Toward Constructive Design

by Chen-Cheng Chen

In traditional architectural education, students employ hand drawings and hand made physical models to represent their designs. Today, thanks to the integration of a variety of digital tools and design processes, drawings made with a computer-aided design (CAD) system can be easily transformed into a physical model using computer-aided manufacturing (CAM) techniques. Consequently, students take advantage of the new CAD/CAM technology when they create their design work. This way, both the design and construction process become reciprocal during a design study. In this paper I present three examples of student projects where today's CAM technology is used to fabricate virtual designs that were first created by the students. The first example is about masonry walls, the second about the construction of a door, and the third about the construction of a small shelter using modular construction units.

The most common way to build a masonry wall when using a 3D CAD program is to draw a single cuboid with proper proportions that correspond to the dimensions of the wall and then use it as the body of the complete wall. After such a cuboid has been created, brick textures preferably with bumps can be mapped onto the wall to complete the appearance of a brick wall. While the digital masonry wall is completed at this point, the tools used hardly suffice for addressing more complex design requirements. For example, using the above method, there is no way to make a masonry wall with void spaces in-between. Needless to say that a computer virtuoso may resort to using image software, such as Photoshop, to generate an image that corresponds to the type of wall he would like to generate. This image is then transferred into the 3D CAD software and is mapped as texture onto the wall cuboid. This appears to have solved the problem, however some masonry designs may be too complicated to be able to represent as an image. What if the void spaces of the masonry wall have different spans? What if the masonry wall layers are not lying horizontally, but are at different angles? What if the bricks are not rectangular? The design specifications of a masonry wall can be even more complicated than these examples. The alternative is, of course, to not represent the wall as a single cuboid, but to build it up with many cuboids that represent the bricks the wall is made of. The first example in this paper is about such explorations of constructing brick walls.

Figures 1(a) through (d) illustrate various methods of generating brick walls with **form•Z**. All these being interesting styles of brick walls, there are also some points that need to be made. Some of the wall designs require bricks with two different shapes in order to allow the bricks to interlock together. This is required in order to achieve basic structural integrity and to make sure that the center of gravity is located in a steady position, or otherwise the wall may easily collapse. While there are additional details that may be critical to the integrity of the wall, working on a computer model that represents the real thing makes it easier for a designer to evaluate a structure. In this study, we may not be able to simulate the brick wall layer by layer, but we have to acknowledge that a computer is a more effective tool to work with than hand drawing would have been. At the same time, it allows us to create wall patterns beyond what we would be able to do with manual means.

It is possible that, in the future, parametric design techniques and even more convenient interfaces may open up additional opportunities for imaginative solutions as well as automatic examination of the structural strength of our masonry walls. Even today there are many more compositional possibilities from what we have shown here. May be even Shape Grammars can be employed for the exploration of additional patterns. It might be fun to see if there is any possibility in taking advantage of the Augmented Reality technology, which may bring our design imagination to the next level. What if the CAD systems become sensitive to gravity? Just as in real life we shall be able to feel the gravity whenever we put down the bricks and even hear the sound of bricks bumping [1],[2]. The software will inform us if the center of gravity is at the proper place, and if not we shall be able to make the necessary adjustments and develop the appropriate details.

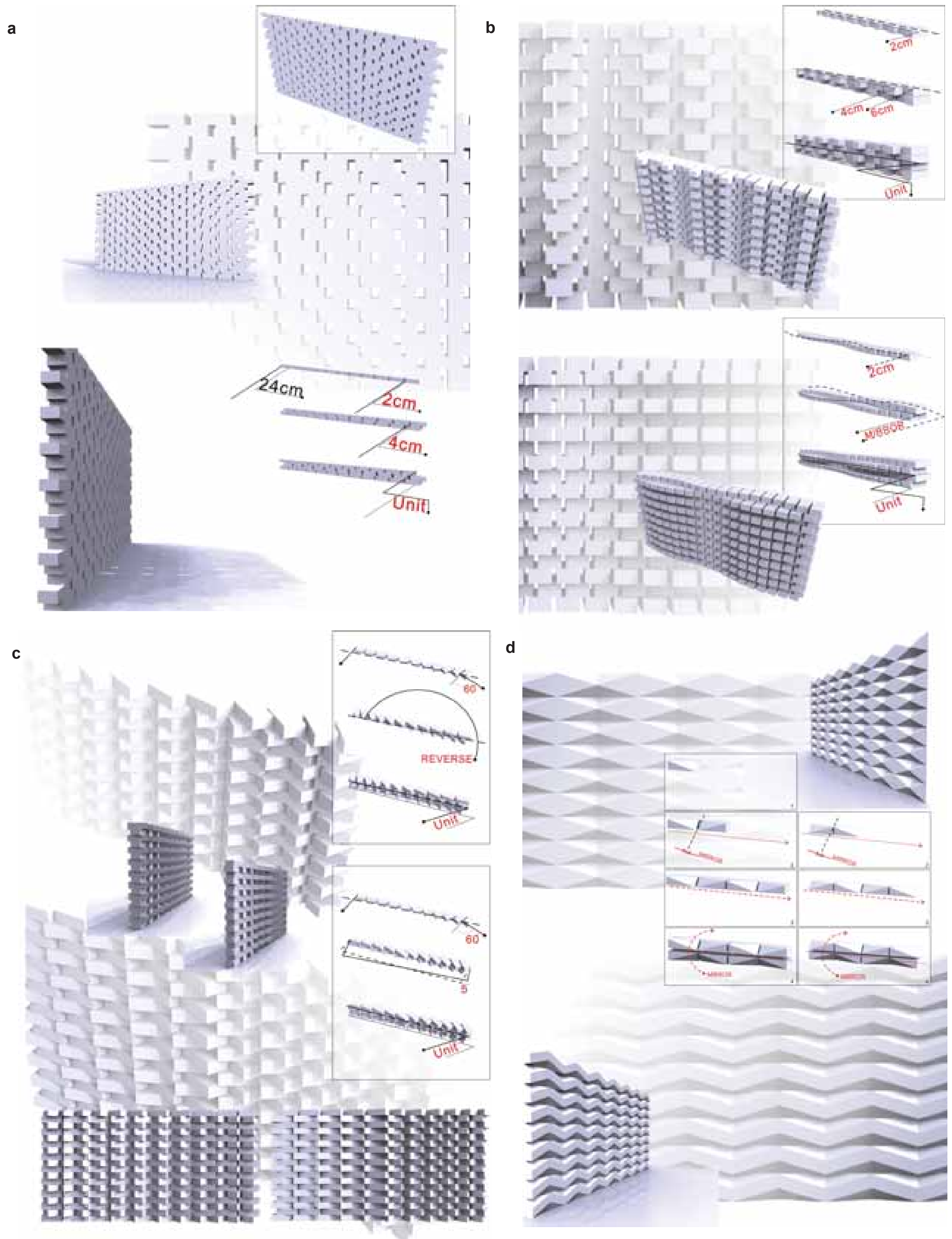

Figure 1: Studies for different masonry walls by Ching-Hang Lee.

Figure 2: The production of a door through a CAD/CAM process, by Ke-Chi Yan.

The next example deals with the design and construction of a door, which deviates from the common doors that typically consist of leaves, a knob, internal windows, and possibly some decorations. Figure 2(a) shows the creation of a different type of a door, which differs from the typical rather banal architectural door. The door shown is divided into six parts, which are (top to bottom): (1) a part that offers the function of lighting; (2) a part that allows peeping; (3) a part for deliveries; (4) a part with penetrated holes that shed light; (5) a part for ventilation; and (6) the baseboard.

At first, the design of the door was completed with a 3D modeling software (**form•Z**) and the details of the design were reviewed until the designer was satisfied that the door design worked well. Next, the details of the door were unfolded and the composite diagrams shown in Figure 2(b) were made. Next, different components were milled with a CNC (computer numerical control) miller. A full-size mock up with all its components was made from medium density fiberboards, as shown in Figure 2(c).

The complete process went through different stages, starting with a 3D digital model and ending with a CAM produced physical model. The process is fast and precise. The result is persuasive and has allowed us to be quite imaginative with the designs of doors, windows, and other types of components. This design study only required the use of a few simple tools. Most important of all is that this exercise made it possible for students to be both designers and construction workers at the same time. In addition they developed a sense that one can easily construct his/her own design.

The last example, shown in Figure 3, is based on a design idea that comes from potato chips packed inside a cylindrical package (Figure 3(a)). The idea is to take a window frame cross section (Figure 3(b)) and to cut it in slices, which then become modular prototypes with which a variety of structures can be derived. After some module and joint studies in **form•Z**, unit chips are generated by milling 3mm-thick fiberboards. Each of the unit chips are 10cm diagonally and have 8 slots on the surface (Figure 3(c)). A 100x100cm (the size is dictated by the dimensions the CNC miller can accept) fiberboard can generate 169 unit chips (Figure 3(d)) and takes an hour to mill. Using a simple design, unit chips were put together within a short time, as shown in Figure 3(e). Using more unit chips, one can construct a small space structure, as shown in Figure 3(f). By relocating the slots on each unit while retaining the shape of the units, the smaller shelter shown in Figure 3(g) can be created. One can imagine that, if the unit chips have different shapes, then additional possibilities for assembling a variety of forms exist. This is an intriguing topic, which may be appropriate for a future exploration. In addition, if one sprayed mortar on top of the shelter as an exterior finish, the lifetime of the small shelter could be prolonged significantly. Finishing methods are yet another topic for future explorations and discussions.

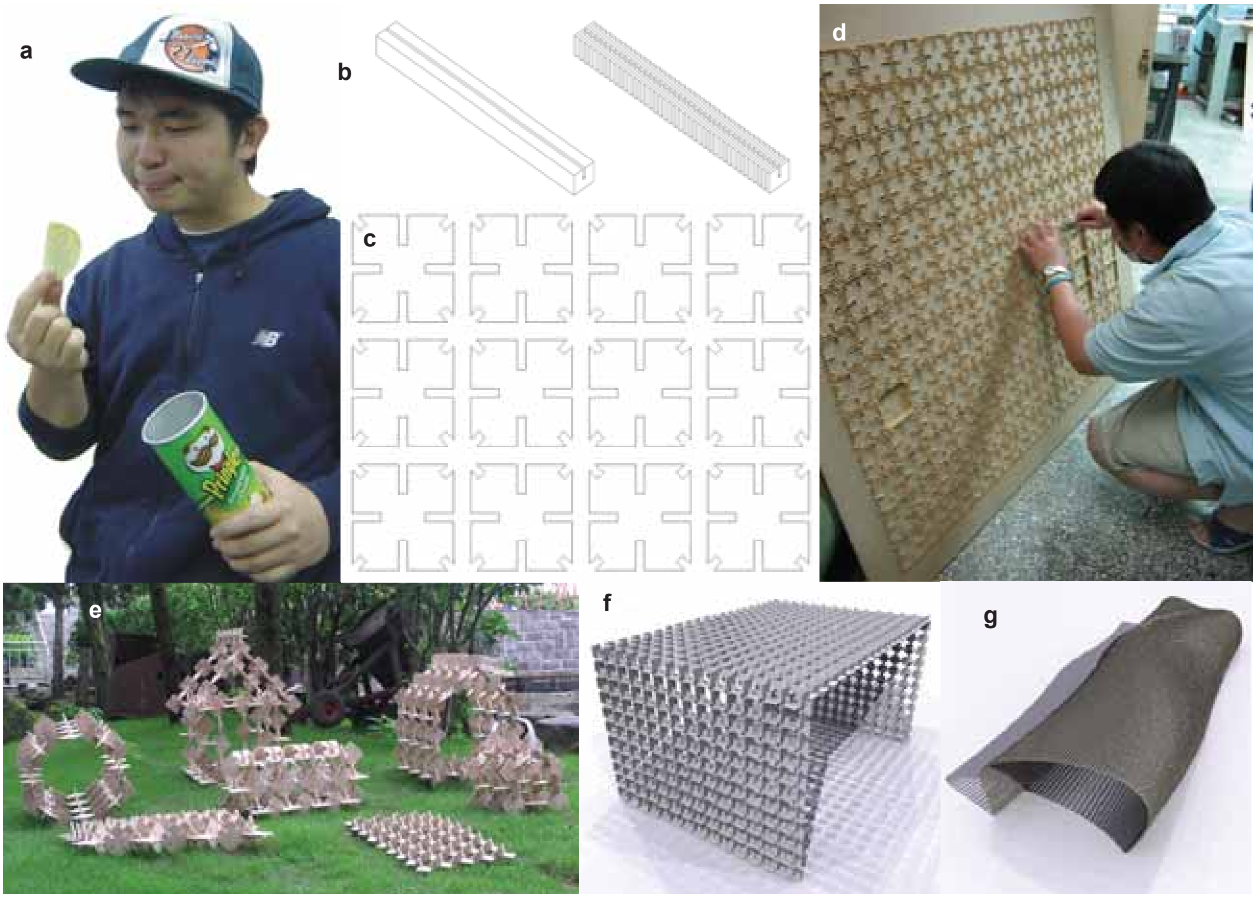

Figure 3: Fabricating unit chips and using them to construct a variety of space structures. (a) through (e) by Chia-Chi Hsieh; (f) and (g) by Ching-Hang Lee.

All the projects that have been presented here can be done easily through the use of a personal computer, a 3D modeling program, and an inexpensive CNC miller. The friendly environments created by today's CAD software benefits the students by allowing them to focus on their design creativity, as it allows them to easily make revision and to verify the validity of their candidate design solutions. Also, in spite of the missing gravity from today's computers, virtual designs can be materialized in the real world using the available CAM devices. We may also take another look at architectural components such as walls, windows, and doors, and be able to uncover more "possibilities" in component based design [3]. The assembly of such "custom design" components may generate different types of architectural designs.

References

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For a biographical summary of Chen-Cheng Chen please see page 108.