

Initial Investigation into the Mechanical Properties of Toy-Grade Air-Dry Modeling Clay

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Abstract

This experiment was an initial investigation into some of the mechanical properties of store-bought, toy-grade modeling clay. The experiment was a compressive test and the data will be used to report about the tensile strength, elastic modulus, and to generate a stress-strain curve for the type of clay that one might find at a craft store. The conclusions drawn from the results we found in our investigation was that the elastic modulus of the clay is too small to be properly measured with our techniques.

Introduction

An investigation into the mechanical properties of a material is vital in understanding how to incorporate it into your design. If you can understand the relationship between cross-sectional area and change in dimension under stress, for example, you can decide what diameter you will need for your cable, what side length you may need for your support beam. You can also use that knowledge to predict what tolerances you will need for all the rest of your design. You can find out whether you need to leave room for a support in case it expands slightly, or whether you need to use an expensive material and need to use as little as possible for your budget. In all cases, knowing the mechanical properties of a material is fundamental.

The way to understand some of those properties is through a stress-strain curve. A stress-strain curve reports the change in shape of an object under a certain load. If an object is subject to a load and yet is able to keep its shape after the load is removed, it is in what is called the "elastic modulus" range of the stress-strain curve. However, if the object does not fully return to its original dimensions after the load is removed, it has started to deform, and is in the "plastic deformation" range of the stress-strain curve.

The curve ends when the object is not only deformed, but completely breaks. - In a tensile test, this is easy to see, but in a compressive test, the curve will "flatten" out.

When it comes to the type of clay we were using for this experiment, the purpose was simply the investigation, and not to remark on the possible uses of air-dry modeling clay in some sort of construction or engineering capacity. The merit of the investigation will become clear with the results.

Methods Used

The objective of the experiment was to measure the change in each dimension of the clay with respects to each load applied. To achieve this objective, it was necessary to measure two things consistently: the weight of each successive load and the change in dimension of the clay. These numbers could then be analyzed later.

The experiment was as follows:

I mixed together a few ounces of the modeling clay and shaped it to make a square prism



Fig 1. The modeling clay in a rectangular-prism shape

Then, I gathered some small objects around the house ranging from a scotch tape dispenser to a 900-page paperback book, weighed each separately by placing them inside a plastic bag and attaching the bag to the hook of an analogue spring scale. These are some of the books that I used:

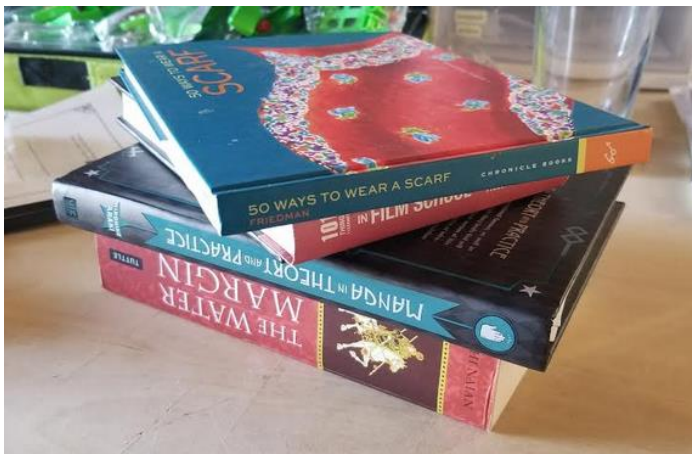


Fig 2: Some books I used as loads

Object	Weight (g)	#
scotch tape	50	1
calculator	125	2
cutting mat	175	3
class notebook	225	4
scarf book	310	5
101 Things I Learned	400	6
How to Write Manga	425	7
The Water Margin	690	8
	550	2+7
	915	8+4
	1090	8+7
	1825	8+7+6+5

Table 1: This is a table of objects I used and their weights. The last four entries are combinations of items.

I used calipers to measure each dimension of the square prism of clay and recorded each dimension three times of the original dimension. After recording the initial dimensions, I placed a load upon the top of the square prism. I decided, for ease of balancing the loads, that the top of the clay was to be the face with the largest area.

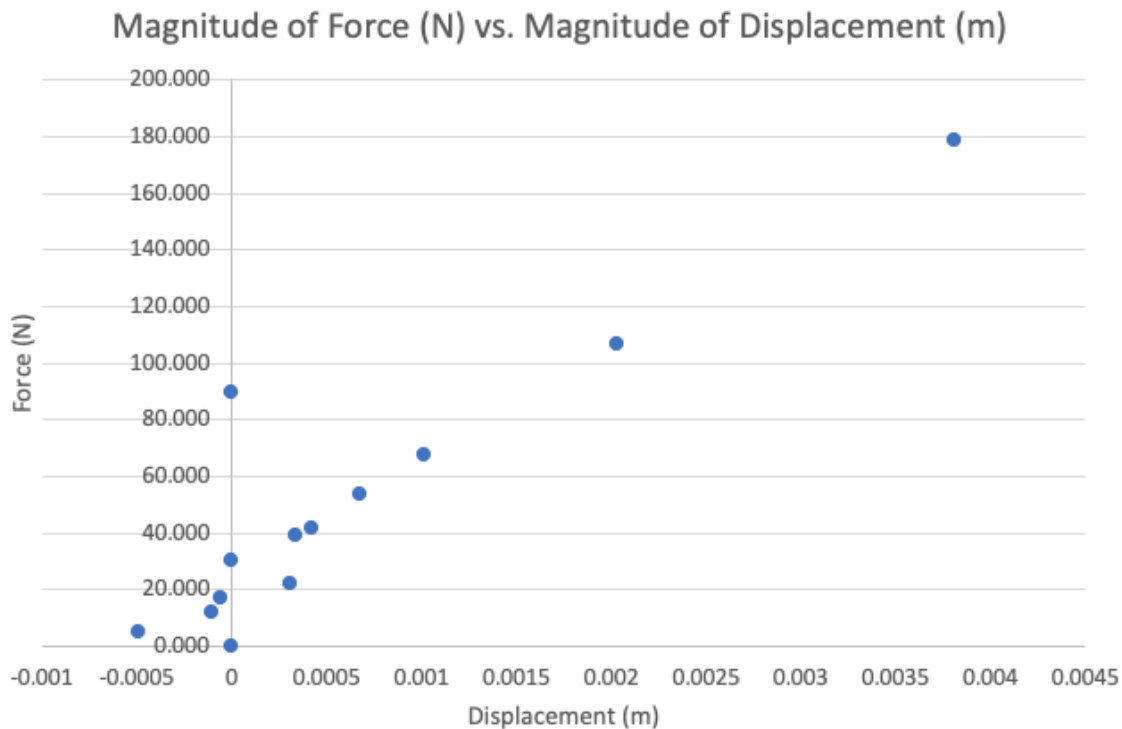


Fig 3. Calipers used to measure the dimensions of the clay

I placed each load for approximately 10 seconds, then measured each dimension of the clay shape three times.

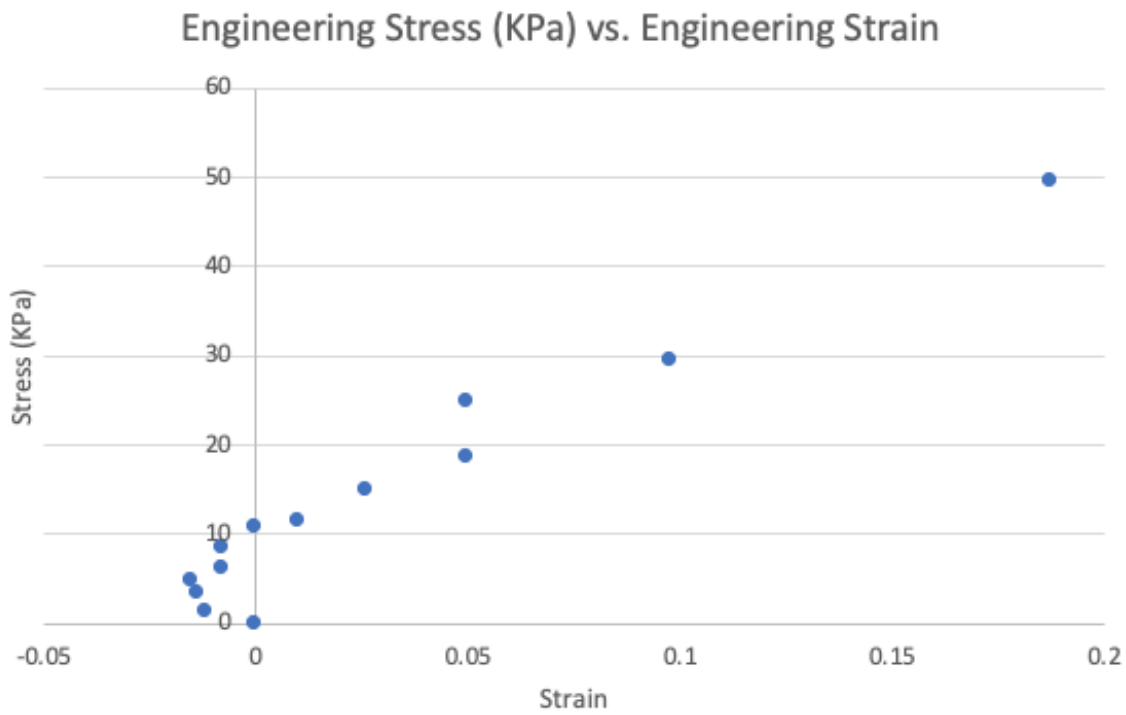
I repeated these steps with larger and larger loads, sometimes combining the loads.

Results



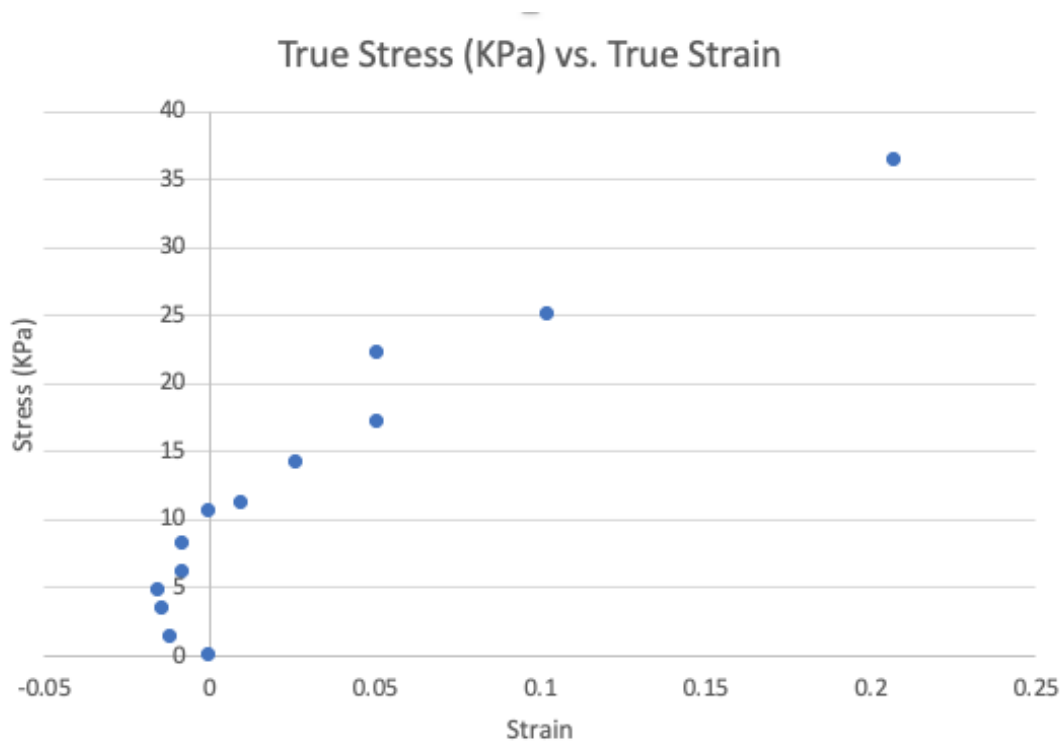
Graph 1: This is a graph of the magnitude of applied force vs. the magnitude of displacement of the clay. The displacement refers to change in height, which was measured from the table to where the load was applied.

Graph 1 shows that as more and more heavy objects were placed onto the clay, the clay's height steadily changed (it decreased) in what seems to be a linear fashion.



Graph 2: Engineering Stress vs. Strain.

Graph 2 shows negative strain when under 10 KPa of stress, then a steady, linear increase of strain as the KPa raises.



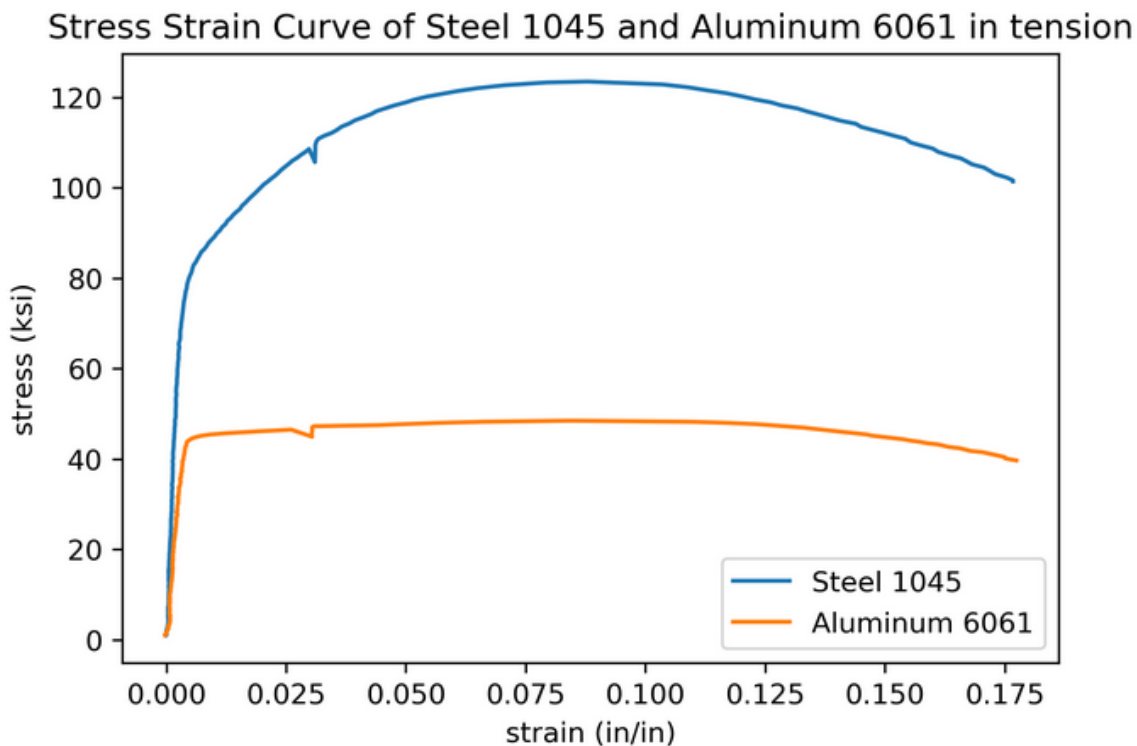
Graph 3: True Stress vs. Strain.

Graph 3 shows that under 10 KPa of stress, the strain appears to be negative, then as stress increases over 10KPa, the strain increases linearly.

Discussion

In this discussion, there are mostly three points of interest: the linear behavior of the stress-strain curves and displacement curve, the uncertainty of the data between stresses of under 40 N, and possible sources of error.

In Graphs 1, 2, and 3, the curves all seem to increase linearly when most stress-strain and displacement curves I have seen have not been linear, and have behaved more like an exponential curve. Perhaps the nature of modeling clay is that it experiences plastic deformation linearly, unlike metals, the stress-strain graphs of which are the only curves I am familiar with. This could also be due to the nature of the limitations of the experiment. Because the scale was limited to measuring only up to 2kg, and I was unable to find suitable books that were in between the 1kg and 2kg range, I do not have data for that range.



Graph 4. A stress-strain curve for both steel (blue) and aluminum (orange). [1]

If you compare Graph 2 from my results with Graph 4, you'll see that the behavior of the curve being linear and not flattening out may just be a factor of the limited amount of load I had available. It may also be the unique attribute of clay that its plastic deformation is mainly linear.

The graphs also mainly only represented the plastic deformation portion of the stress-strain curve for clay. In the experiment, the clay appeared not to change shape until after the first few loads, but the noise in the measuring uncertainty covered if any changes were happening.

In all of the graphs, there is odd behavior in the range of the smaller loads, specifically in loads under 40 N. Again, this is due to the above issue with measuring error being too great to get any sense if there is any actual change of shape going on.

The sources of error were large in this sort of experiment, the largest contributor being the uneven shape of the rectangular prism of clay. That is why I decided to take measurements from multiple points in the shape and average them out. But any one dimension of the clay shape could have been different to within at least a few hundredths of an inch.

Conclusion

The objective of this experiment was to perform an initial investigation into the mechanical properties of modeling clay. The results were that loads of at least 40 N caused plastic deformation to the clay, and any data from lighter loads was obfuscated by the errors inherent to the level of skill and tools present in the home lab setting.

Acknowledgements

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Citations

[1] Plotting a Stress-Strain Curve with Python and Matplotlib
<https://pythonforundergradengineers.com/stress-strain-curve-with-python-and-matplotlib.html>