Building in Paper

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Graduate Project in Digital Fabrication, Syracuse University School of Architecture

Abstract

Generated from an assignment for a digital fabrication class at the Syracuse University School of Architecture, this project demonstrates how the simple application of digital fabrication techniques to everyday materials can create innovative construction methods and expose the potential for new architectural design.

The assignment called for a wall to be constructed solely out of paper, twelve feet in length and at least eight feet high using the principles of digital fabrication.

From the very outset, our understanding of the problem was simple: paper does not resist any load applied in plane when it is left unmodified, it merely buckles. However, as soon as a single sheet of paper is folded its ability to resist load increases dramatically. It then became an exercise in testing combinations of folded paper to maximize both compressive strength as well as lateral stability, the final result being the simplification of previous iterations.

Project

One of the significant goals of the graduate architecture program at Syracuse University is to push the limits of contemporary architectural practices, thus preparing its students for an innovative career in such a dynamic field. As part of that agenda the school purchased a Universal Laser Cutter in the spring of 2004 and began to implement the concepts of digital fabrication into its curriculum. An introductory class was offered that spring to first year graduate students which began to explore the potential of the technology and in the fall of 2004 an advanced class was also added to the curriculum. It was through the assignments of that advanced class that the Laser Cut Paper Wall was developed and completed.

The assignment was simple: construct a wall at least twelve feet long and eight feet high solely out of one ream (500 sheets) of 11” x 17” paper without the aid of glue or any other fasteners. Emphasis was placed on ease of fabrication and ease of construction. Two people should be able to erect the wall in a relatively short period of time. Our group consisted of five graduate architecture students: Tyler Hinckley, Emmanouil Vermisso, Christian Callaghan, Joshua Parker, and Jeremy Tobin.

With such simple guidelines we soon came to a clear understanding of the issues at stake. Paper is a very weak construction material that buckles easily when any load is applied to it. But as soon as a fold is introduced a single sheet of paper gains much rigidity and its ability to resist load is dramatically increased. This principle became the guiding force behind the design process for the project.

Initially, we sought a modular unit that could be stacked in a much more varied manner, thus producing a wider variety of forms. By folding the paper into thirds and then introducing a number of carefully placed slots along the long edges we could stack the folded pieces of paper to create the wall. Early prototypes, however, could not reach higher than a few rows before they would buckle or topple over. From that point onwards the design process was driven more by functional needs.

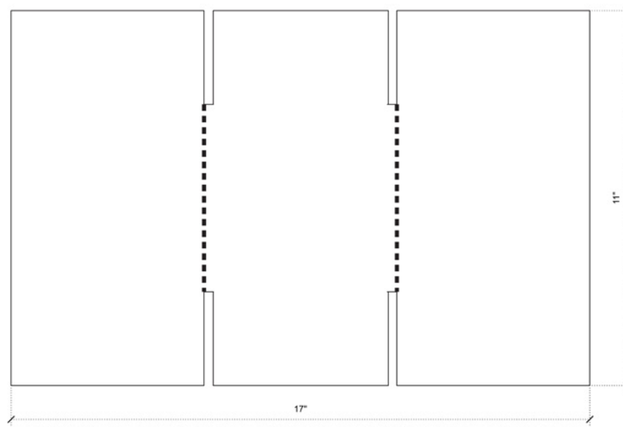

Figure 1. *Initial folds*

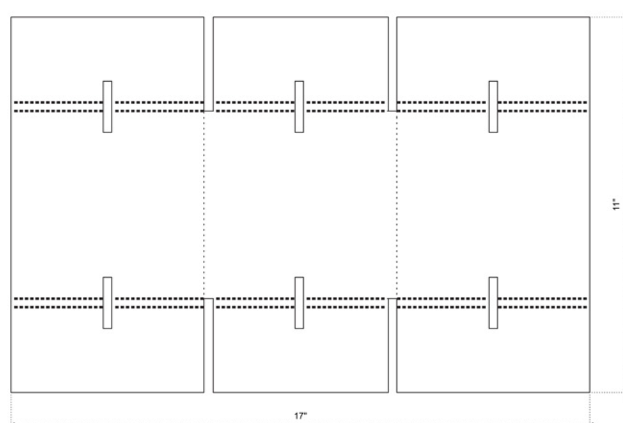

Figure 2. *Secondary folds*

The turning point in the design process occurred when we introduced thickness to the folded pieces of paper. In addition to folding the paper into thirds along the long edge of the sheet, we also made a number of additional folds in the other direction which added thickness to the modular unit. The bold dashed lines in figure 1 illustrate the initial folds from the earliest iteration and the bold dashed lines in figure 2 demonstrate the additional folds made to add thickness to the unit.

Once that step had been made, the design quickly progressed. In order to maximize strength and ease of construction we simplified the design further. Due to functional constraints we combined two folded pieces of paper to create a cube form that we called a "brick." These bricks could be easily mass produced and stacked to create the desired wall.

The fabrication process was also streamlined to maximize efficiency. While the laser cutter has the ability to score paper to provide accurate folds, that would have required each sheet of paper to be cut separately. Instead, we utilized the laser cutter's maximum cutting depth of ¼ inch by stacking the sheets of paper. To create accurate folds we perforated the stacked sheets of paper with small cuts instead of scoring each individually. This method allowed us to greatly decrease the time of production. As one person monitored the laser cutter the other team members folded the pieces of paper to create the bricks. One pack of paper produced 250 "bricks" and we stored them in plastic bags to be assembled the following day.

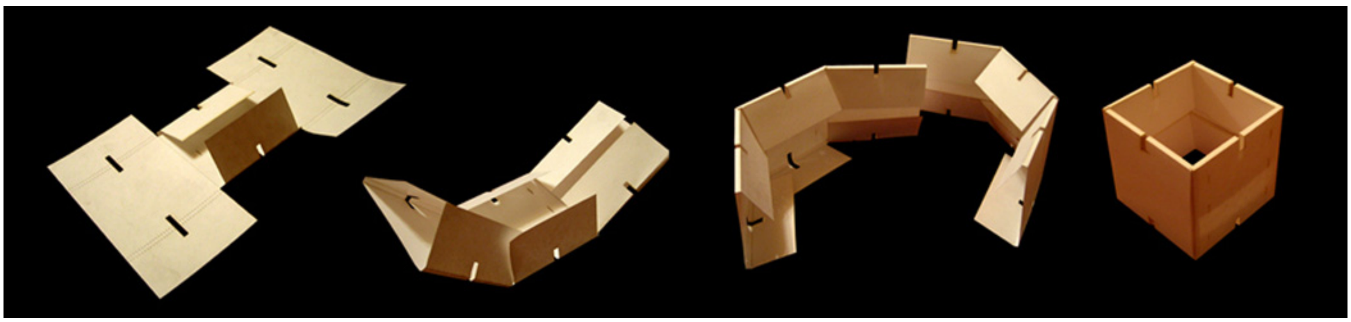

Figure 3. *Fabrication Process*

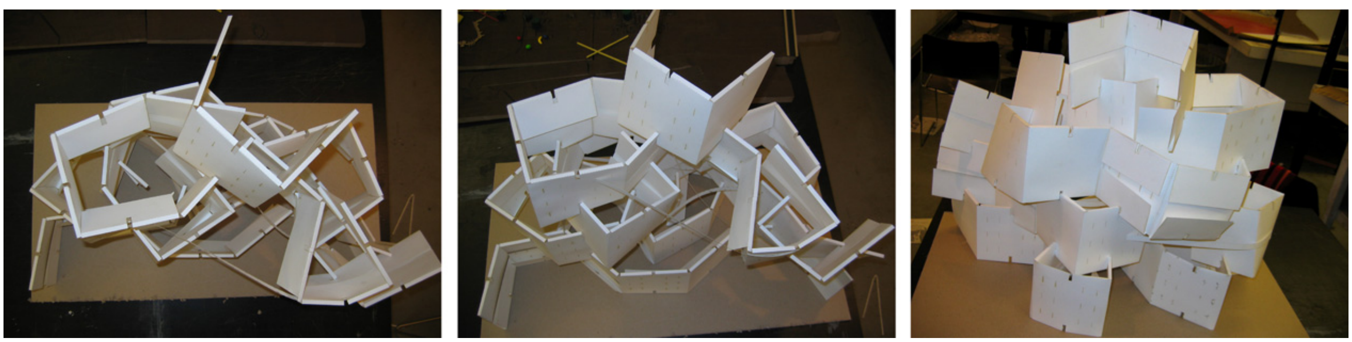

Figure 4, 5, 6. *Study Series*

Figure 7, 8, 9. *Fabrication, Installation, Recycle/Reuse.*

Because of the ease of construction, it took our team merely half an hour to erect the wall which actually surpassed the eight foot height requirements. While our design process was driven by the functional demands of creating the strongest possible wall with the material, we were able to create an elegant wall nonetheless, a feat that was perhaps due to the simplicity of the design.

The true accomplishment of the project was the development of the fabrication and installation process. By designing a method of construction that utilizes an economical material such as paper, we have created something with applications far beyond the classroom.

By merely modifying the process slightly a more durable and useful product will result. For example, the shortcomings of paper as a material can be easily remedied by adding a protective coating. Insulation can be added by spraying foam into the hollow cavities of the wall. Also, more rigid materials that are still paper products such as cardboard and chip-board can be used to lend even more strength to the construction. By transferring the process to alternate modes of digital fabrication, such as CNC milling, even more varied materials may be used such as paper pulp to create the bricks needed to build a wall.

Because of the speed and ease of construction the process may be ideal for the temporary structures needed for disaster relief or homeless shelters. Imagine an area decimated by earthquake or hurricane that needs quick, temporary housing. Pre-cut packages of paper could be delivered and assembled on site, and just as easily dismantled and recycled when more permanent solutions have been implemented.

Additionally, the process may also lend itself well to temporary installations designed for art or retail display. The easily customizable wall could be used to not only separate spaces but also to support display shelves or projection screens.

Recently the design process has become more and more complicated. The distance between the designer and the finished product has grown, resulting in uninspired buildings that do not reach the potential of their design intentions. The use of the laser cutter, however, brings the designer much closer to production. Not only do the techniques of digital fabrication allow for rapid prototyping which helps optimize the design process, but the technology also gives the architect more control of the final product.

Figure 10. *Finished wall viewed from above*

In past years the field of design has been far more advanced than production capabilities. Architects had been designing buildings and techniques that could not be realized. But as digital fabrication progresses architects must also adapt their designs to properly incorporate the potential of the available technology.

In our project for the Laser Cut Paper Wall, by accepting the limitations of the material and optimizing the strengths of the fabrication process we were able to create a simple, functional, and elegant solution to the problem.

Figure 11. *Completed wall installed in Slocum Hall lobby, Syracuse University*

Author Biographies

Tyler Hinckley received his Bachelor of Arts degree in Economics from The University of Virginia (2003) and his Master of Architecture degree from Syracuse University (2006). He is currently working at Stephen Dynia Architects in Jackson, Wyoming.

Emmanouil Vermisso was born in Greece (1977). He received his Diploma in Architecture from the University of Westminster in London (2001) and his post-professional Master of Architecture from Syracuse University (2005), where he conducted research on new design paradigms that combine digital organicist tendencies with more traditional languages such as Classicism. He is currently working at Foster and Partners in London, UK.