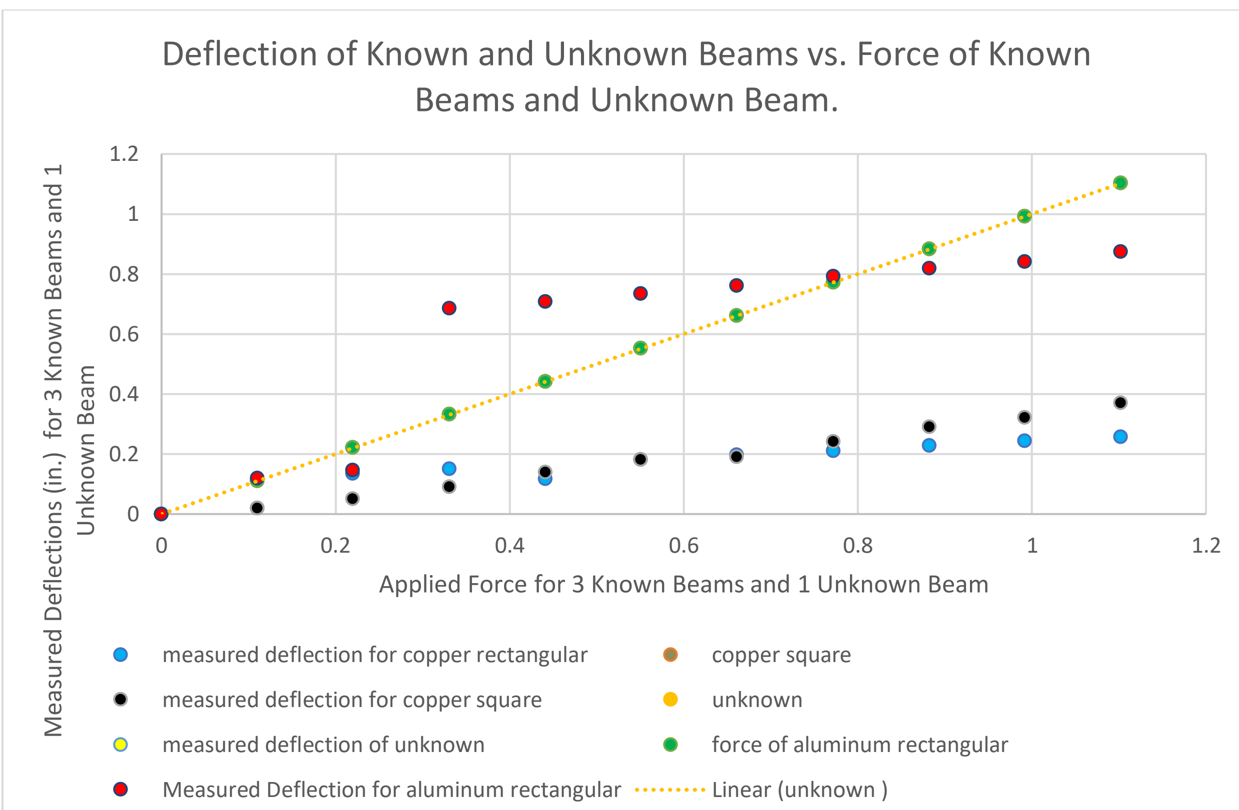

Theoretical Deflection vs. Force of Copper Rectangular Beam
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
-0.020
Theoretical Deflection (in.)
0.000
0.200
0.400
0.600
0.800
1.000
1.200
Force (weight) applied to the beam (lbf)
Theoretical Deflection (in)
Linear (Theoretical Deflection (in))


Theoretical Deflection vs. Force for Copper Square Beam
Absolute Deflection (in)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.000
0.200
0.400
0.600
0.800
1.000
1.200
Force (weight) applied to beam (lbf)
Theoretical Deflection (in)
Linear (Theoretical Deflection (in))


Measured Deflection vs. Force for Copper Square Beam
Absolute Deflection (in)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
-0.050
0.000
0.200
0.400
0.600
0.800
1.000
1.200
$R^2 = 0.9932$
Force (weight) applied to beam (lbf)
Measured Deflection (in)
Linear (Measured Deflection (in))



Measured Deflection vs. Force of Unknown Beam
Slope: 0.1461
y = 0.1461x - 0.0046
R² = 0.9958
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
-0.020
0.000
0.200
0.400
0.600
0.800
1.000
1.200
Absolute Deflection (in.)
Force (weight) applied to beam (ibf.)
Measured Deflection (in)
Linear (Measured Deflection (in))



Deflection of Known and Unknown Beams vs. Force of Known Beams and Unknown Beam.
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
Measured Deflections (in.) for 3 Known Beams and 1 Unknown Beam
Applied Force for 3 Known Beams and 1 Unknown Beam
measured deflection for copper rectangular
copper square
measured deflection for copper square
unknown
measured deflection of unknown
force of aluminum rectangular
Measured Deflection for aluminum rectangular
Linear (unknown)

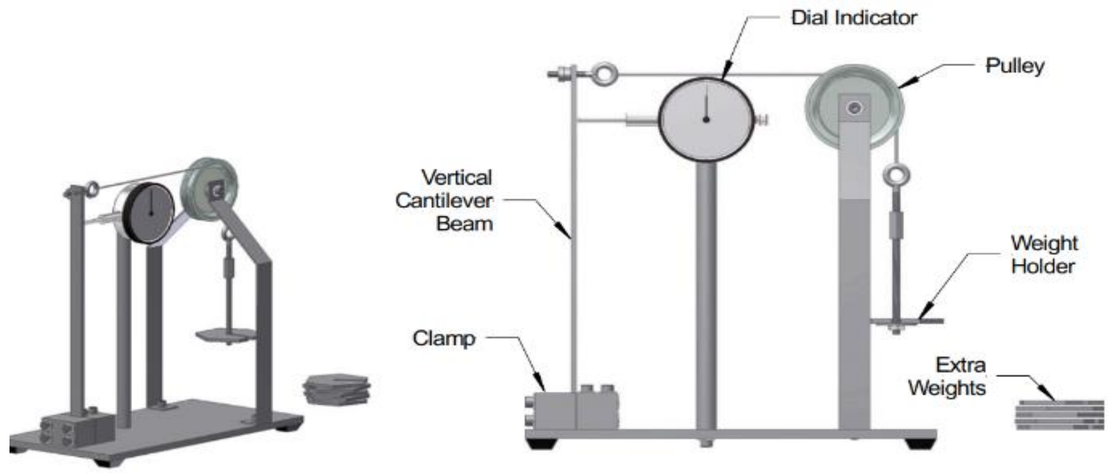


Figure 3: Beam Apparatus

Conclusions and Recommendations:

Summary:

In this experiment we took 4 beams and found measured and theoretical deflection, the Young's Modulus, and the moment of inertia, and force. Force was constant throughout this experiment because we applied the same amount of weight on each beam. We also found that if the Young's Modulus was high than the deflection values were lower and vice versa. Also, if the Young' Modulus value was high then the moment of inertia was lower. There were many trends that effected our results, some of those trends include: shape, material, and different errors. ~ [9]

Resolving Error:

The possible sources of error that were discussed were human/random error and systematic error. Systematic error could be resolved by ensuring all the equipment is calibrated correctly and still in good working condition. The human/random error would obviously be more difficult to mitigate since it is completely random and cannot be easily tracked. One easy way to eliminate human/random error is to repeat the experiment with more trials for each beam. With repetition of the experiment, human/random errors that occurred initially should slowly decrease and therefore decrease the average error of the experiment. ~ [10]

Client Brownfield Recommendation:

We found the unknown beam's material to be titanium. Titanium is just as durable as steel, but half the weight, so it has many uses, especially in engineering. Such recommendations for titanium uses could be things like sports car materials for lightweight chassis verses heavy materials like steel or iron. Another use for titanium is the formation of prosthetic limbs, and the components that go into prosthetics, because titanium is lightweight and durable, the patients would get to enjoy a durable mechanical replacement without as much strain on their bodies. ~ [11]

References:

[1]. Ohio State College of Engineering. (n.d.). *Beam Bending Lab Procedure* . buckeyesharepoint . https://buckeyemailosu.sharepoint.com/sites/ENG-EED/EED%20Shared%20Curriculum%20Materials/Forms/AllItems.aspx?id=%2Fsites%2FENG%2DEED%2FEED%20Shared%20Curriculum%20Materials%2FEED%20ENGR%20Class%20Materials%2FENGR%201181%2FLab%5FENGR%5F1181%5F2023%2D2024%2FBeam%20Bending%20Lab%2FLab%2004%20%2D%20Beam%20Bending%20Lab%20%2D%20Procedure%2Epdf&parent=%2Fsites%2FENG%2DEED%2FEED%20Shared%20Curriculum%20Materials%2FEED%20ENGR%20Class%20Materials%2FENGR%201181%2FLab%5FENGR%5F1181%5F2023%2D2024%2FBeam%20Bending%20Lab&p=true&ga=1

[2]. Ohio State College of Engineering. (n.d.). *Beam Bending Lab Procedure* . buckeyesharepoint . https://buckeyemailosu.sharepoint.com/sites/ENG-EED/EED%20Shared%20Curriculum%20Materials/Forms/AllItems.aspx?id=%2Fsites%2FENG%2DEED%2FEED%20Shared%20Curriculum%20Materials%2FEED%20ENGR%20Class%20Materials%2FENGR%201181%2FLab%5FENGR%5F1181%5F2023%2D2024%2FBeam%20Bending%20Lab%2FLab%2004%20%2D%20Beam%20Bending%20Lab%20%2D%20Procedure%2Epdf&parent=%2Fsites%2FENG%2DEED%2FEED%20Shared%20Curriculum%20Materials%2FEED%20ENGR%20Class%20Materials%2FENGR%201181%2FLab%5FENGR%5F1181%5F2023%2D2024%2FBeam%20Bending%20Lab&p=true&ga=1

[3]. Ohio State College of Engineering. (n.d.). *Beam Bending Lab Procedure* . buckeyesharepoint . https://buckeyemailosu.sharepoint.com/sites/ENG-EED/EED%20Shared%20Curriculum%20Materials/Forms/AllItems.aspx?id=%2Fsites%2FENG%2DEED%2FEED%20Shared%20Curriculum%20Materials%2FEED%20ENGR%20Class%20Materials%2FENGR%201181%2FLab%5FENGR%5F1181%5F2023%2D2024%2FBeam%20Bending%20Lab%2FLab%2004%20%2D%20Beam%20Bending%20Lab%20%2D%20Procedure%2Epdf&parent=%2Fsites%2FENG%2DEED%2FEED%20Shared%20Curriculum%20Materials%2FEED%20ENGR%20Class%20Materials%2FENGR%201181%2FLab%5FENGR%5F1181%5F2023%2D2024%2FBeam%20Bending%20Lab&p=true&ga=1

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