Improving Bridge Designs Using 3D Printing

Carina Beebe, Garren Bryant, Rebecca Cazarin, Alyssa McGinnis,
Asa O’Neal, Abigail Pendell, Joshua Taylor, Isabella Winegar

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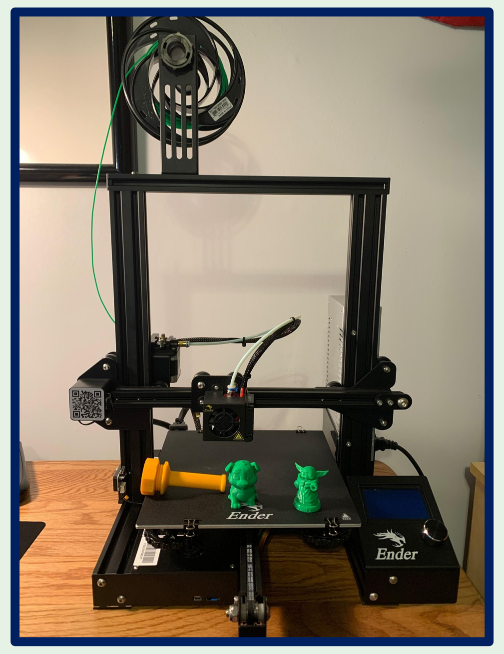
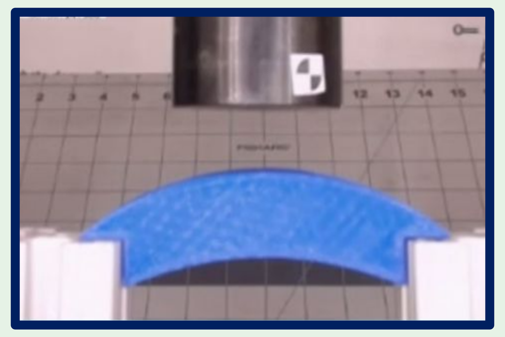
Introduction

In recent years, there has been rapid growth in the use of 3D printing by hobbyists and researchers alike. 3D printing has the capability to produce custom parts or designs very efficiently and at a low cost. Currently, 3D printing is widely used in medical research and in the design/fabrication process of complicated parts that would be hard to manufacture using traditional methods. While the 3D parts themselves aren’t always used as the final product, they allow engineers to quickly produce scale models for testing. This research project focused on testing the strength of various 3D printed models. The objective of the project was to become familiar with the 3D printing process and computer aided design (CAD) programs and to test the load capacities of bridges with various print orientations, infill patterns, and relative masses.





Background

Overview:

- 3D printers have dropped from $20K to $200 dollars in less than two decades, and this machinery is a common component of our research today.
- In order to utilize 3D Printers, one needs 3D modeling software. This use of computers to assist in design optimization is called Computer-Aided Design, or CAD for short.
- A hydraulic press, which is a cylindrical shaped machine press, was used for strength testing the bridges. This apparatus was used to destroy the 3D printed bridges with varying qualities and provide insight into the relationship between variables that are custom in designing 3D prints.

3D Printing Software:

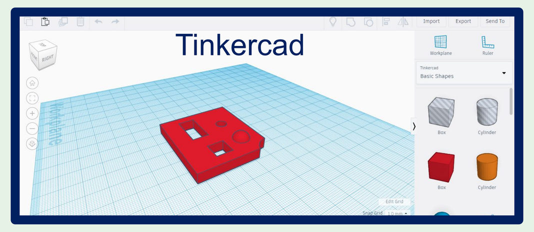
- **Cura**- 3D printing software is used to see the slicing and amount of PLA filament needed for a project. It gives detailed info regarding the interior layers, patterns, and structure. It can form .gcode files from .stl files. Weights, structures, and print orientation are all factors that can be examined.
- **Tinkercad**- 3D CAD design tool used to design and improve the bridges made. It creates .stl files for use in programs such as Cura.
- Autodesk Fusion 360 and Inkscape are also widely used programs in 3D printing.

Terminology:

- **Filament**- The material 3D printers use to make an object; can be made of a variety of materials.
- **PLA**- Polylactic Acid; the material that the filament is made of, which is what was used in this research.
- **Slicing**- The process of creating instructions for the 3D printer from the solid model file.
- **Infill Patterns-** Patterns that the nozzle of the printer can make on the inside of a 3D printed object; affects strength of prints.
- **.Gcode, .stl, .obj, and .3mf files-** The different types of files that are compatible with either the programs used or the 3D printer itself.

Materials and Methods

- Creality Ender 3 Printer
- Cura (Slicing Software)
- Cut-Resistant Gloves
- Data acquisition board
- Diagonal Cutters
- Google Sheets and Docs
- HP Laptop
- Hydraulic press
- Load Cell
- Micro SD Card
- PLA Filament
- Pliers
- Print Removal Spatula
- Safety Goggles
- Tinkercad



1. Assembled 3D printer and leveled bed using printer paper
2. Designed bridges using Tinkercad and saved them as .stl files
3. Sliced .stl file using Cura software and downloaded them as .gcode files
4. Put .gcode file on SD card, moved SD card to printer, then printed design from SD card
5. Removed print from plate with spatula after it was finished (clean plate if necessary)
6. Checked print for any mistakes
7. Removed supports (if any)
8. Strength tested parts using hydraulic press
9. Created chart using Google Sheets with the data collected from the tests
10. Returned to step 2 if necessary

Acknowledgements

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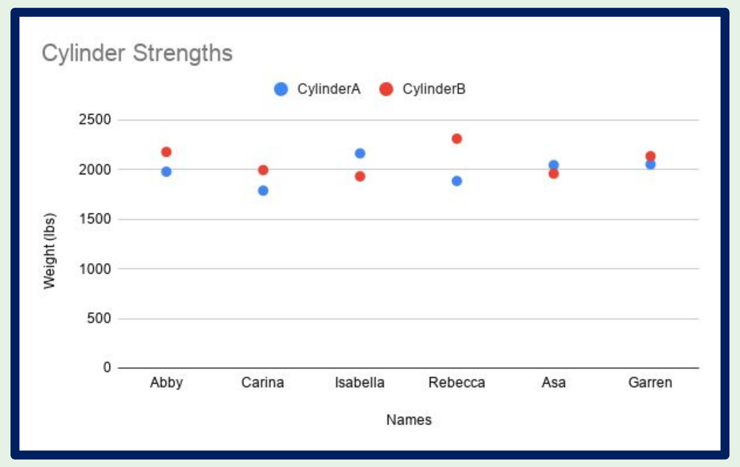
Results

The objective of this project was to create a sturdy 3D printed bridge through the use of different print orientations, infill patterns, weights, and structural designs.

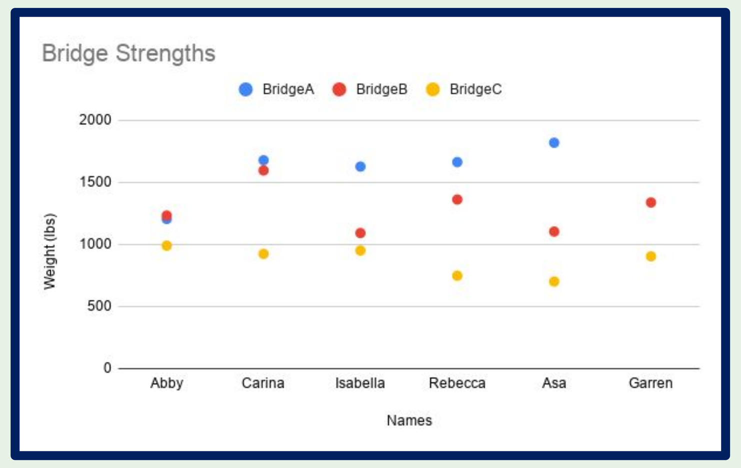
Testing Infill Patterns:

- Tested 2 identical cylinders with different infill patterns
  - Cylinder A - Concentric Fill
  - Cylinder B - Gyroid Fill
- The consistently low difference between the maximum weight supported by Cylinder A and Cylinder B in 6 different tests show that infill patterns have little effect on the strength of prints.



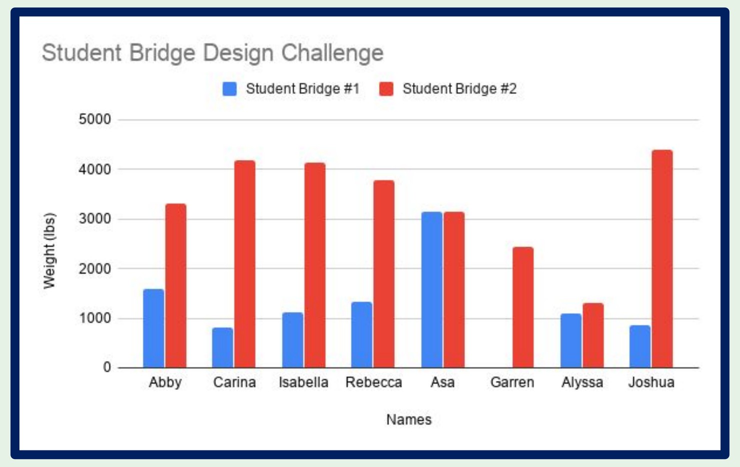
Testing Print Orientations:

- Tested 3 identical bridges printed with different orientations
  - Bridge A-Printed on its side
  - Bridge B-Printed on its base
  - Bridge C-Printed on its end
- The results, which consistently show Bridge A supporting the most weight and Bridge C supporting the least, suggest that print orientation has an effect on a print’s strength. Orientation affects layering which causes a print to be weak in one direction and strong in another.



Testing Structures:

- Each participant designed and tested a bridge, then used those results to redesign the bridge to increase its strength.
- The graph shows the improvement made from the first bridge design to the second bridge design.
- All bridges, except for two outliers, showed an increase in strength between double to quadruple the previous amount.



Conclusions

The goal of this research project was to determine what practices lead to the strongest 3D printed bridge designs. To identify these practices, infill patterns and print orientations were experimented with in a hydraulic press strength test. The different infill patterns showed no significant changes in the strength of the print after being tested with two cylinders of different patterns. Print orientation showed a profound effect on strength with great variation in results depending on whether the object was printed on its base, side, or end. The parameters were correctly identified based on the fact that the redesigned bridges exhibited almost double the strength of the initial bridges after the weaknesses were examined. These principles hold true for engineers in the real world and serve as a guideline for creating serviceable designs and structures in society.