Modulus of Rupture of Ceramics and Bending of Sandwich Structures

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Abstract

In this experiment we conducted bending tests on several different specimens of Aluminum as well as Ceramics. Using the data gathered from these tests as well as measurements we took of their primary dimensions, we calculated (for each specimen) modulus of rupture, flexure strain, Young's modulus, as well as specific strength and stiffness. These tests gave us insight into new characteristics of aluminum and ceramics that allowed us to better understand their applications in industry.

1 Introduction

Our objective in this lab was to determine the Poissons ratio and Youngs Modulus for different specimens of Aluminum. These included high purity aluminum, aluminum honeycombed, and solid aluminum. To do this, we used raw data gathered from bending tests we conducted of these specimens with two different tensile testing machines. Using a micrometer, we also measured the dimensions of each of the specimens. The equations we used to calculate Modulus of Rupture, flexure strain, and the youngs modulus are all shown below. The MOR (modulus of rupture) is calculated using:

$$\sigma_(fb) = \frac{3LP_f}{2tw.^2} \tag{1}$$

For flexure stain:

$$\epsilon_f = \frac{6wv}{L.^2} \tag{2}$$

And for calculating the youngs modulus:

$$E_B = \frac{L.^3m}{4tw.^3} \tag{3}$$

$$Stiffness(Specific) = \frac{E_B}{Density} \tag{4}$$

$$Strength(Specific) = \frac{P_f}{Density} \tag{5}$$

In these equations, P_f is the load at the fracture while L, t and w are the length, thickness, and width of each specimen respectively.

2 Materials and Procedure

We first measured the primary dimensions of each of the specimens using a micrometer A picture of the specimens are shown below.

Figure 1: Small Specimens

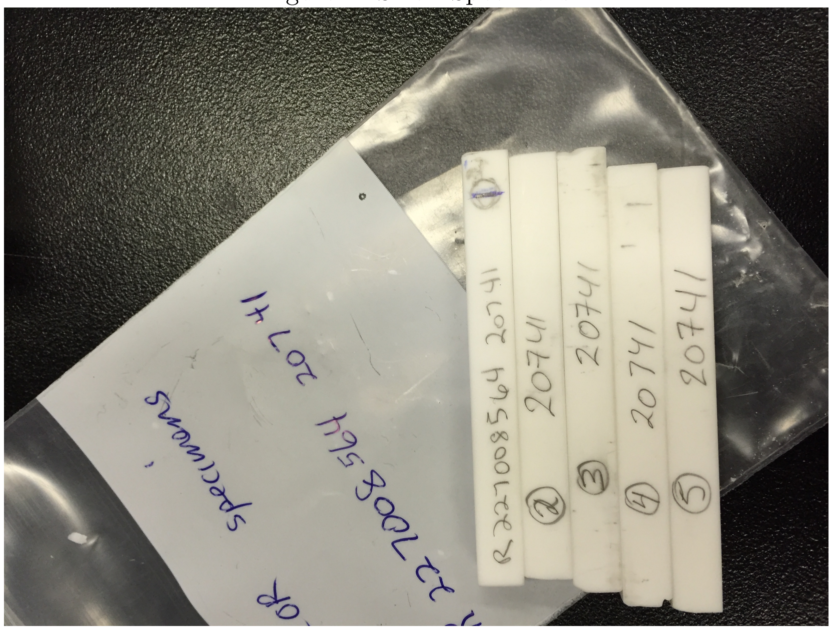
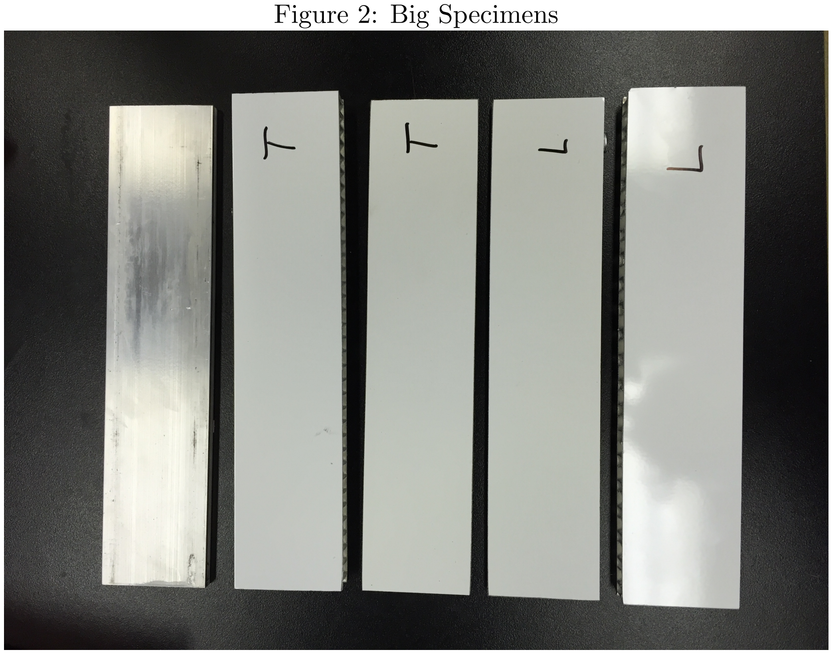


Figure 2: Big Specimens



We then conducted bending tests using the INSTRON 5500R and 4500R. As more and more force was applied, we could visibly see the samples form a

V-shaped bend in the middle.

Figure 3: Bending Test (Before)

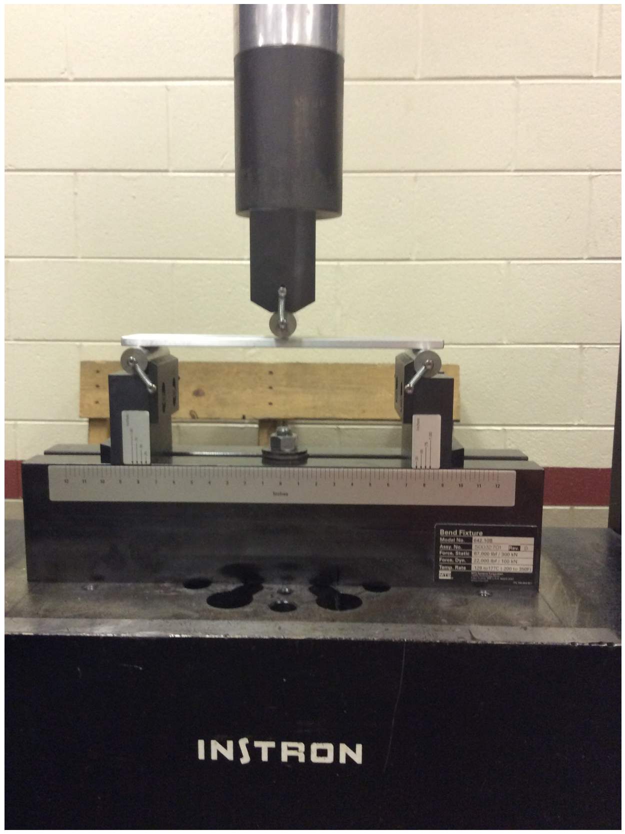
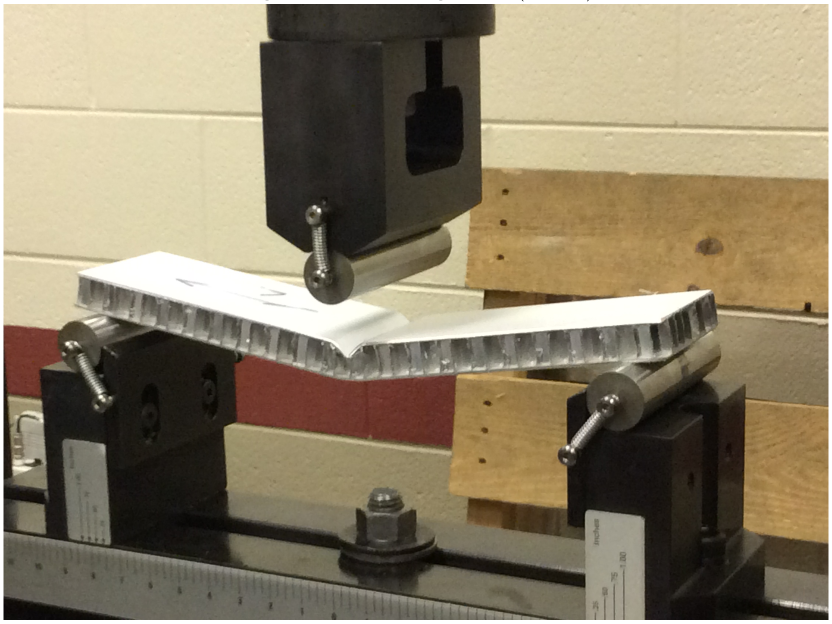


Figure 4: Bending Test (After)



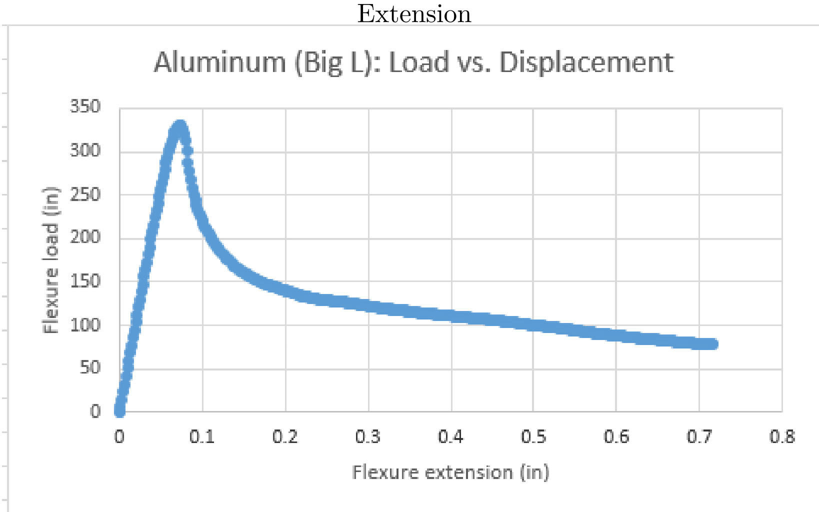
3 Results

Our measurements of the primary dimensions using a micrometer is shown in the table below.

Figure 5: Measurements of Primary Dimensions

Material	Length - in.	Width(2c) - in.	Thickness- in.	Mass - g
HoneyComb				
Big L	9.0	0.5112	2.012	68.0
Little L	9.0	0.2255	1.976	36.9
Big T	9.0	0.5098	1.973	69.1
Little T	9.0	0.2255	1.984	36.1
Alumnium	9.0	0.2526	1.996	200.7
Ceramic				
1	2.357	0.2512	0.2551	6.6
2	2.415	0.2548	0.2594	6.6
3	2.398	0.2548	0.2597	6.6
4	2.364	0.2514	0.2551	6.5
5	2.380	0.2510	0.2558	6.5

Figure 6: Plot of Aluminum (Big L): Change in Flexure Load Over Flexure Extension



We plotted Flexure load vs Flexure displacement (extension) for each of the specimens using Microsoft Excel as shown below.

Figure 7: Plot of Aluminum (Big L): Change in Flexure Load Over Flexure Extension

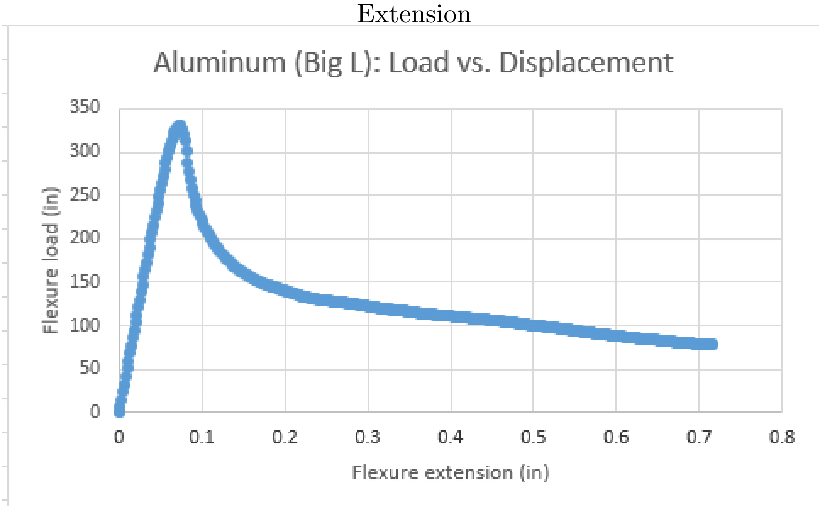


Figure 8: Plot of Aluminum (Big T): Change in Flexure Load Over Flexure Extension

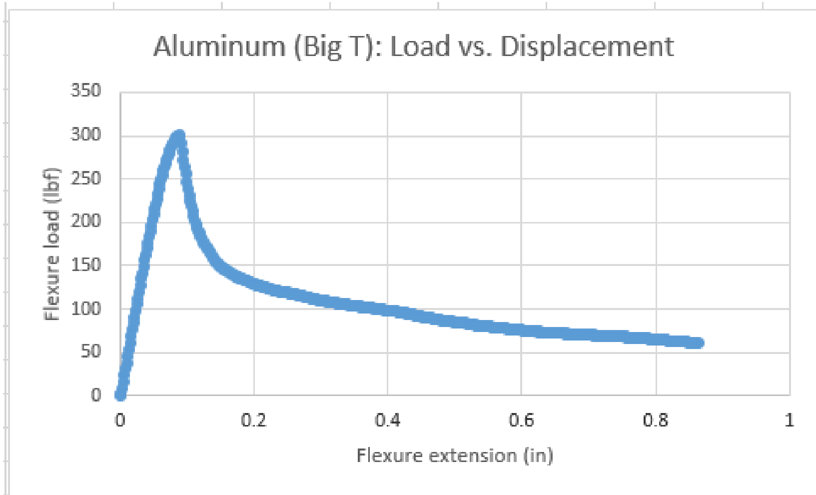


Figure 9: Plot of Aluminum (Small L): Change in Flexure Load Over Flexure Extension

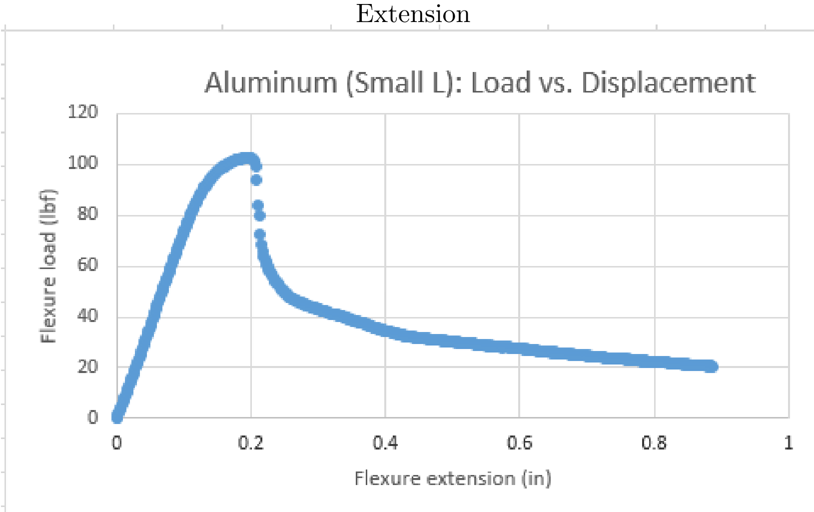


Figure 10: Plot of Aluminum (Small T): Change in Flexure Load Over Flexure Extension

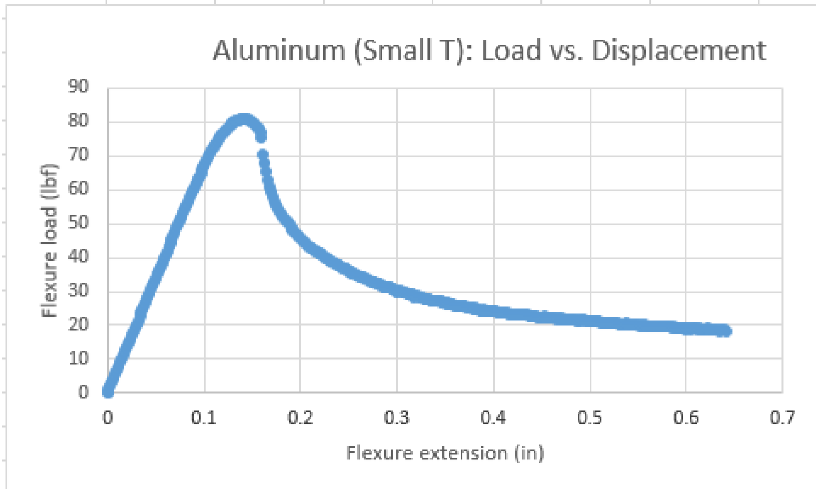


Figure 11: Plot of Ceramic (1-201151): Change in Flexure Load Over Flexure Extension

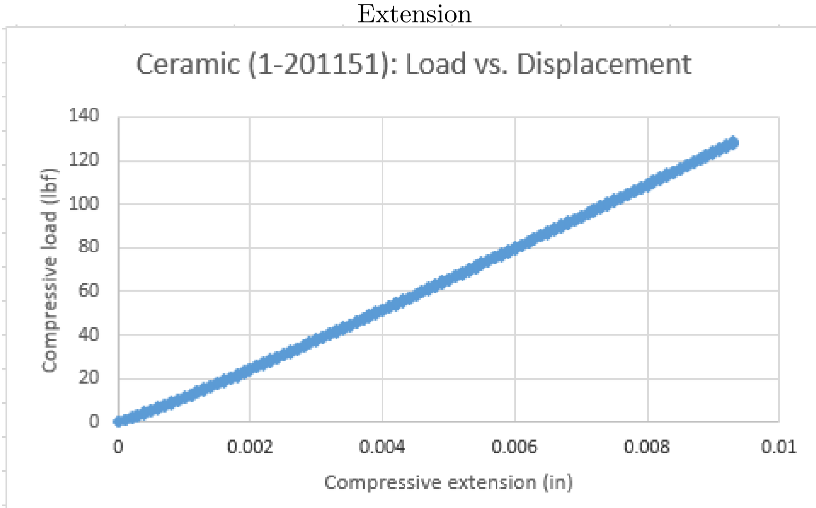


Figure 12: Plot of Ceramic (2-201151): Change in Flexure Load Over Flexure Extension

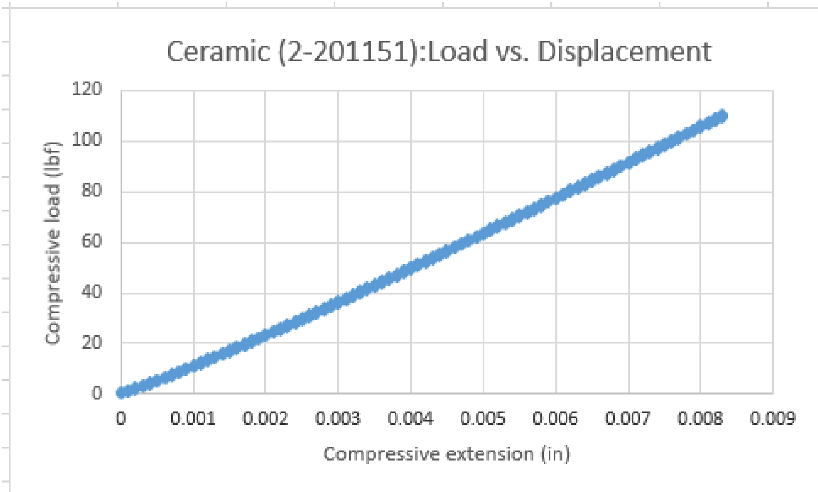


Figure 13: Plot of Ceramic (3-201151): Change in Flexure Load Over Flexure Extension

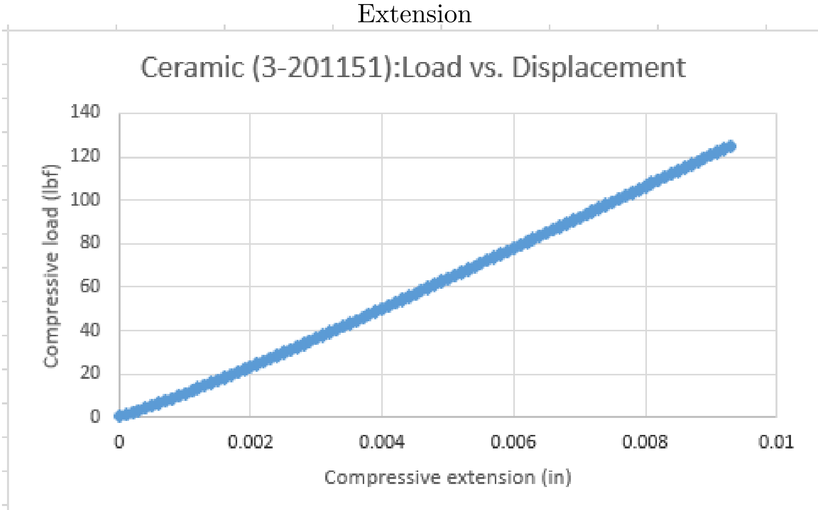


Figure 14: Plot of Ceramic (4-201151): Change in Flexure Load Over Flexure Extension

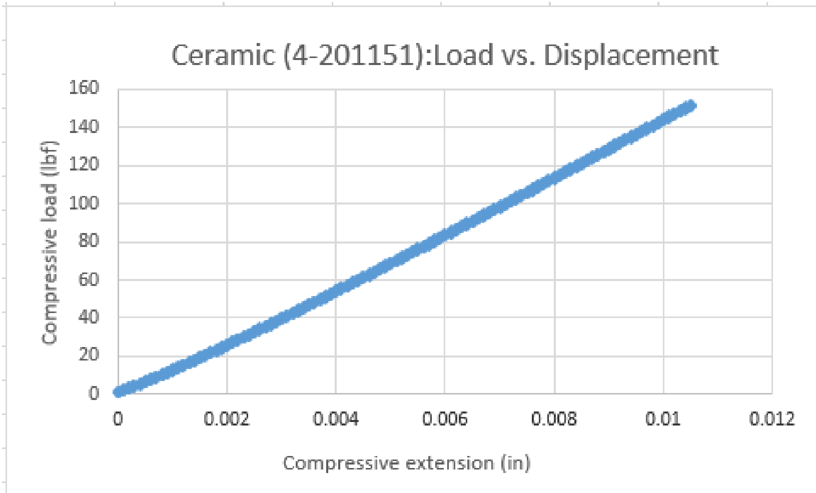
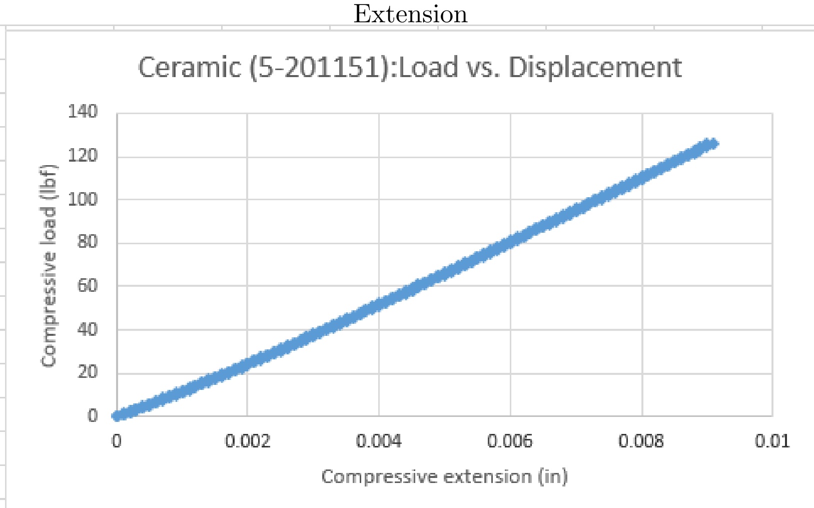


Figure 15: Plot of Ceramic (5-201151): Change in Flexure Load Over Flexure Extension



Our calculated values for MOR, Flexure Strain, and Young's Modulus is summarized in the table below. In addition to these results, we also have calculated specific strength and stiffness data for aluminum.

Figure 16: MOR, Flexure Strain, and Young's Modulus Values

Material	Fracture Load (lbf)	Fracture Strain (in)	M value	MOR	Flexure Strain (in)	Young's Modulus (lbf/in)
HoneyComb						
Big L	77.67789	0.71649	5068.2	1994.442509	0.027131088	3436535.0
Little L	20.54871	0.88649	739.66	2760.821313	0.014807666	5949398.9
Big T	61.5264	0.86317	4165.6	1619.826597	0.032595857	2904146.5
Little T	18.36942	0.64149	678.8	2458.071165	0.010715259	5437860.5
Alumnium	786.30906	0.61148	2451.8	83348.88968	0.01144147	13889672.4
Ceramic						
1	128.67	0.0093	13950	28260.40711	0.002523101	11293371.12
2	110.64	0.0083	13431	23798.61823	0.002175677	11021266.91
3	125.4	0.0093	13633	26752.67277	0.002472494	10939784.3
4	151.77	0.0105	14555	33379.79461	0.002834072	11860100.15
5	126.29	0.0091	14085	27976.23042	0.002419427	11735619.68

Figure 17: Specific Strength and Specific and Stiffness Values

Material	Volume (in.^3)	Mass (lbm)	Density (lbm/in^3)	Specific Strength (lbf/lbm*in^3)	Specific Stiffness (lbf/lbm*in^2)
HoneyComb					
Big L	9.2568096	0.020407748	0.00220462	35234.14012	1558787903
Little L	4.010292	0.00884117	0.00220462	9320.749154	2698605172
Big T	9.0525186	0.019957364	0.00220462	27907.93878	1317300268
Little T	4.026528	0.008876964	0.00220462	8332.238662	2466574976
Alumnium	4.5377064	0.010003918	0.00220462	356664.2142	6300256907

The M-values are the slopes of the elastic regions of the flexure load versus flexure strain plots. These were determined by finding trendlines of elastic regions of these plots as shown below.

Figure 18: Linear Fit of Aluminum (Big L): Change in Flexure Load Over Flexure Extension

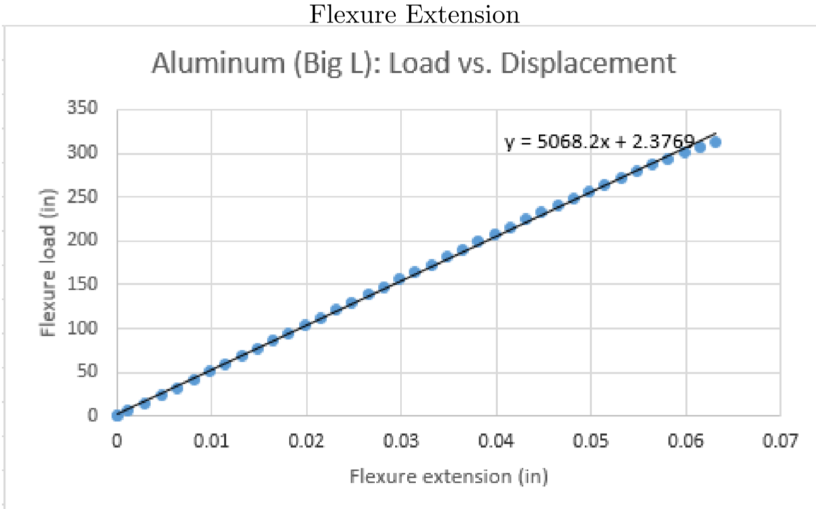


Figure 19: Linear Fit of Aluminum (Big T): Change in Flexure Load Over Flexure Extension

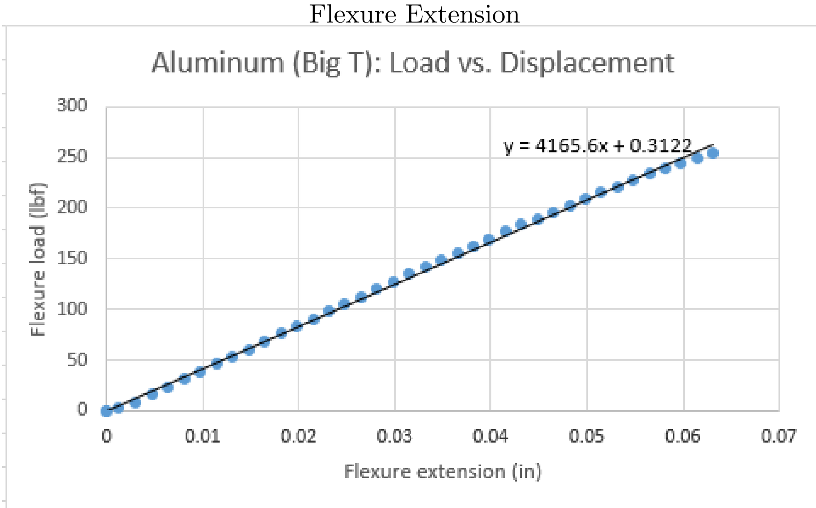


Figure 20: Linear Fit of Aluminum (Small L): Change in Flexure Load Over Flexure Extension

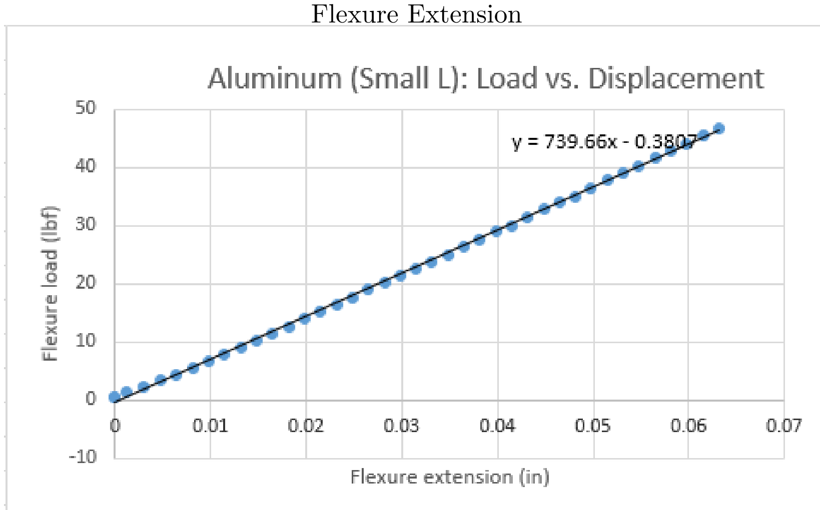


Figure 21: Linear Fit of Aluminum (Small T): Change in Flexure Load Over Flexure Extension

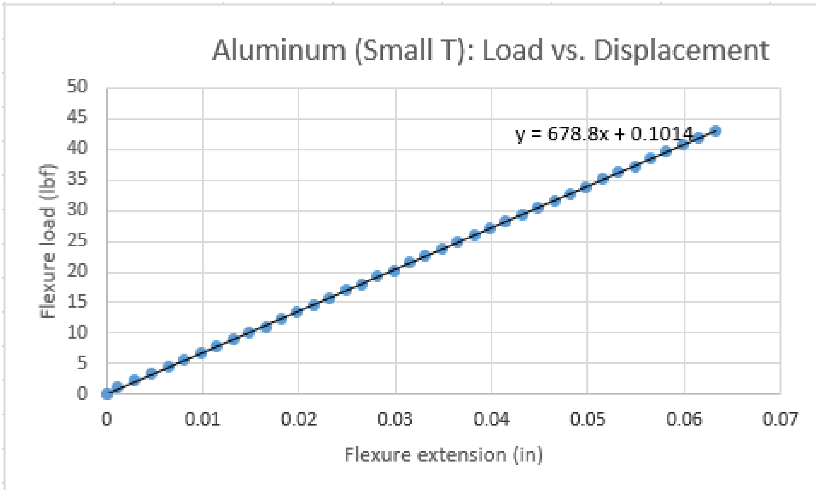


Figure 22: Linear Fit of Ceramic (1-201151): Change in Flexure Load Over Flexure Extension

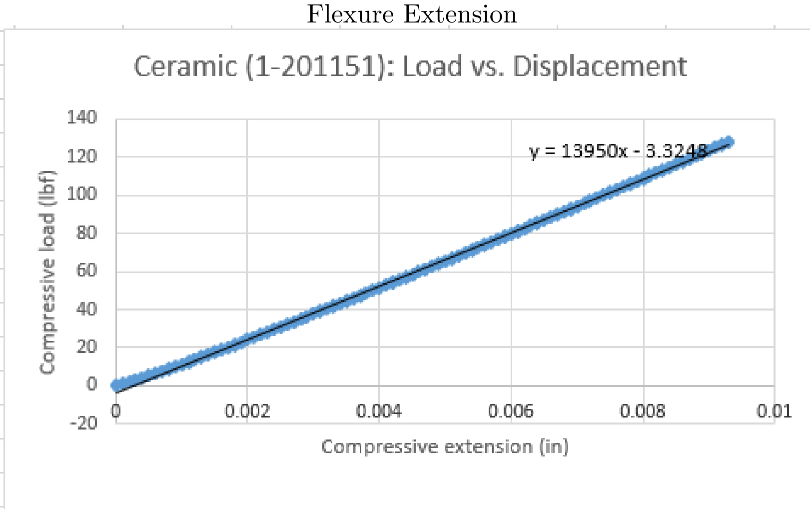


Figure 23: Linear Fit of Ceramic (2-201151): Change in Flexure Load Over Flexure Extension

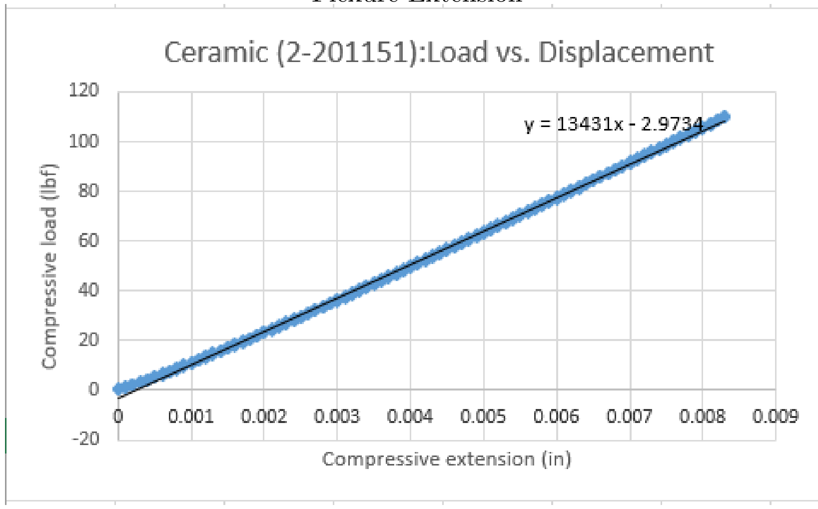


Figure 24: Linear Fit of Ceramic (3-201151): Change in Flexure Load Over Flexure Extension

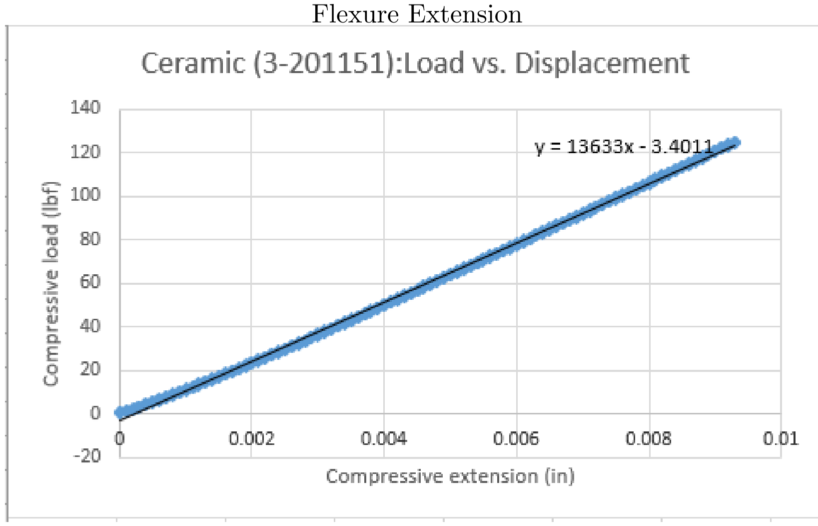


Figure 25: Linear Fit of Ceramic (4-201151): Change in Flexure Load Over Flexure Extension

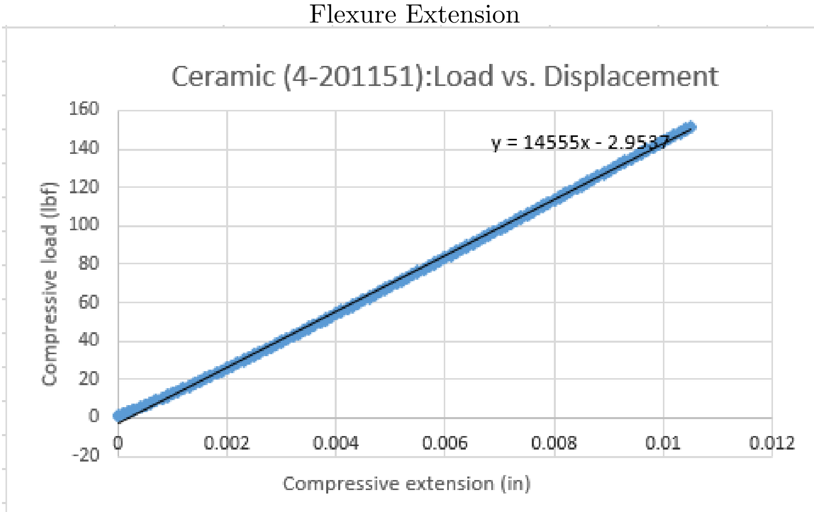
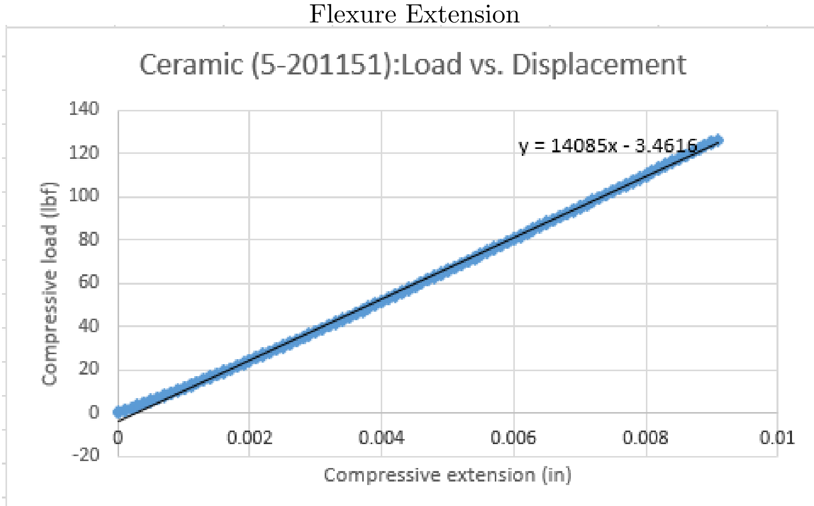


Figure 26: Linear Fit of Ceramic (5-201151): Change in Flexure Load Over Flexure Extension



4 Discussion

Our data overall looked very solid.Though not very obvious, there is most probably a bit of error in our results. There are many reasons why our data contains the error it does. Human error can always be a culprit either in the form of random or systematic error. In addition to this, our bending tests never reached visible fracture for any of our specimens despite they all had a V-shape. However, this is not as issue since, based on the shapes of the plots of load vs displacement, we can clearly say that we had practically reached the fracture point. The materials we tested had distinct similarities and differences. The aluminum specimens all had similar graph curves as did all the ceramic ones. In addition to this, the aluminum specimens had a defined yield strength and thus a clear elastic and plastic region. Whereas, the ceramic specimens only had elastic deformation as they clearly only had linear slopes for the flexure load versus flexure strain plots. Another interesting thing to note is that there was a huge variety in the values calculated for Aluminum (MOR, Modulus, Specific strength and stiffnes, etc...) while those for the Ceramic specimens were all reasonably within the same range of values. This may or may not be due to the inherent properties of aluminum versus the ceramics specimens.

5 Conclusion

This lab was very useful as it revealed that Ceramics materials seemed to share more similar characteristics (in terms of the closeness of the values we calculated for the different Ceramic specimens) as opposed to Aluminum specimens. Such information could be very useful for industry as it could point to how different materials can be used practically in conditions to maximize benefits they have. For example, from this lab, we could potentially conclude that more various ceramic specimens have consistent characteristics between them as opposed to Aluminum. Thus they could be used in situations that require stable materials. Aluminum, on the other hands, seems to have a plethora of characteristics for various conditions. Thus,. they could be used for all sorts of structures and applications that require flexibility. This is only one example and thus bending test could be very useful in determining other materials' ideal functions in industry.