Cardboard Furniture for Disaster Relief

Multiple Legs
Tommy E., Daniel J., CJ Nesbit

University of Dayton
School of Engineering
EGR 103 – Section 01
10/02/2024

Abstract

The objective of this project is to create safe and easy to assemble piece of carboard furniture with a height between twenty-eight and thirty-four inches, a length of no more than twenty-four inches, and a top with a surface area of no less than 480 inches that can support a minimum of 650 pounds when placed into a press, and can support a can of coke on each corner of the top surface. This is to be done using only six glue sticks, 2640 square inches of quarter inch cardboard, hot glue guns, box cutters, T-squares, and a yard stick. Multiple ideas were created and the initial furniture design that was selected consisted of two inverted triangular prisms nested within each other called modern art. Modern art was tested in the MTS press and failed the crush test with a weight of six pounds. The results of other groups initial designs were used to create the final design of a lemniscate shaped cylinder supporting a twenty-two-by-twenty-two-inch piece of carboard with cardboards braces supporting the glue seems of the cylinder and the corners of the top surface. This design fit all the criteria for the furniture and supported a max weight of 714 pounds when placed in the MTS press.

I. Introduction

When disasters strike, it can leave families reeling and in need of necessities. While furniture is not considered an immediate necessity like food, water, or shelter, the damage to supply chains resulting from natural disasters make it difficult for families to regain the things they lost. Cardboard tables provide a cost effective and easy to assemble solution. Although this may seem like a simple objective, a lot must go into the research and development of these tables. Stability and strength are the two most important qualities to account for in the design. These considerations resulted in the goal of creating a table with a safety factor of two (650 pounds) and enough stability to balance items on each corner (coke can test). If these two goals are met these disaster relief tables will be able to help a large population of natural disaster victims.

II. Generation of Design Alternatives

When generating design alternatives, our team focused on general themes that made successful designs rather than specifics. One of the first patterns that we discovered was in terms of shapes – cylinders and triangles were the strongest shapes available. As a result, our brainstorming sessions were centered around generating sturdy designs that utilized those shapes as the centerpiece. In addition to the functionality, we also ensured that each design could be realistically constructed multiple times, and that it had the appearance of a table. Finally, we decided that to maximize cardboard efficiency, all designs would possess a 22x22 inch top,

which gives the consumer 484 square inches of cardboard. This square design utilizes the minimum cardboard usage while also providing an actual tabletop.

Our first design [“Modern Art”] was our only triangle-based design. It consisted of two triangular prisms with the faces cut out to save cardboard, such that the only remaining parts were the three walls of the body of the prism. These to prisms would be attached inversely to each other and stacked perpendicularly (see sketch). Each prism body was 14 inches tall. To increase cohesion, we designed each prism to have a double-folded attachment point that would cut into the other prism. Finally, excess cardboard was used to reinforce the overall stucture.

Our second design [“Multiple Legs”] adhered most to having the appearance of an actual table. Despite its silly name, it was a relatively simple design: The 22x22 inch top, supported by a various amount of symmetrically distributed cylindrical legs. Our original sketch and design called for a minimum of four legs, but the design could be incorporated for even more. However, the more legs you add, the harder the structure becomes to assemble efficiently and soundly.

Our third design [“Rocket Man”] relied on the cylindrical research the most. The design was one large cylinder, with a radius of 6-8 inches, to support the entire table. Of course, this design does not look like an actual table at all. This design is extremely cardboard efficient as amount of cardboard consumed by the cylinder is linearly proportional to the radius. Thus, extra cardboard could be used to add triangular supports to the top and bottom of the cylinder, which can be seen in the design sketch.

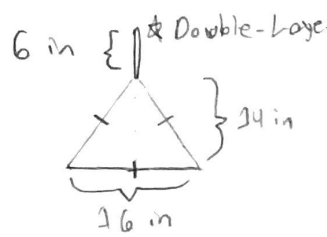
II. Generation of Design Alternatives

"Modern Art"

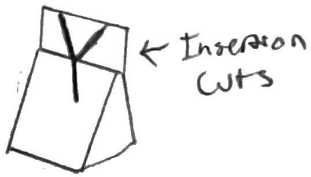
1) Top

Total Area: 484 in²

2) Triangular Prism (x2)



- Side View (x2)



* Symmetrical

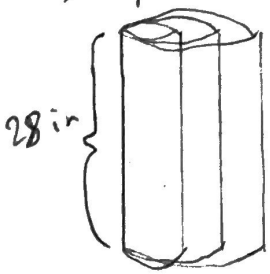
Modern Art does not have a base.

"Multiple Legs"

1) Top

... (also 22x22)

2) Cylinder Legs (x4-12)



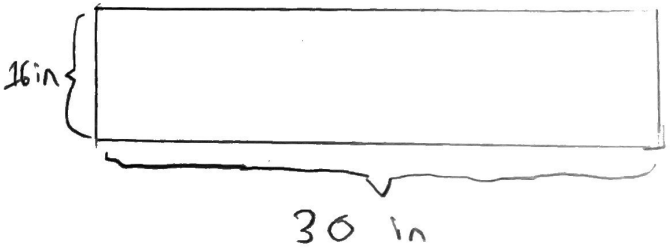
Cylinder Count	Radius (in)
4	3 (3.06)
6	2 (2.04)
8	1.5 (1.53)
10	1.2 (1.23)
12	1 (1.02)
n	$= \frac{2156}{56\pi \cdot n}$

"Rocket Man"

1) Top

... (also 22x22)

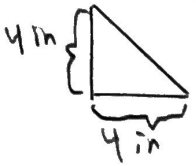
2) Main Cylinder Support



3) Base

--- (Same dimensions as top)

4) Triangle Supports



x min 8

III. Design Selection Process

For our first design, we chose the “Modern Art” double triangular prism design. Part of this decision was influenced by our drive to create a meaningfully unique product by being diverse. All other teams were selecting cylindrical or square-based designs, so our triangular appearance added diversity to the builds. Other criteria that we strongly considered were assembly time/ease and utilization (can the design be used as a table in every definition of the word – not just supporting 650-pound force – and also other factors like transportation ease).

(Table out of 5)	**Modern Art**	**Multiple Legs**	**Rocket Man**
Appearance	5	4	2
Assembly Ease	4	1	3
Utilization	5	3	3

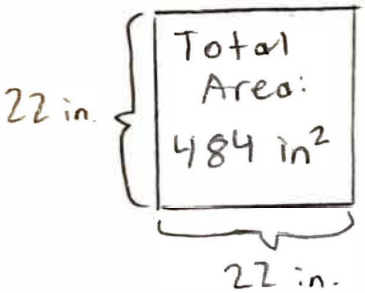
Based on our evaluations, we decided that “Modern Art” would be the best design. It was more visually appealing, could be assembled the quickest, and could be easily transported and even inverted, as it was vertically symmetrical.

IV. Final Design

Our final design choice was a double-cylinder support system reinforced with vertical cardboard slabs. The dimensions of the top remained 22x22 inches. The base of the structure was slightly smaller, measuring 20x20 inches. The two cylinders both had radii of 3 inches and measured 30 inches in height. On the long side of the cylinders, there were cardboard support strips, measuring 30 inches of height as well, and six inches of length. The base was reinforced by gluing a long, 2-inch-tall cardboard strip around the cylinder bases. The length of this reinforcement is around 34-36 inches, depending on how tightly it is wrapped around the base. To ensure stability across the entire top surface, four 8x8 inverted triangles were placed in the top corners. The final design utilized 2,584 square inches out of the 2,640 provided, which translates to 97.9% material efficiency.

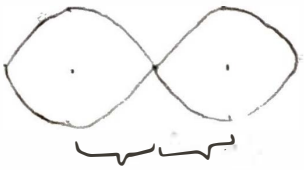
Final Design - "Infinity"

Top (1)



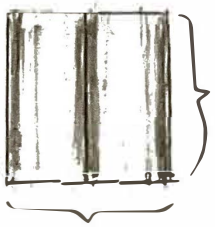
Double Cylinder Towers (2)

- Top View

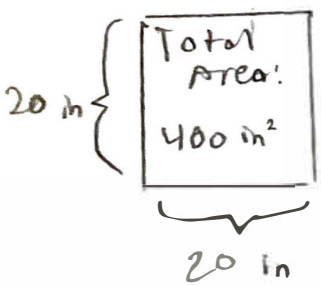


Total Perimeter: 37.7 in.
≈ 38 in.

- Side View (not drawn to scale)

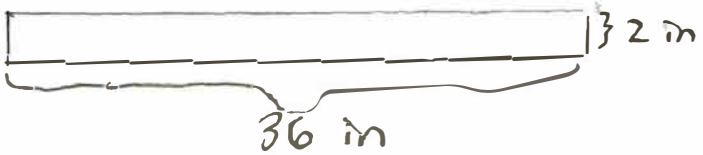


Base (3)

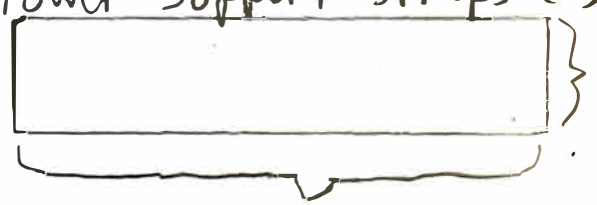


Base Support Strip (4)

- Actual Dimensions before curling around base

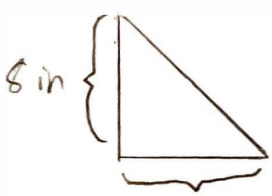


Tower Support Strips (5)



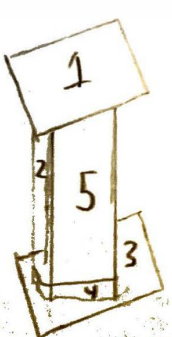
x 2

Triangle Top Supports (6)

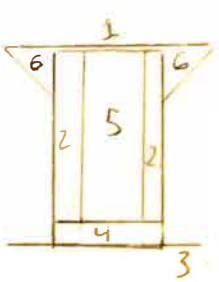


x 4

Full:



Side:



V. Testing the Design

To test the designs stability and durability two tests were used. The first test was the Coke can test which was used to test the stability of the design. During this test a can of Coke was placed one at a time on each of the top corners of the design and the design had to support the can without tipping. The final test was the durability test. For this test the design was palced into an MTS press with a piece of plywood placed between the top of the design and the press to evenly distribute the weight. The arm of the press would slowly extend and place more weight onto the design until the design eventual failure. The machine collected hundreds of data points throughout the testing and assembled them into a weight vs time graph. In order to pass the durability, test the design must have supported a minimum of 650 pounds. the Table below show a matrix of the each of the tests and their passing criteria.

What is Being Tested	How is it Being Tested	How Does the Design Pass
1. Stability	A can of Coke is to be placed on each of the top corners of the design.	The design supported the can of coke in each corner without tipping
2. Durability	The design is placed into an MTS press machine with a piece of plywood between the presses arm and the top surface of the design to distribute weight. The machine then would slowly extend the arm and crush the project while sending the data points to a computer to be compiled into a weight vs time graph.	The design must support a minimum of 650 pounds of weight during the test.

VI. Results

Stability Test

The double cylinder design “Infinity” supported the coke can with minimal tipping. After the coke cans were removed the top of the structure returned to being level. The coke cans were placed on the corners for 10 seconds. Any extra time was unnecessary as the tipping occurred instantaneously when the coke can was placed on the structure. The supports quickly reached equilibrium, and the vertical component of the tipping was estimated to be around 0.24 inches (0.61 cm).

Durability Test

The double cylinder design “Infinity” supported the required minimum weight of 650 pounds. The design dimensions were also kept in accordance to the dimensional measurements of the MTS press machine, such that the design could fit into the machine in all three dimensions. The design sustained a maximum of 714 pounds, which happened at 0.43 inches of extension. This translates to 0.06 inches of compression for every 100 pounds. After structural failure, the design did not return to the initial height, and instead remained compressed by around 0.8 inches.

VII. Conclusion

Our design met and exceeded all expectations for sound cardboard furniture. Infinity supported a load of 714 pounds due to the strong central reinforced double cylinder supports, and its triangular corner supports easily carried the weight of a coke can. The design is easy to assemble due to its minimal number of simple, straightforward parts. In light of these factors, Infinity would be an exceptional design choice for cardboard furniture.

VIII. Recommendations

While our design certainly exceeded all expectations, it still contains a few suboptimal design flaws. Our design failed after 700 pounds because the vertical supports that prevented cylindrical expansion started folding, especially near the top of the design, where the pressure was causing the most stress. Reinforcing these supports would be the top priority when redesigning. This would hopefully reduce the height compression caused by the load mentioned in the “Durability Test” section of the results. Also, we theorized that reinforcing the top could cause complications in the foundation after more force is applied. Our foundation did not sustain any noticeable stress after 700 pounds, but we theorize that if the top is reinforced, the foundation will be the next to give. Therefore, designing a better foundation could also be called for. Perhaps the foundation could be four triangles, mirroring the top supports. This would also make the design almost entirely vertically symmetrical.

References

Box, M. C. (2024, September 16). *A practical solution for disaster relief*. Cardboard Furniture. https://cardboardfurniture.co.uk/cardboard-furniture-a-practical-solution-for-disaster-relief/

Appendices

Unit Cost Analysis

Materials	Price Per Unit	Amount	Total Price	Price of Final Product
Carboard	$0.52 per 94 square inches	2640 square inches	$14.60	
8 Inch Glue Sticks	$6.29 per 48 sticks	6 sticks	$0.79	
				$15.39

Supporting Calculations: Radii required for "Multiple Legs" design:

https://www.desmos.com/calculator/ojqn5xksey