# Sustainable Chair Challenge

Bartlomiej M. Patrzalek
*MMAE 232: Design for Innovation, Fall 2012*
*Illinois Institute of Technology*
*Chicago, Illinois, US*
*bart.patrzalek@gmail.com*

***Abstract*** **- This report consists of sample designs, analysis, and prototype of a sustainable chair solely build out of foam-core board. The chair is both aesthetically pleasing and strong enough to support a 80kg person. A simple stress analysis was performed on each proposed design and is presented in this paper. Also the manufacture and testing of the prototype is presented. The final design of the chair proved to be successful and met all of the design specifications.**

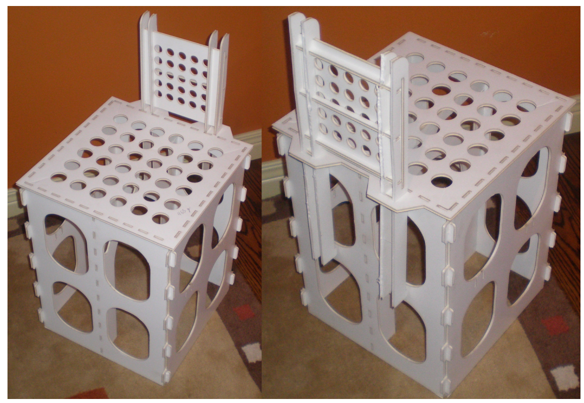
**Keywords: Chair; Foam-core; Sustainable; Laser Cutter;**

## I. Introduction

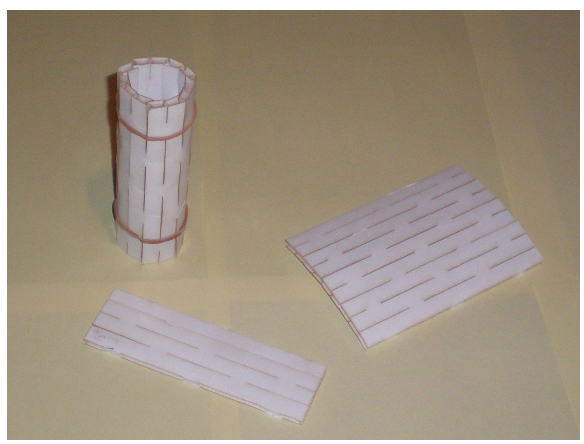
This report describes the results of a challenge where the goal was to design and fabricate a sustainable chair. The prototype had to not only support a weight of 80kg but also meet specific size and sustainability requirements. One of the tougher requirement was a 500g weight limit and the fact that only foam-core board was to be used, no other fasteners or glue. Overall the final design (fig. 1) proved to be successful and was completed on time.

## II. Ideas and Concepts

To determine the best approach, three designs were analyzed and their strong and weak points were identified. Next a decision matrix was used to pick the design to prototype. Each design was sketched out and a simple stress concentration analysis was performed[1]. The first concept utilized a complicated kerf bending technique to build the vertical columns with a frame structure similar to a simple wooden chair. Samples (fig. 2) were created to perfect the bending operation and test sample structures that



*The final prototype (fig. 1)*



*Sample structure for testing (fig. 2)*

could be made in this manner. Also the stress concentrations were quite high on the corners of the seat where the horizontal load was transferred into the columns. This problem was to be fixed by adding gussets to the top portion of the legs but proved to be too complicated due to the cylindrical nature of the columns.

The second design also utilized the bent foam-core but consisted of only one large column. In this concept the seat was integrated inside the main support structure with horizontal beams running underneath it. As for the backrest it was an extension of the main bottom column and wrapped around the seat. During analysis this design proved to be one of the strongest and best looking ones but yet again it was rejected due to weight concerns.

The third and final design (fig. 4) was quite different from the rest. There was no bent sub-structures and it only consisted of flat panels. A lot of material was removed in order to meet the weight requirement and also add style to the chair. Each vertical panel connected with each-other using interlocking hooks that protruded from the corners. In the middle of the bottom structure there was another panel added to transfer the loads from the seat and add rigidity. The backrest consisted of two simple vertical beams that were put in through openings in the rear of the seat and locked in against one of the vertical side panels.

To make the comparison between the three designs easier a decision matrix (fig. 3) was implemented. Design number three was chose as the one to be prototyped due to all of its advantages.

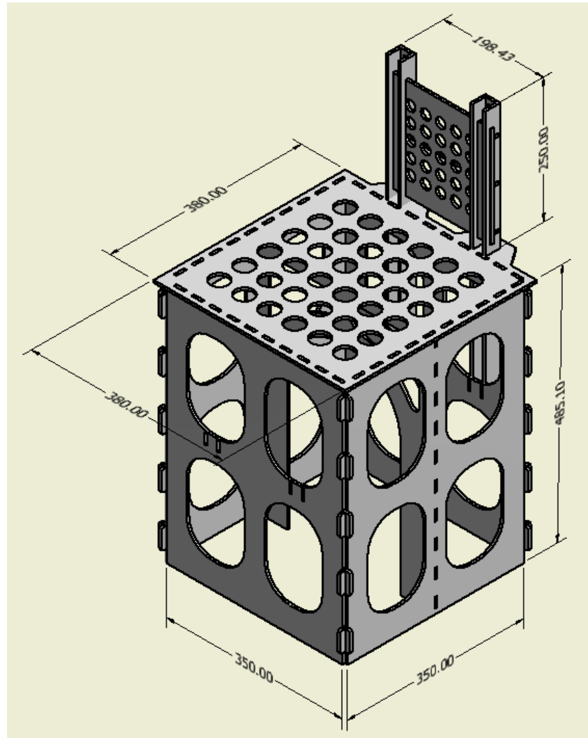
| **Criteria** | **Weight** | **Design 1** | **Design 2** | **Design 3** |
|---|---|---|---|---|
| **Weight** | 3 | - | - | + |
| **Style** | 1 | + | + | 0 |
| **Ease of Assembly** | 2 | - | + | + |
| **Strength** | 3 | 0 | + | + |
| **Total** | | -1 | 2 | 3 |
| **Weighted Total** | | -4 | 3 | 8 |

*Decision matrix (fig. 3)*

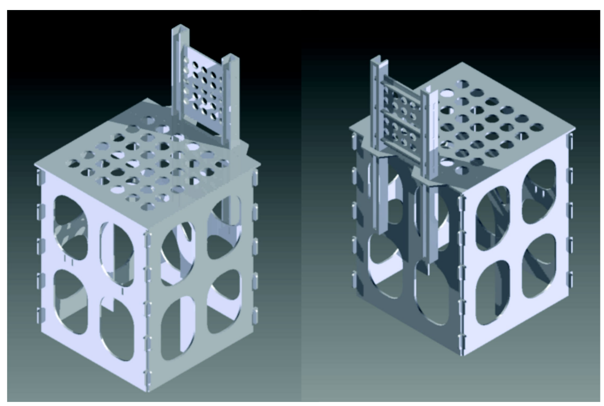
## III. Prototyping and Assembly

The first step in making the prototype was to model each part using Autodesk Inventor and complete a full assembly of the chair in 3D space. Not only this gave a better idea as to the dimensions(fig. 4) of all parts it also added another level of assurance that the parts would fit together once assembled. All of the engineering drawings for each part as well as an exploded view of the assembly are attached on the continuing pages.

The actual manufacture of foam-core parts was done using a laser cutter. Each 24in x18in sheet was filled with as many pieces as possible to conserve material and follow the sustainability requirements. Overall the whole chair was cut out of 6 sheets of




*Size of final prototype (fig. 4)*



*Render of final prototype (fig. 5)*

foam-core board. Before assembly all parts were weighed and amounted to 463g which is way below the 500g limit.

## IV. Testing and Analysis

Testing of the prototype (fig. 5) consisted of a sitting trial executed by Dr. Matthew Spenko. During testing the chair was subjected not only to vertical loads of around 80kg but also side to side forces that are always present when a person sits on a chair. The prototype performed well, it held the weight, but there was some creaking that could be heard while loading the seat.

After further investigation it was determined that the creaking noise came from the middle vertical panel (fig. 6) that deformed due to the load applied. Part of the middle support simply buckled but the failure was so small that the whole chair retained its strength and passed the test. Since the prototype was 37g under the weight limit, for the next prototype, more material should be added in that spot in order to strengthen it.

*Failure in middle panel (fig. 6)*

## V. Conclusion

The prototype proved successful and was made on time. The project was constrained with tight requirements and all of them were met. In order to fabricate the chair, only 6 sheets of foam-core board were used, in tune with the sustainability aspect of the design. The lesson learned from this challenge was that there should be no weak points in load bearing structures, such as the middle panel, that buckled during testing. If a second prototype was made this is where extra materials would be added so no further deformation would develop. Also the abandoned design concepts could be developed more to meet the requirements in new, inventive ways. To optimize each design a better analysis could be applied where the actual strength of the material is taken into account and all of the necessary calculations are carried out. This way the chair would be the strongest in places where it needs to be and unneeded material would be removed to lightweight the structure.

## VI. References

[1] H.C. Ohanian and J.T. Markert, “Physics for Engineers and Scientists”, W. W. Norton & Company, New York, NY

[2] Dr. Matthew Spenko. (September 6, 2012). *The Design Process.* In MMAE 232 Week 3. Retrieved September 20, 2012, from http://prezi.com/e3ad0oqrcagu/mmae-232-week-3-part-a/?auth_key=f2d2c8f919d1eea649292725720946e0bfe11a10.