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Design build studio

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Abstract. The paper presents a design build studio that investigates the role of waste as building material and develops a proposal for an installation that uses CAAD and CAM tools in combination with traditional fabrication tools to design and build an installation out of waste materials. The paper describes the concept development and the construction process through the help of computational tools. Recycling is in the process of becoming an integral part of sustainable architecture. However, there are very few digital design projects that use re-used or recycled materials in combination with their architectural and aesthetic qualities and potentials. The potential of such an investigation is explored within a design build studio. What is junk? What is a building material? What are the aesthetics of junk?

Keywords. Education in CAAD; digital fabrication and construction; practice-based and interdisciplinary CAAD; parametric modelling.

1. Introduction

In January of 2011 the ETH Zürich introduced a student competition for the Global Alliance of Technological Universities. The participating universities included ETH Zürich of Switzerland, the Indian Institute of Technology of Bombay, India, Shanghai Jiao Tong University of China, Nanyang Technological University of Singapore, and the Georgia Institute of Technology of Atlanta, USA. The competition sought to enhance complex holistic thinking in a sustainable context through a challenge to participating schools: Build a tower using only local materials, your know-how, and your hands that is a symbol of your country, region, or university.

The idea of the competition organisers was to investigate aspects of sustainability in a collaborative design built project. Each team consisted of 8–12 students with a given budget of $1000 and a time frame of three months to complete and document the competition that included four phases: conceptual development, design, material collection, and construction. The teams were restricted to using local materials and to constructing their entries in a single week.

2. Studio approach

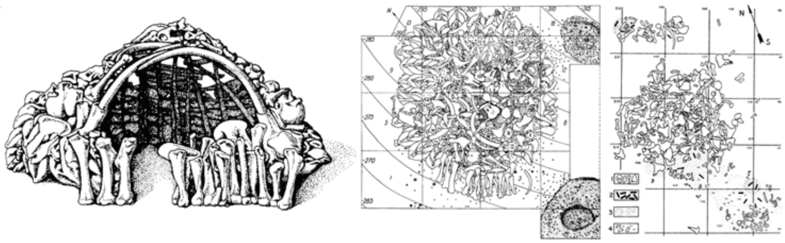

Figure 1. The mammoth bone huts of 16,000–10,000 BC are the earliest known example of reuse, Mezhirich Excavation, diagrams by Hoffecker (2002).

The presented project is the competition entry from the Georgia Institute of Technology, which was developed as part of a senior design studio. For the conceptual phase of the competition, the team's initial step was to determine an overall approach to the prompt. McDonough and Braungart (2002) explain in Cradle to Cradle that nature operates according to a system of nutrients and metabolisms, in which there is no such thing as waste; one system's waste is another systems food. Therefore, waste equals food. Humans, however, have found more and more ways to manipulate materials to increase their effectiveness in use, without considering their performance as waste. According to Braungart and McDonough these types of engineered materials have an abnormal conversion to base components and cannot safely be returned into earth's surface. Thus, in their view humans have created waste that cannot be converted to food. Sometimes these waste products are "recycled", which more accurately results in down-cycling – meaning the conversion of goods to lesser quality goods. The aim of Braungart and McDonough here is "not to reduce or delay the cradle to grave material flow but rather to create metabolisms that allow for methods of production that are true to nature and in which materials are used over and over again" (EPEA 2011).

In light of this, the students aspired to repurpose a waste product whether or not it could be "recycled". Some of the earliest precedents of repurposed materials are the mammoth bone huts built between 16,000 and 10,000 BC. The huts were 20 feet in diameter and made from interlocking mammoth bones. While bone huts were useful as dwellings, Marcel Duchamp repurposed items as art. The early 20th century artist created less than 20 “Readymades” in his lifetime, which were ordinary objects slightly modified and signed as art. This minimalist art exemplified the idea of reuse of ordinary materials at a time, when western industry was rapidly expanding. After a phase of initial investigations the team focused on two ideas linked to plastic as a material. The first idea was an amalgamation of modules of plastic clothes hangers. The second idea was a tapering cylindrical tower of plastic soda bottles, directly representing the amount of plastic waste by the university community over a given period of time. At the end of this phase it was decided to concentrate efforts on both ideas, bottles and hangers, to create a dual installation as competition entry.

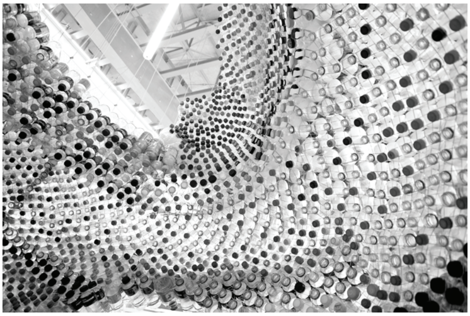

Figure 2. Bottle tower – interior view.

3. Theory and vision

Though both are made of polyethylene terephthalate (PET) soda bottles and clothes hangers have different means of consumption. On the one hand, soda bottles have become an icon of recycling and sustainability. They have increasingly become more recyclable, using lesser amounts of plastic per bottle, and they have even started using plant material to improve biodegradability of the bottles. Individual consumers use the bottles personally, and their recycling characteristics are often displayed prominently on the bottle. On the other hand, clothes hangers are used by private stores, which typically reuse the hangers. When stores receive new hangers, they amass old hangers, which are thrown out or sometimes, depending on the store, recycled. This consumption is hidden to the individual, unlike the consumption of the bottles, for which the individual is directly responsible. Given a single material with two starkly different stories of consumption, the team showcased the different physical properties of the items through two installations as a parallel to the different modes of consumption.

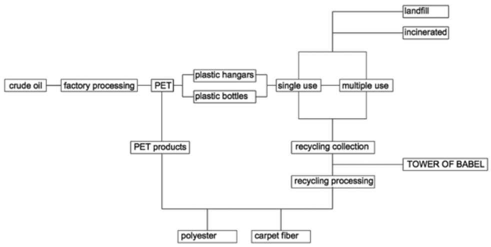

Figure 3. Diagram of PET product usage.

However, as different as the two installations are on a material level, they share a common vision of experience for a user. Each installation immersed the user amongst towers of waste generated by flawed human consumption patterns. The users were not only exposed to, but were surrounded by physical representations of their wasteful behaviour.

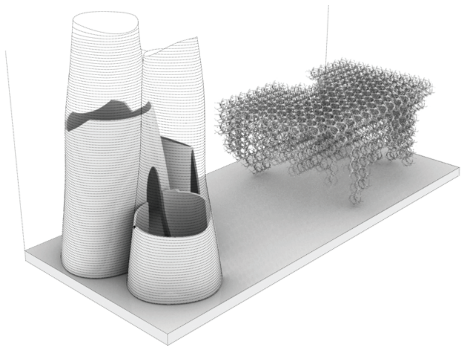

Figure 4. Tower morphologies: digital model.

4. Tower morphologies

The concept for the bottle installation was three towers composed of roughly the same amount of PET that the university community threw out, rather than recycled, in a typical week. The number is an estimate that is based on information gathered from the university's Office of Solid Waste Management and Recycling. Though it was a very rough estimate, the number of 19,000 bottles gives an idea of the enormity of waste produced by a campus in a week, which could be avoided, if individuals would dispose of them by using the existing recycling system rather than throwing them into the regular trash.

Capturing the enormity of waste in a physical form, the design of the bottle installation included three towers of different heights and widths, with the central tower being the largest at 25 feet tall and 15 feet in diameter. The tops of the towers undulated to give the appearance that the towers were not yet complete, representing the continuously amassing piles of waste in the region. The inhabitable towers worked together, forming a sequence of movement through them.

The hanger installation is conceptualised as a grid of inverted towers reaching down to various heights from a suspended surface. The 9 × 18 grid of hanger towers begins 12 feet high and the individual towers vary in length. The determined lengths and locations of the towers allow people to pass through the installation and observe the multiple densities of the plastic and prismatic affects that the hangers have on the light passing through. The fingers of towers hanging from above juxtaposed the bottles towers and immersed the observer among the clean, crystalline structure of the hangers.

The experience of waste as beautiful and pedagogically positions the project in proximity to current movements in sustainable architecture, which proclaim a hedonistic sustainability (Ingels 2010). One example is the waste management plant for Copenhagen in Denmark, which was designed by BIG. The plant incinerates waste for heat and electricity generation and provides a ski mountain with 3 different slopes with a total length of 150 m at the same time. According to Ingels the project demonstrates that "sustainability is not a burden" (Ingels 2010), that sustainability can be fun.

5. Materials/system design

5.1. BOTTLE TOWER

Greg Lynn's installation "Blob Wall" is one of the few installation that investigates recycling, digital design and fabrication at the same time. The "Blob Wall" is designed from recyclable plastic blob units, or "bricks", which are different from each other in the way that they attach to their neighbouring units. The variation lies in the intersection of two units.

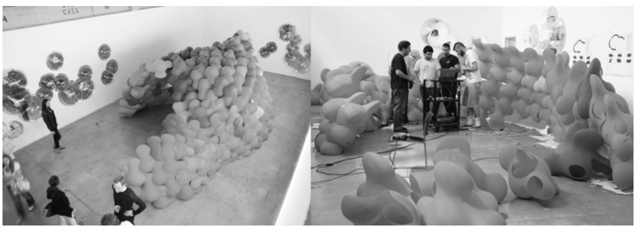

Figure 5. Greg Lynn Blob Wall 2008.

In the case of the bottle towers the variation results not from the units, but from the variation of the joints, of the in-between spaces. The system deforms through the gaps allowing for curvature in plan and tapering in elevation. But it also allows for transformation: When the diameter becomes too small, “bricks”/bottles are skipped. Also, the assembly system for the bottle towers is designed to showcase the visual material properties of the bottles without impacting their ability to be recycled after deconstruction. The bottles are arranged as circular courses of bricks laid horizontally with their caps pointed towards the centre. Each course is offset from the adjacent courses and therefore any individual bottle is supported by the two bottles below, essentially creating a running bond.

The bottles were sorted by label type and stacked in three rows of a given label; for example, three courses of Coke, followed by three courses of Diet Coke, followed by three courses of Sprite, etc. building the bottle towers as cohesive units up to 25 feet-high required proverbial mortar for the bricks of bottles. Through this pattern one could perceive some order in an otherwise chaotic aggregation of parts. The approach is similar to brick architecture of William Butterfield, also called the “Streaky Bacon Style”, or, more recently, to the Historical Museum in Ningbo from Amateur Architecture Studio, where 20 different kinds of grey and red rubble stones and bricks, all repurposed materials, are used for the building skin. The material chosen to hold the bottles together without damaging them was elastic bands. This system created a network of lines that were more visible inside the towers, where the tops of the bottles faced, than outside, where the bands were more hidden by the bottom of the bottles. The bands allowed for easy disassembly and left the bottles in the same condition they were in prior to construction. While the elastic bands were favourable for a number of reasons, one drawback was that they did not create rigid connections, so the towers would tend to buckle under their own weight. To solve this problem, a system of 3/8” thick acrylic rings was CNC-fabricated and placed every 25 courses up the tower. The rings acted as structural straps that one typically sees on a brick tower to keep it from buckling.

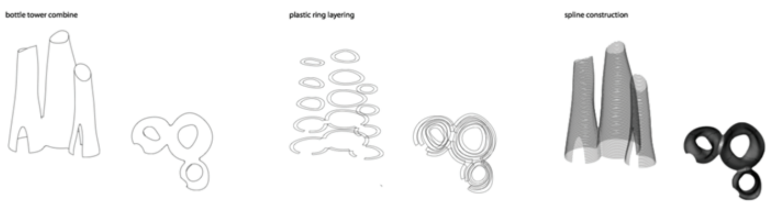

Figure 6. Fabrication matrix of CNC-cut rings.

5.2. HANGER TOWER

Four hangers formed the top "plane" of the cube, with 2 hooks reaching towards the outside and two hooks reaching towards the inside, and four hangers formed the bottom "plane".

Figure 7. Hanger structure.

Combining the modules into towers involved interlocking the hooks with the neighbouring modules on the top and bottom respectively. The suspension of these modules created the towers. Where the modules of one tower aligned with the modules of another, the outside hooks were interlocked to provide further rigidity to the installation. Although this interlocking system had inherent structural integrity, plastic zip ties were used at every joint within the modules and towers as a whole, to bolster the strength and security of the system.

7. Parts fabrication

Construction of the bottle towers began with the plastic rings, which were designed to reflect the profile of the bottles. This also allowed the rings to act as a template for sandwiching courses of bottles: each profile in a ring would have a bottle banded above and below, establishing the number and placement of bottles in each course around the ring. The rings were divided into segments and cut on a CNC router. Each segment was labelled by script with its specific tower, course number, and placement within its ring.

After the ring segments were cut, prefabrication began. Each segment acted as a template for a panel of 25 courses of bottles. However, since the towers tapered towards the top, the upper courses required fewer bottles than the lower courses. A VB script, that populates a given Nurbs geometry with bottles, calculated the number of bottles needed for each layer. Assembly began according to the banding system as described in the digital file.

Prefabrication of the hanger installation involved creating the previously described 12-hanger modules out of the 6000 hangers collected. The modules were assembled first and then each joint was zip tied for security.

8. Reception

The installation was well perceived during the exhibition and during the following symposium "I imagine, I see, I make" in two ways: firstly it was appreciated, that the installations visualise the invisible by showing the amount of waste produced and secondly during the symposium the tectonics of the two structures were positively discussed with reference to current design methodologies in digital design that explore emergent systems with variation.

Visitors during the exhibition enjoyed the spatial experience and the aesthetics of the installations and were highly surprised by the enormity of waste. Unfortunately, the circumstances of the exhibition in an interior space made the installation only accessible to exhibition visitors and limited the access for the general public. A more public display would have benefitted the intention of the installation.

The proposal received the 2nd prize in the overall judgment and was placed 1st in 3 out of 7 sub-categories (creativity, presentation and coordination). One member of the jury, V. Sorenson, recommended the team in the following way: "The use of hangers and bottles is excellent. Bringing attention to the fashion industry's waste is creative and relevant especially to young fashion conscious students and therefore a good choice for a university setting. Relating the scale to amount of campus use is good. The tower designs are highly impactful, both as beautiful, aesthetic designs that can be studied and experienced from multiple physical perspectives, but also from multiple content and conceptual approaches..." (Tower of Babylon 2010). Another juror critiqued the emphasis on aesthetics rather architectural functionality.

9. Junk as building material

The two installations did not intend to focus on the invention of an actual building material or building component from waste products. But the investigation of that process is certainly interesting to study. There are a number of different examples for the re-use of materials: the rural studio projects in Alabama, that used tires filled with earth as construction material and carpets as a façade material, the re-use of bricks by Amateur Architecture Studio for the Historical Museum in Ningbo, the use of wood waste and car screens for the shoe shop Duchi by the Dutch office 2012 architecten and other examples (Kaltenbach 2010). But to discuss these project in details would exceed the framework of this paper, therefore it seems appropriate to mention projects related to the installations: bottle houses. Early examples of bottle houses like Grandma Prisbrey's Bottle Village, a folk art piece in Simi Valley, California, use glass bottles and a binding material like cement, stucco, clay, plaster, mortar etc. to play with coloured light effects. The more recent projects use plastic bottles. There are numerous examples, where earth-filled plastic bottles have been used for the construction of passive solar houses as bricks (for example projects by Andreas Froese/Eco-Tec in Nigeria and Honduras). These projects are often situated in tropical climate zone and rural, less prosperous areas. Next to architecture in development countries we can find another example for a plastic bottle building in the EcoARK Exhibition Hall, Taiwan, by Arthur Huang, which uses the POLLI-Brick system by Miniwic. POLLI-Brick, made from recycled Polyethylene Terephthalate Polymer, is a system of interlocking, especially engineered bottles with improved thermal and sound insulation. Obviously, we are leaving the field of re-used materials with the POLLI-Brick and enter into the world of recycling products, which are highly engineered. Maybe that is necessary in order to develop a product from waste material, but it might be interesting to explore venues, in which a re-used material instead of recycled material could be modified with means of digital fabrication as a continuation of Greg Lynn's approach.

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