Lab Experiment # 9

Three Point Bending Test of Ceramics

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Objective
The Jominy End-Quench Test is intended to measure the hardenability of various steel

Equipment/Materials

- 3 small, polished glass specimens
- 3 small, grounded glass specimens
- 3 large Polished glass specimens
- Instron universal testing machine (with 3 point flexure bending test)
- Micrometer

Experimental Procedure

1. Take initial measurements of each glass specimen unsing the micrometer
2. Place one of the samples into the instron testing machine and increase load until the specimen breaks, taking note of the fracture load.
3. Determine the fracture strength of the material and take the mean and standard deviations of all the specimens
4. Construct the stress vs strain graph of each specimen types and compare fracture locations

Experimental Results

The fracture strength is determined by the following equation:

$$\sigma_{fs} = \frac{3F_f L}{2db^2}$$

Where F_f is the fracture force, L is the length of the specimen and d&b represent the cross-sectional areas.
Flexure strain can be calculated by:

$$\epsilon_f = \frac{6\delta d}{L^2}$$

Where δ is the max deflection at the center, L is the support span.

<table>
<tr><th colspan="4">Dimensions</th></tr>
<tr><td></td><td></td><td>Width (mm)</td><td>Thickness (mm)</td></tr>
<tr><td rowspan="6">polished</td><td>small 1</td><td>25.1</td><td>1.2</td></tr>
<tr><td>small 2</td><td>25.16</td><td>1.21</td></tr>
<tr><td>small 3</td><td>25.57</td><td>1.21</td></tr>
<tr><td>large 1</td><td>50.46</td><td>0.95</td></tr>
<tr><td>large 2</td><td>50.44</td><td>0.95</td></tr>
<tr><td>large 3</td><td>50.43</td><td>0.94</td></tr>
<tr><td rowspan="3">grounded</td><td>small 1</td><td>25.05</td><td>0.97</td></tr>
<tr><td>small 2</td><td>25.13</td><td>0.96</td></tr>
<tr><td>small 3</td><td>25.08</td><td>0.96</td></tr>
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Figure 1: Measurements taken from specimen prior to fracture to be used in calcauting flexural stress, strain and modulus.

		Flexture Strength (MPa)	Mean Value	Standard Deviation	Actual Flexture Value (MPa)	% error
polished	small 1	49.1	56.5	7.10	69	18.09
	small 2	63.25				
	small 3	57.21				
	large 1	57.41	56.2	1.37	69	18.59
	large 2	54.7				
	large 3	56.4				
grounded	small 1	27.39	27.9	0.64	69	59.50
	small 2	28.646				
	small 3	27.8				

Figure 2: Obtained Flexure strength of each specimen compared to the actual flexure strength values

		Elastic Modulus (GPa)	Mean Value	Actual Elastic Modulus (GPa)	% error
polished	small 1	60.4	78.34	69	13.54
	small 2	89.29			
	small 3	85.33			
	large 1	198.43	191.62	69	177.7
	large 2	193.34			
	large 3	183			
grounded	small 1	43.2	44.323	69	35.76
	small 2	50.67			
	small 3	39.1			

Figure 3: Obtained Elastic modulus compared with accepted values of all glass specimens.

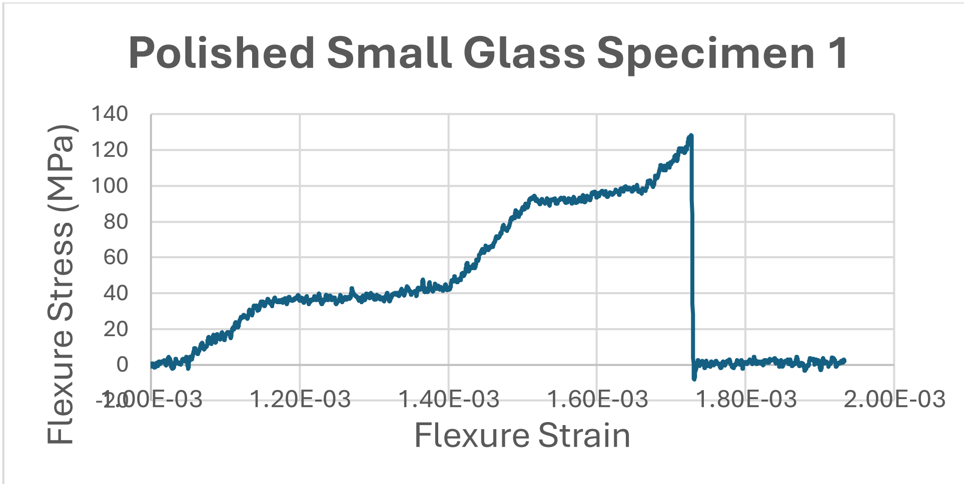

Figure 4: Flexure stress vs Flexure strain of the polished small glass specimen 1

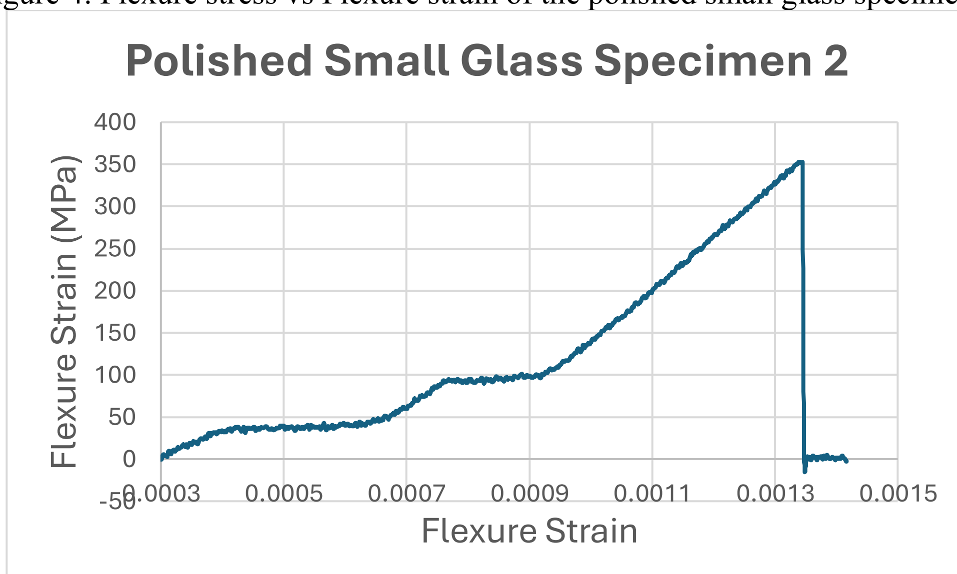

Figure 5: Flexure stress vs Flexure strain of the polished small glass specimen 2

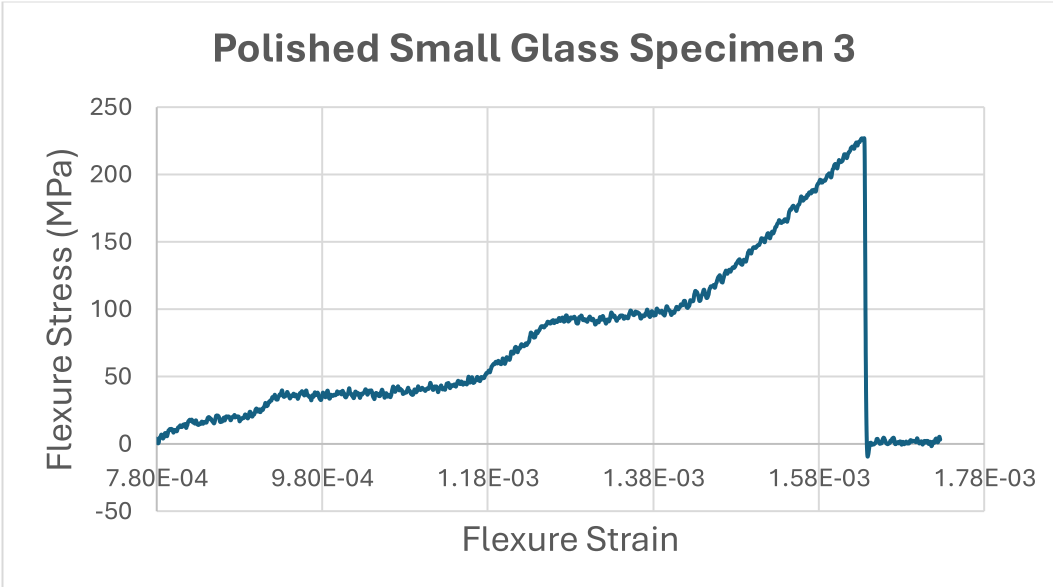

Figure 6: Flexure stress vs Flexure strain of the polished small glass specimen 3

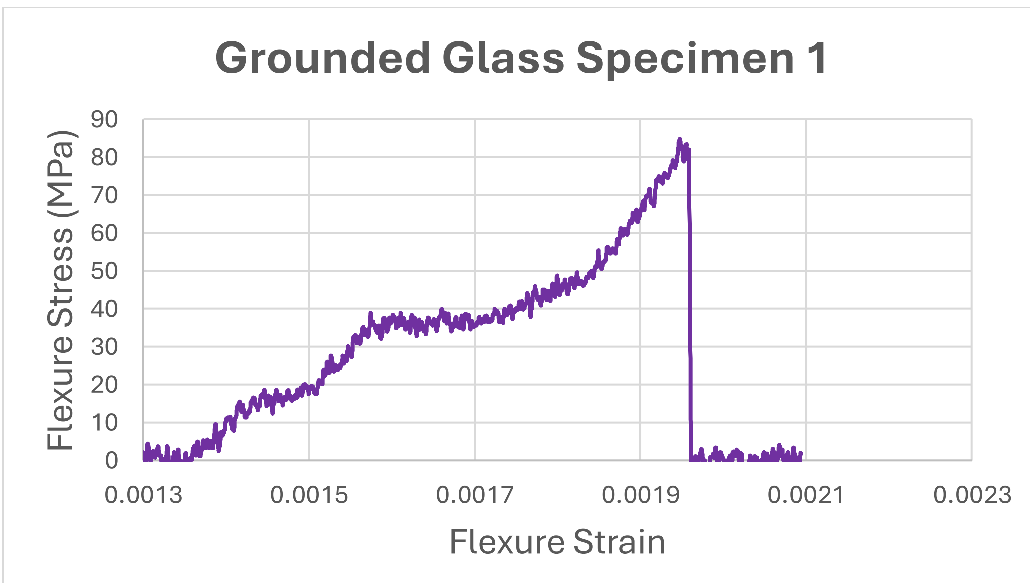

Figure 7: Flexure stress vs Flexure strain of the grounded small glass specimen 1

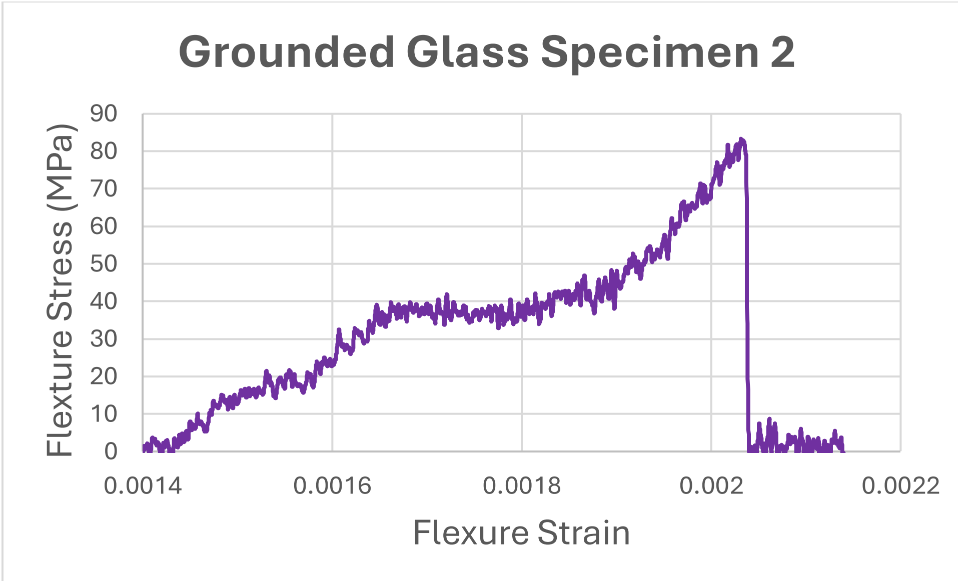

Figure 8: Flexure stress vs Flexure strain of the grounded small glass specimen 2

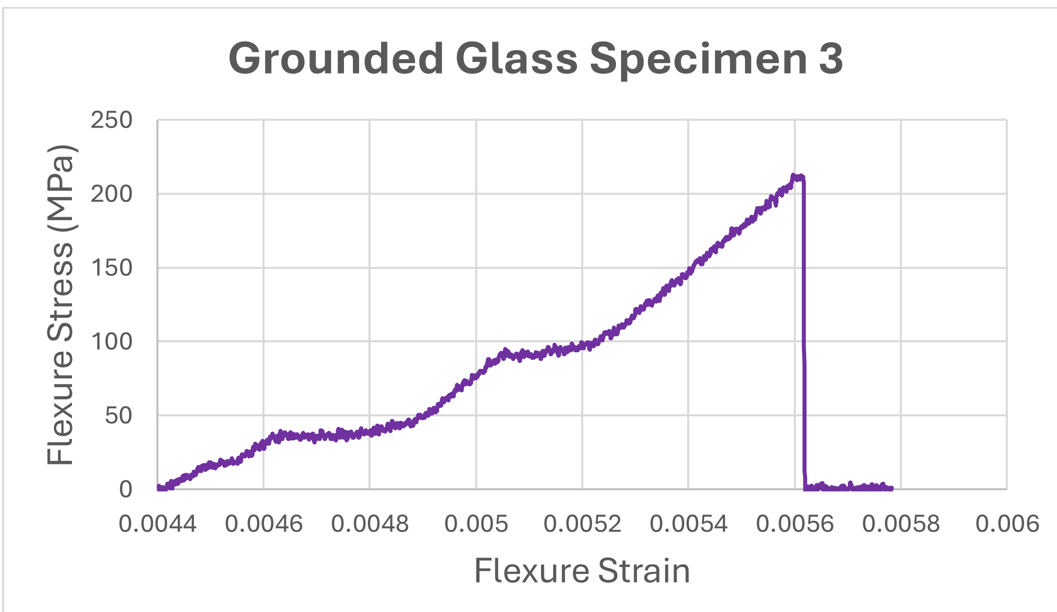

Figure 9: Flexure stress vs Flexure strain of the grounded small glass specimen 3

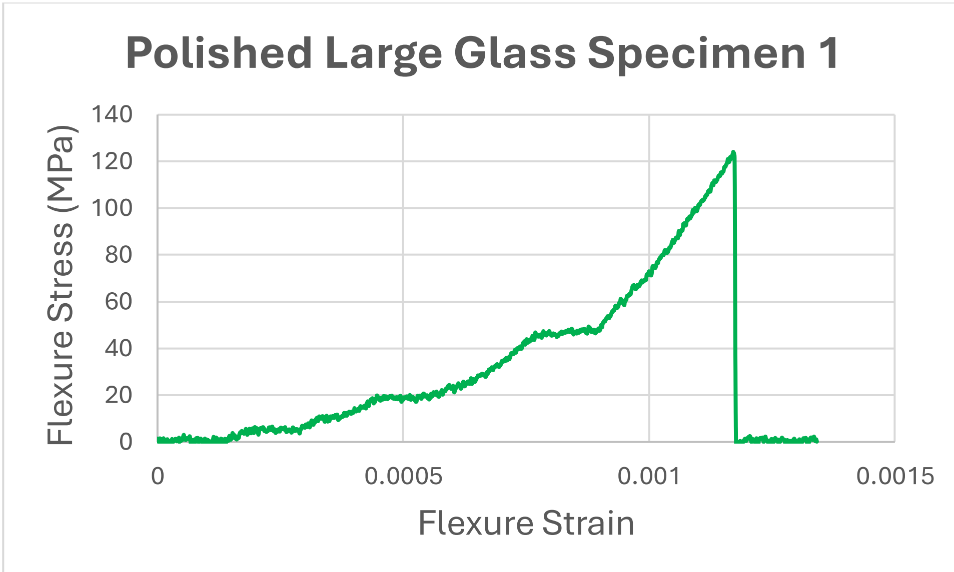

Figure 10: Flexure stress vs Flexure strain of the large polished glass specimen 1

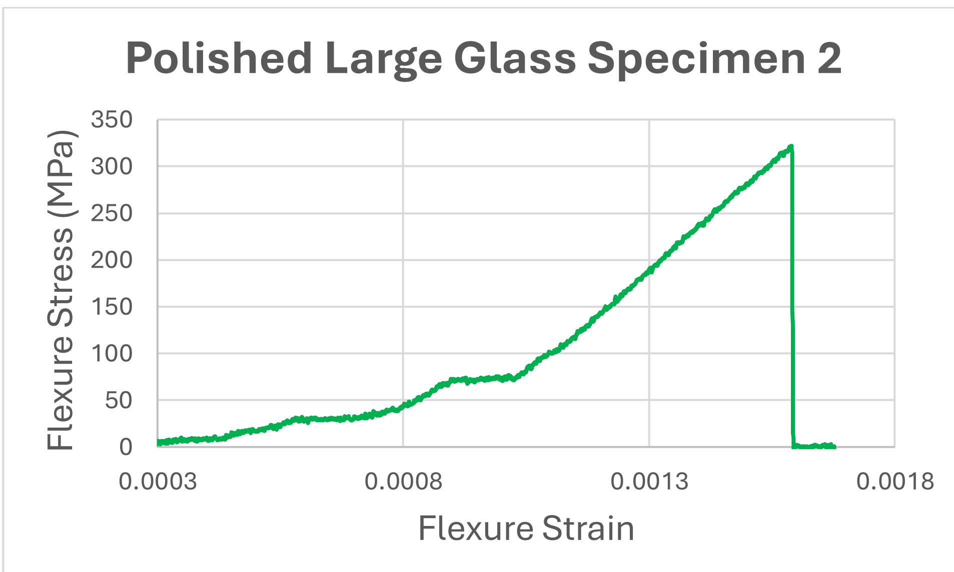

Figure 11: Flexure stress vs Flexure strain of the large polished glass specimen 2

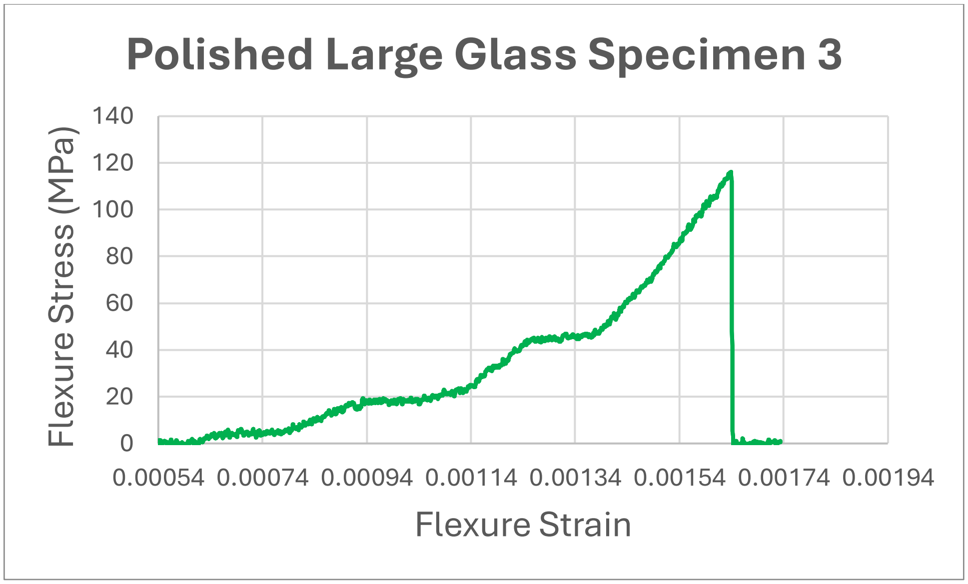

Figure 12: Flexure stress vs Flexure strain of the large polished glass specimen 3

Figure 13: Fractured glass specimen results. Large polished (left), small polished (middle), small grounded (right).

Discussion of Results

Polished specimens were observed to have a larger flexure strength than that observed by the grounded glass specimens. The results can be explained through the finish of the polished glass contain less defect and therefore have less opportunities for crack propagations. An grounded specimen can be seen with rough surface which under bending which allows for more tensile loading to exemplify the flaws.

Glass, as a ceramic can be seen to be far more brittle than other material types as well as larger number of defects. When load is applied, it is less predictable as to the direction and load amount. Being able to observe fracture site is thus an important step that must be done. As seen in figure 13, fracks will form towards the line along where the load is applied, with both cross sectional area and finished affecting the shape of the fractures. Geometry plays a large role as well, with a larger cross sectional area changing the fracture site of the polished specimens. Though, it is important to know that the values found have high error possibly due to placement of the specimen and inconsistent defects of specimens.

Conclusion

Three point bending tests are done for materials who may not be tested through tensile testing. From this lab, it can be seen that both finish and geometry of the same material may have a large effect on the overall observed flexure strength. Due to the defect's unpredictability, seen in high amounts in ceramics, it is far more likely to have unpredictable fractures. Flexure strength is an important parameter is determine an material ability to withstand bending and can be done to negate compressive or tensile stresses as the factor for failure.

Review Questions

1. What are the causes of the scatter in the values of the flexural strength for polished specimens?

Ceramics often has many impurities throughout the material, often differing than that of metals. Such impurities can cause differences in the strength at different locations of the same specimens

2. List some advantages and disadvantages of this test.

The three point bending test is a fast and simple way of measuring the flexure strength of ceramics. Due to ceramics brittles, it may be harder to properly secure the specimens in the saem manner on the tensile testing grips. However for materials with more internal variations, this method may not be able to accurately described such variable as such test creates a concentration of stress at one point. This limits the testing to materials that are brittle and shatters and is heavily dependent on the geometry, making the preparation for the testing more expensive and time consuming.

3. Is it better to have a three-point bending or a four-point bending test? Support your answer.

Four point bending tests are better at capturing the variability within a material as stress will not be concentrated at just one point. Although a 3-point bending test may be simpler and quicker, due to the limitations of the materials that may be tested, a four point bending test may be applied widely. However, for simple testing of brittle materials that fracture, it may not be necessary to perform a four point bending test.

4. Is the obtained modulus of rupture an indication of the tensile or compressive strength? Why?

The modulus of rupture indicates the tensile strength as during the testing, it can be seen the specimens fail under tension rather than compression. Ceramics are more capable of receiving compressive load therefore under the bending test, the portion of the specimen under tension will cause the fracture.

5. Is there a significant difference between the mean value of the flexure strength for ground specimen and that for polished specimen? If there is, how can you explain the reason?

The flexure strength seen by the polished surface is observed to be higher than that of the grounded surface specimens. With the grounded surface more surface imperfections are present which can be the site where crack propagations may occur. Surface defects are often the causes of failure with increase load applications.

6. Examine the fractured surface and location of each specimen. How can you comment on it?

Fracture for the smaller polished glass is seen to be along the line of applied force as well as with the grounded specimen. The larger specimen can be seen to have more shattered fracture. However, such results may not be conclusive due to the defects present in glasses making such fracture unpredictable and hard to determine with small amount of trials.

7. If the test is carried out on wrought iron, would the shape of the fractured surface be different? Why or why not?

Wrought iron is often more ductile than that of ceramics. As it is also low in carbon, it is highly ductile. The fracture site will be less of a clean cut but rather more jagged due to plastic deformation that will occur before it fractures.

References

[1] CCNY ME 46100 Lab Report Preparation, CUNY blackboard website.
[2] CCNY ME 46100 Lab Manuals, CUNY blackboard website.
[3] CCNY ME 46100 Lab Data, CUNY blackboard website.
[4] Jr. William D. Callister_ David G. Rethwisch - Materials science and engineering _ an introduction (2018, Wiley)