Bridging the Gap

Delta Cole, Evelyn Crall, Ethan Finch, Shiv Patel, Neal Singh, Luciano Spaventa, Aayliana Van Dee, Sidney Vass

Appalachian Regional Commission/Oak Ridge National Laboratory Math-Science-Technology Institute 2021

Introduction:

Have you ever thought of something you want to create and need to be able to design and prototype it efficiently? A few years ago, this would have been impossible and would have taken quite a long time, but over the past couple of years, technology has advanced and now allows us to prototype, build, and edit our ideas quickly. The 3D printer makes this possible. 3D printers vary in the size and quality with which they can print, but there are many factors in the software you use to set up the printer that can be manipulated to yield the results you are looking for in the parts you design. In this workshop, the focus was on how temperature, orientation, and amount of plastic affect the strength and durability of the prints. This knowledge helps to build stronger parts that will last longer and perform more consistently.

Background:

A 3D printer functions by extruding thermoplastic filament through a nozzle and printing distinct layers. The layer width and height can vary depending on the g-code programmed into the printer. To design something, an idea is needed to put into the modeling software. Once designed, it is put into a slicing program to generate a g-code for the 3D printer. Depending on the temperature, layer width, and infill percentage, the strength of a print can vary. *G-codes* are specific instructions on how the printer should print the model. The final step is to print models and test their strength. In this experiment, a hydraulic press was used to test the strength of the prints. A *hydraulic press* is a machine that uses a hydraulic cylinder to make a solid compressive force. This machine is used to test the prints' maximum loads, and it helps to learn how different designs and printing methods contribute to strength.

Materials:

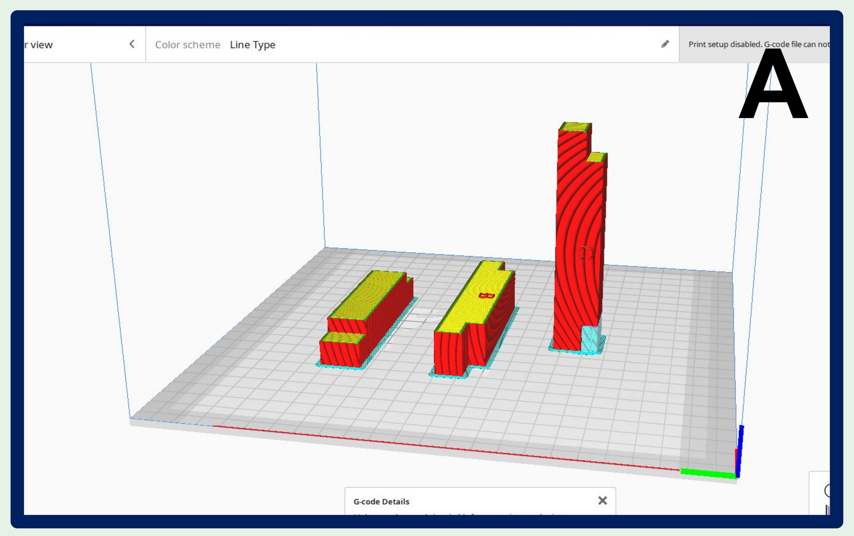
- Creality Ender 3 Pro - 3D Printer
- Hatchbox polylactic acid (PLA) 1.75 mm filament
- Hydraulic press
- Ultimaker Cura 4.9.1; slicing application
- Tinkercad; a 3D modeling program

Methods:

A. Printed three of the same bridges with three different orientations, each designed in Tinkercad; one sitting normally on its bottom, the other lying on its side, and the last standing vertically

B. Printed three different cylinders at temperatures of 190°C, 200°C, and 210°C; different temperatures were used to prevent plastic from hardening and to hold its shape

The bridges were sent via FedEx to Los Alamos National Laboratory to be tested in a series of rounds, round one and round two, each were crushed with a hydraulic press in order to determine their breaking points and to understand how different designs and printing methods contribute to strength.

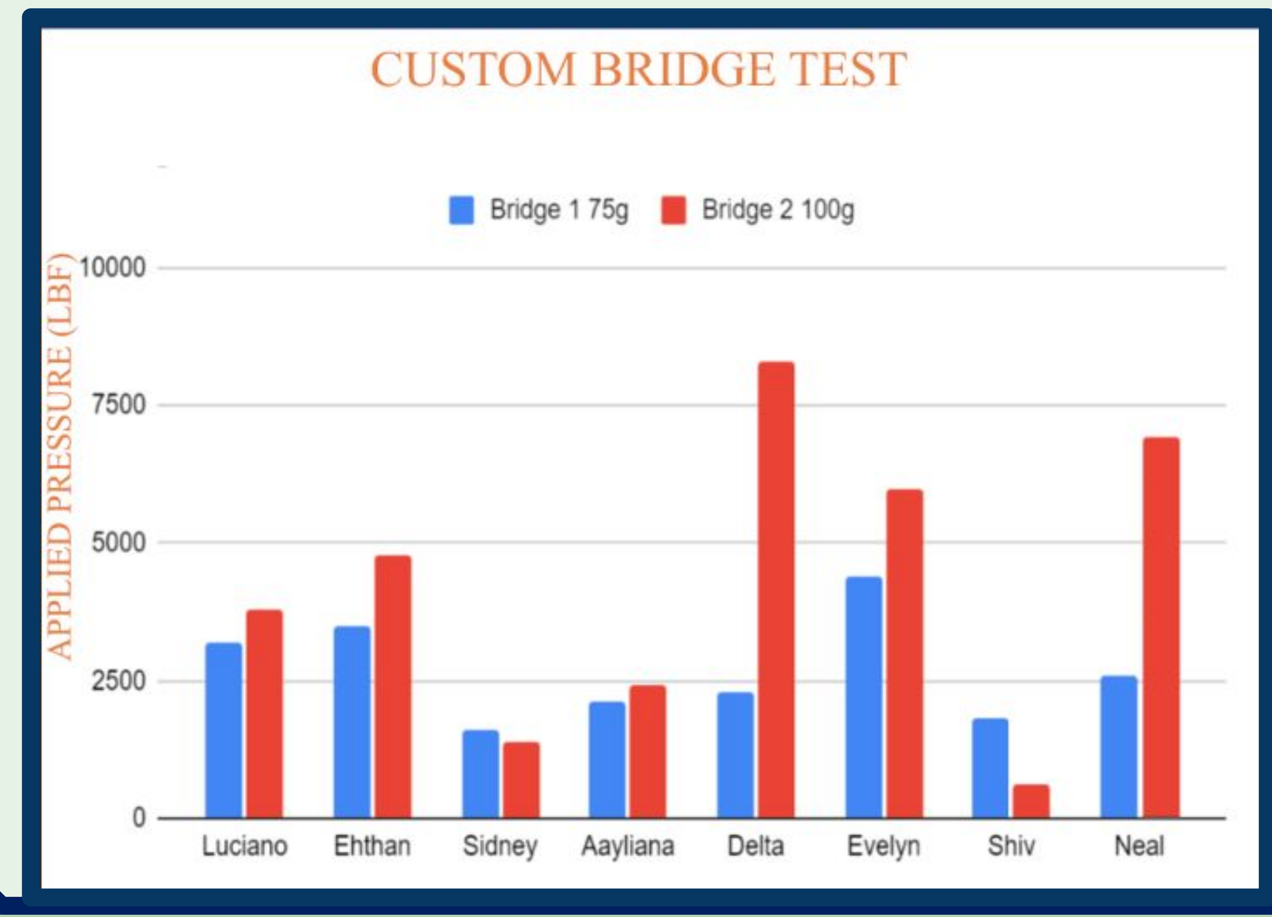


Results

- The bar graph shows an improvement of the maximum load of each student's bridge as they were redesigned with a weight limit change from 75g to 100g.
- The tables show averages and standard deviation of the amount of pressure each print was able to endure.

Cylinders Applied Pressure			
	190°C Cylinder	200°C Cylinder	210°C Cylinder
Average:	**885.57lbf**	**880.03lbf**	**923.26lbf**
Standard Deviation:	**539.27lbf**	**657.78lbf**	**684.15lbf**

Bridges Applied Pressure (lbf)			
	Bridge A	Bridge B	Bridge C
Average:	**211.80lbf**	**342.74lbf**	**104.28lbf**
Standard Deviation:	**144.974lbf**	**246.73lbf**	**57.05lbf**



Analysis:

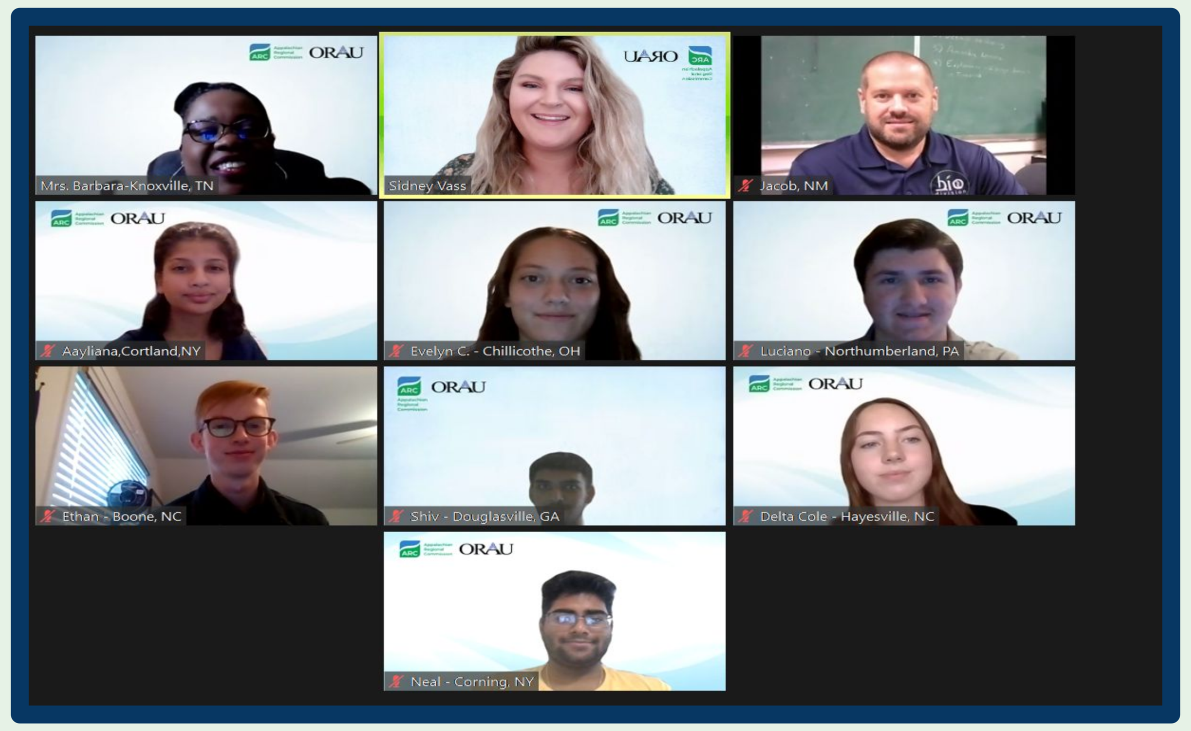
During the utilization of the Ender 3 Pro 3D printers, there was an abundance of successful outcomes. However, since it was a brand new piece of technology, there were many challenges in learning how these machines work properly. Luckily, there was an outstanding group of mentors who were willing to go out of their way to help achieve the goals and have successful prints.

Problems were faced in:

- Belt Tensioning
- Plate adjustment
- Middle bar leveling
- Extruder wheels

Conclusion:

Even though issues were encountered, the leading causes were identified and overcome. The bridges were efficiently printed and some turned out to be very successful and very durable. The factors which enabled a print to sustain more weight were determined to be the orientation of bridge B and temperature of the 210° C cylinder; these were better performing prints. Future models can be reinforced using this knowledge. Understanding how to improve the prints' strength has provided better knowledge of the printers themselves, and the tools to create prints strong enough to serve their intended purpose in the future.



Acknowledgements:

Thank you to Jacob Yoder, Remington Bullis, Amanda Farnsworth, Conrad Farnsworth, Michael Spano, and Jessica Williams. We appreciate the opportunity provided to us by Los Alamos National Laboratory, Oak Ridge National Laboratory, Oak Ridge Associated Universities, and the Appalachian Regional Commission.