GNG1103

Final Design Report

X-Bocks Cardboard Bed

Design Report

Submitted by

Cardboard Bed Team 1

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Abstract

As society develops further domestic violence, poverty, and global warming has become exponentially more controversial topics, as they are becoming issues that are getting harder to handle than ever. A team of five first year engineers participated in a project to develop, design, and construct a temporary cardboard bed for the people who are caught as the victims of these horrible tragedies. While testing the "X-Bocks" prototype, it was discovered to be able support a whopping 600lbs, while the full sized design is estimated to support a full metric tonne. Overall, the final design was a success in achieving every single need of the client and nearly every single want of the client. It is important that further development puts forth a more aesthetically pleasing design.

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List of Acronyms

Acronym	Definition
CAD	Computer Aided Design
STEM	Science, Technology, Engineering, Mathematics
3D	Three Dimensional

1 Introduction

Problem Statement

A woman is killed every 6 days due to domestic violence. Although there are 5 shelters throughout Canada which hold around 4000 women usually with 1-2 children, over 300 women and children get turned away every day. Although we are not quite focused on the general structure of some cost-effective houses, we will be providing comfort to the individuals in need with a bed that is lightweight, portable, made out of cardboard, and most importantly, comfortable with a mattress.

This is one of the many problems that occurs in today's society that would benefit in the designing and building of a cardboard bed that is also low to the ground. In today's society there are so many areas which this bed would be highly useful, at a cost-effective price. Other problems that could make use of a cardboard bed design could include, but is not exclusive to: Homeless shelters, soldiers in the field, disabled individuals (they could make a high use of the level that the bed is to the ground), and they could also be included in care packages to countries in the world that are facing a terrible natural disaster. This would give the individual a comfortable place to sleep while also being durable.

Some of the many places that could utilize the cardboard bed design is domestic violence shelters, homeless shelters, hotels (primarily to accomodate for the physically disabled), and various not-for-profit organizations such as World Vision and Me To We.

The cardboard bed that was designed is superior to other products for its immense strength and durability. The bed itself is capable of supporting a metric tonne through come

calculations and judging by the way the weight is dispersed through the entire bed, it will have a lifespan of approximately 2 years. It was decided that amongst the team that aesthetics should not be our primary goal, and that strength, durability, and easy accessibility should be what we focus on. The bed was intentionally raised a foot off the ground so virtually anyone can sleep in the bed. This would be especially useful to physically disabled individuals who visit a hotel, as hotels do not currently accomodate for these people.

The bed was designed in such a way that it folded into three pieces. The two legs and the platform for the mattress folded separately making three, easy to assemble pieces. All the assembly requires is to unfold each part and slide the legs into the slots underneath the mattress platform. After that is completed, the entire bed is assembled.

2 Need Identification and Product Specification Process

We were tasked with creating an easy to assemble bed made out of cardboard for use in a small, modular home. The bed is designed to be inexpensive while still providing comfortability and easy assembly. We started to search the internet for pre-existing bed designs for some ideas.

Figure 1. Already made conceptual cardboard bed designs.

Figure 1 shows some preexisting cardboard bed designs found online. From these we started to formulate ideas until we found one that would satisfy the conditions of the design criteria. The biggest or most challenging condition is it must be foldable. We started thinking about how we could make the bed fold and we used the benchmarking as a guideline. We finally came across a final idea but it took lots of testing and prototyping to get there.

Question	Customer Statement	Interpreted Needs
Bed dimensions?	Prefferably a Twin but a double or even a queen would be acceptable	Bed needs to be able to switch between matress sizes
Recyclable?	Doesn't matter but recycled is preffered.	Cardboard should be recycled
Installation?	Prefferably one piece but if you are unable multiple piece is okay	Bed needs to be a one piece installation
How does the bed rest on the ground?	The bed needs to be a foot off the ground resting on a frame	Bed Needs to be one foot off the ground
Does the bed need to be fully cardboard?	No, you can use metal as long as its not too heavy	Metal can be interpreted into the bed.
What weight does the bed need to support	The bed needs to support at least 250 pounds.	Bed needs to support at least 250 lbs. (113.4 kg)
What is the desired weight of the bed itself?	The bed needs to be lightweight and portable	Build a lightweight and portable bed
Does there need to be a headboard?	We'll say no but if we can implement it into the design then it would be good.	The bed needs a headboard

Need #	Needs	Importance
1	Changable frame size	2
2	Recyclable	3
3	One piece installation	4
4	One foot off the ground	4
5	Needs to support 250 lbs. (113.4 kg)	5
6	lightweight and portable	5
7	Headboard	2
8	Metal interpretation	1

Table 1. List of needs and prioritized design criteria.

	Design Specifications	Relation (=, <, >)	Value	Units	Verification Method
	Functional Requirements				
1	Made of cardboard	=	yes	N/A	N/A
2	Height above the ground	>	12	inch	Analysis
3	Ability to fold	=	yes	N/A	Test
4	Portable	=	yes	N/A	Test
5	Weight supported	>	250	lbs	Test
	Constraints				
1	Weight	<	30	lbs	Analysis
2	Cost	<	100	$	Estimate, check
	Non-Functional Requirements				
1	Lifespan	>	2	years	Test
2	One-piece setup	=	yes	N/A	Test
3	Foldable legs	=	yes	N/A	Test

Table 2. Bed metrics.

Table 1 shows the needs that we interpreted from our first client meeting as well as the prioritized design criteria that we decided on based on customer needs. Table 2 shows the metrics that we followed when designing the bed.

3 Project Plan, Execution, Tracking & Bill of Materials

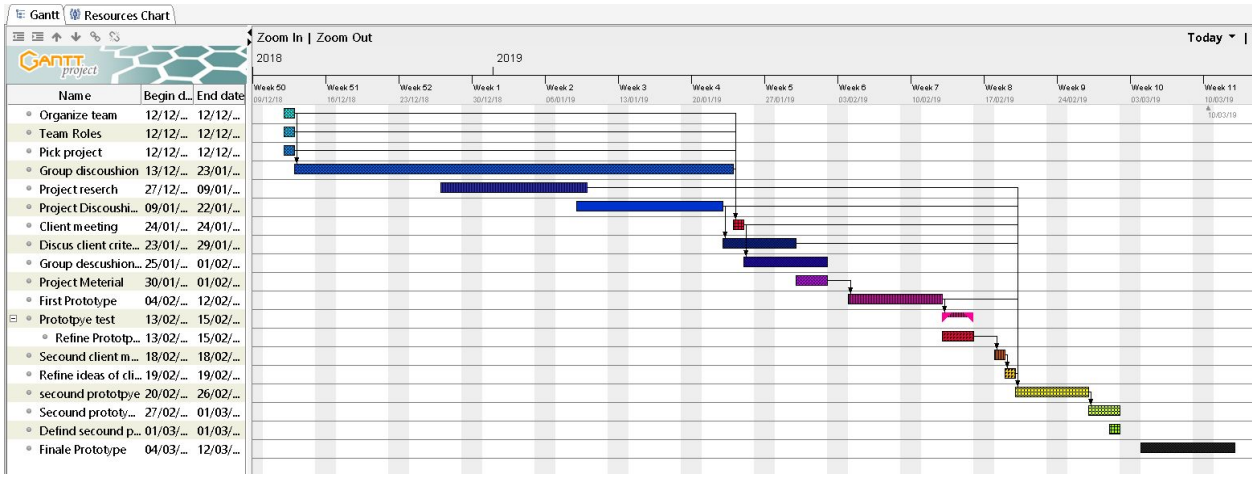


Table 3. Our project Gantt chart.

Execution:

Our team first had to have enough expertise and technical resources to complete the project given by the client. With the training sessions in the STEM building as well as additional training sessions that can be taught to us from the Maker space, we believe that this can be within our grasp of building the cardboard bed. Some examples of mechanical processes the STEM lab taught us was to use Autocad for making 3D renders prototypes, as well being able to use the laser cutting machine. This will come essential to us when we need to perform precision cuts.

With every project, there is always a organizational factor that comes into play which determines the outcome of the end result. One of the main one is keeping the group organized as a whole. This is a key part to the group's success, because if we were aren't organized, this will lead to the product not being complete or even complete to our full potential. This can be easily

avoided by constantly communicating with the members to always keep them in the loop of when things are due or if we had to work on a side assembly for the project. Little things like that helped keep the group organized and be able to finish the project with success.

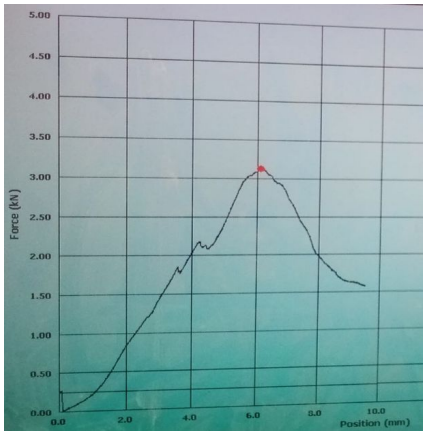
The main deadlines that we need to consider were Building the first prototype layout, this helped with determining that ideas to pick. after having the layout for our product our team need to construct test prototypes for testing. our team needed thes test and designs reay befor our second client meeting. once the client gave use their feedback we began on the Final product. We believe that the dates are reasonable, as long as the group can meet at least for 3 hours a week to work on the project and at least get some hands on work with the cardboard bed every week moving on forward. Our Gantt chart schedule helped us to stay on track when completing the deadlines at hand.

Tracking and Bill of Materials;

Item no.	Description	Supplier	Quantity	Unit price	Net price
1	Wood glue	Walmart	236 mL	3.62$/100mL	8.54$
2	40” x 48” cardboard sheets	Uline	25	2.75$/sheets	68.75$
				SUBTOTAL	77.29$
				TAXES	87.34$

Table 4. Bill of materials.

4 Analysis:



$$stress = \frac{force}{area}$$

Figure 2. Graph of bed stress test.

Figure 2 shows the force per unit area allowed by the tic-tac-toe/X-Bocks leg design as determined by testing using a hydraulic press. We found the safe stress that the legs were capable of withstanding was 2.5 kN or around 560 lbs. Using the stress formula we were able to calculate the amount of weight the full sized leg design which we found to be 10 kN or 2240 lbs. This is over 1 ton in weight, and only for a single leg.

5 Prototyping, Testing and Customer Validation.

Many ideas came and went before we decided on our final model solution. In our weekly meetings we discussed different possible ideas, most importantly about the legs and how we would be able to make them foldable and compact. We discussed the pros and cons of every idea, as in accordance with the “ideate” stage of the design process, and decided to build prototypes of the ones we thought would work best. Our first prototype was called the “Double Star”. The legs consisted of 4 cardboard sheets all crossing at a singular point to reach the sides and corners of the bed.

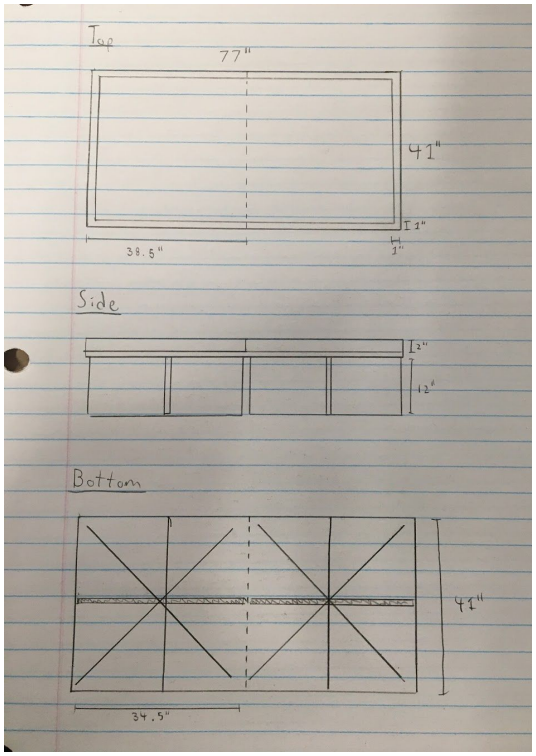


Figure 3. Hand sketch of the Double Star leg design.

Figure 3 shows how the legs would be placed underneath and gives a visual so that one may imagine how the legs would be able to fold into themselves as seemings 4 sheets stacked on top

of each other. However, testing proved that this design did not hold up under minimal stress. Because the design requires 4 sheets all crossing at the same point, the cross section area at that point is reduced to a quarter of that of the original sheet.

Figure 4. Testing results of the Double Star.

We tested the Double Star design with a simple test of sitting on it, and figure 4 shows how it immediately and spectacularly failed.

Even though the Double Star design was a failure, we still liked how in theory it was very compact because of easy folding. So, we improved on our original idea with our second prototype, the “Box Star”. Instead of having 4 sheets cross at the middle, only 2 sheets cross there and half sheets extend out the sides, making it so that the legs are still foldable.

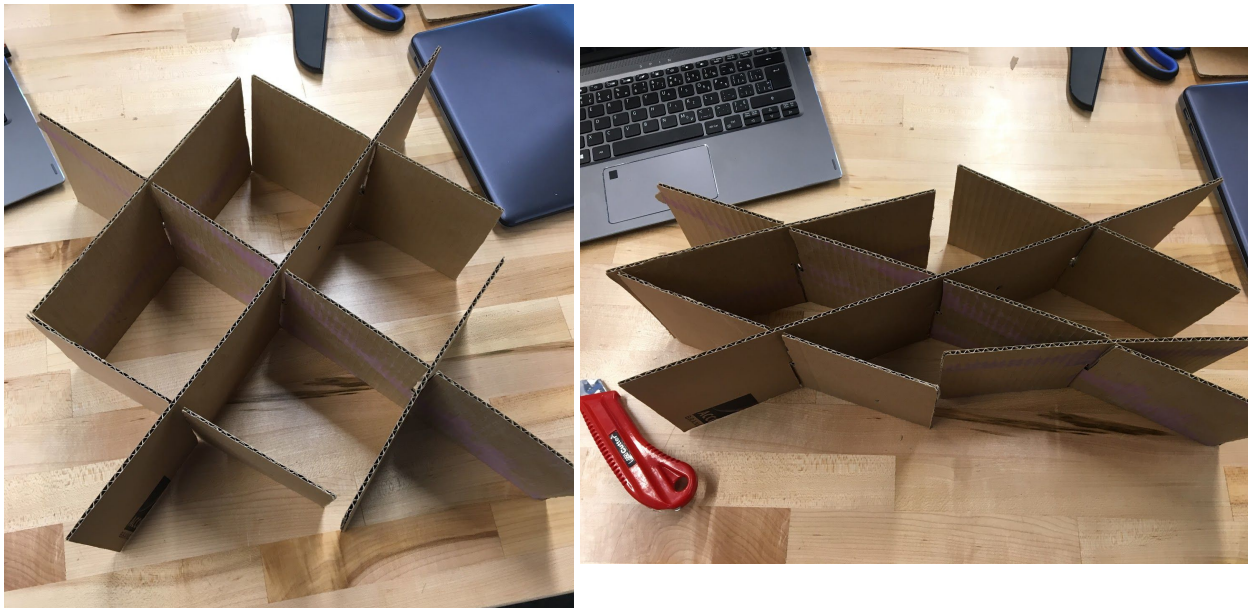


Figure 5. The Box Star design and how it folds.

Figure 5 shows the improved leg idea and how it folds up. However, this design also proved to be a failure. Because the side supports are just half of the main supports and are only attached at the middle, the sides were very wobbly and would not consistently stay straight. This prototype did pass the sitting test by not collapsing like its predecessor, but we realized that in addition to the side supports being flimsy, the corners of the bed would be unprotected by this design and would easily collapse under almost any force applied it it. During our second client meeting, we presented the client with the Box Star design to explain where our process was headed. She was very pleased with the fact that the legs were foldable to be compact, and we assured her that the design was on its way to being completed by suggesting possible improvements to the design that we had already brainstormed, such as connecting the side leg pieces together so eliminate the wobbling. With this, she approved of our design so we knew that we were on the right track and that we would soon realize our final solution.

6 Final Solution

Our final solution is the “X-Bocks” cardboard bed model. This model builds off of our previous model and prototype, the “Box Star”. Unlike the Box Star, the legs are crossed and connected at 9 locations instead of the previous 5.

Figure 6. Final design of the X-Bocks legs.

As shown in Figure 6, each leg is connected at 3 locations. By doing this, leg movement is vastly reduced as all legs have many supports along their width. Figure 6 also shows how T-shaped leg

pieces are places in 8 locations at the corners of each bed half. These pieces prevent collapse if someone were to sit on a bed corner or side where the main legs do not support. The legs are inserted into slots of cardboard strips and held in place, meaning that the legs do not move out of place and the bed can be assembled upside down and then flipped over.

Figure 7. The compact form of the leg components.

The leg components are designed to take up as little space as possible when the bed is not in use. Figure 7 shows how the main legs fold together into singular long strips and how the corner leg pieces can easily be stacked into a small box. In addition to the bed components being compact, the bed itself is able to be folded in half when not in use for better and easier storage.

Figure 8. The bed folded in half.

A cardboard strip connects the 2 halves of the bed together. The strip has many cuts in it, allowing the bed to fold at the middle while still remaining attached together. Figure 8 demonstrates this and shows how the bed can be reduced to half its original length.

To test the X-Bocks leg design, we built a scale model and used a hydraulic press to test the force that the full size bed could theoretically withstand. This test showed that our design could withstand a metric ton of force before beginning to collapse. This is much more than our required weight threshold of 250 lbs, so we knew that our design was feasible enough to be used in our final design.

Figure 9. The X-Bocks bed, as featured at Design Day at the University of Ottawa.

The finished product stand just over 9 inches tall not including the mattress. We went with a low-to-the-ground approach with the bed to accommodate the need to be accessible by people with disabilities that would otherwise make getting into a taller bed much harder. Figure 9 shows what the bed looks like with a simple inflatable twin-sized mattress. We made our final model with a twin-sized mattress in mind, but the X-Bocks design could be implemented for larger mattress sizes as well.

7 Conclusions and Recommendations for Future Work

This project was a quite the endeavour to take on. There were a great deal of lessons learned during the course of designing this cardboard bed. One of the lessons learned was we discovered that not all projects will go according to plan and there should always be some level of expectancy that the original plans will be altered. Another piece of information we have learned from this project is the strength and durability of cardboard. It was surprising to us that cardboard could support so much weight.

Some next steps to improve the design in the future could be to alter the design to make it more aesthetically pleasing and further reinforce the legs to make them eligible to hold more weight. Finally, another addition that could be made to the bed would be to replace the centre hinge made out of cardboard with a living hinge made out of thin sheets of wood. This would improve the connection between one half of the bed and the other.

APPENDIX I: User Manual

Parts List:

- one bed frame (A)
- six 39” leg pieces (B)
- six 42” leg pieces (C)
- eight corner support pieces (D)

Assembly:

1. Take three 39” pieces (B) and three 42” leg pieces (C) and cross them in the shape of a Tic-Tac-Toe (figure 1) keeping the three B pieces lined up and the three C pieces lined up perpendicular to the B pieces. Do this twice
2. Place bed frame (A) so that the ridges are facing up. Place the two leg components lining them up with the ridges and insert them firmly in place (figure 2).
3. Insert the eight corner pieces (D) into the designated slots, keeping the short pieces to the outside.
4. Flip the entirety of the bed so that the legs are facing downwards. Place mattress on bed frame and enjoy your sleep!

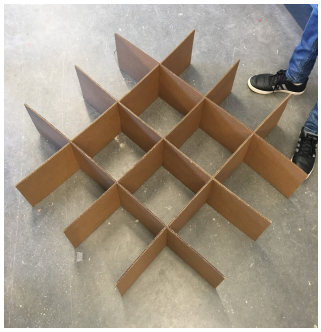


Figure 1. Assembled legs (parts B and C)

Figure 2. Assembled bed (Upside Down)

APPENDIX II: Design Files

https://makerepo.com/lwhit108/gng1103d1bed