A Better Flip-Flop

An Honors Thesis (HONR 499)

by

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Ball State University
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April 2015

Expected Date of Graduation
May 2015
Abstract

Ocean pollution is a very real and very visible problem in our world, the result of a century reliant on plastics. One of the most visible symbols of this casual destruction of the environment is the flip-flop; cheap, nonbiodegradable, and unsustainable, they litter beaches from Manhattan to Madagascar. A Better Flip-Flop details my mission to create an entirely sustainable and biodegradable flip-flop. My design, through an iterative prototyping process, takes advantage of modern rapid prototyping techniques in an attempt to create a new functional, beautiful, and environmentally responsible flip-flop. This paper documents the research, materials, and processes I used to create a unique pair of footwear which accomplish this goal while also recording the problems I faced and lessons I learned, concluding with a discussion of the future of this project.
Acknowledgements

Thank you to Mr. Kevin Kenyon for advising me and keeping me on task throughout this project, as well as for being at least partially the inspiration for this idea. Additionally, I would like to thank Phil Breckler, Reed Thompson, and Randy Lazo for providing critical feedback on the design, as well as George Elvin for his input and experience. I'd also like to thank anyone who took the time to read my occasionally lengthy and pun-filled blog posts and offered their feedback in other ways. God bless you all.
The Problem of Ocean Pollution

For all the recent talk about sustainability and its importance to the world as a whole, we have yet to take real steps to confront even the most basic problems that have resulted from a century of excess in the West. One of the most obvious results of this carelessness is pollution. Pollution can be seen in cities, on the sides of the road, tasted it in the air. However, the most visible results and most dramatic consequences of pollution occur in the world's oceans.

The scale of the problem was first realized by the public in the late 1990s, with Captain Moore's discovery of the Great Pacific Garbage Patch, a massive collection of ocean-borne garbage collected by the Great Pacific Gyre (National Geographic). Since then, research done primarily by the NOAA has revealed that the habitual dumping of nonbiodegradable materials—most notably glass and plastic—has greatly affected marine life on a global scale. Plastics are particularly dangerous, as the way in which they float mimics many of the natural foods of ocean animals and causes disruptions in the natural food chain (National Geographic). Not only do they mimic food, but recent research suggests that when plastics break down they find their way into the skin and flesh of fish and eventually back into humans' bodies (Barclay). These plastics, as I have recorded in my materials study (Add. 1), are harmful from the beginning of their life to the end.

Flip-flops are one of these resilient plastic items routinely dumped into the ocean, either intentionally or by accident. Typically cheaply made, poorly designed, and easily broken, it is seen as no great loss if a pair is thrown away, left on the beach, or washed out to sea. In terms of sheer volume, flip-flops are likely not even one of the top ten forms of ocean pollution;
bottles, bags, and packaging are much more common. However, they are symbolic of the habitually careless and callous attitude we have towards pollution and the environment. This pair of environmentally responsible flip-flops does not just serve to replace less sustainable flip-flops; it is also a step towards making consumers more conscious of the other items they may be leaving on the beach or washing down the drain.

Precedent

While initial research revealed that no other company was making a flip-flop with quite the same purpose as mine, I realized that there certainly must be other individuals and companies who had thought to tackle the flip-flop problem from a similar perspective or who had thought to innovate in the direction of ocean sustainability. I found that though there were organizations attempting to combat the problem and recycle found flip-flops directly, and a few companies which touted their beach footwear’s biodegradability, and a whole host of designers marketing their flip-flops’ sustainability, there were very few which offered both a sustainable product and a way to responsibly dispose of it at the end of its lifecycle.

The first organization I encountered was called Ocean Sole, a flip-flop recycler and art cooperative based in Nairobi, Kenya. The cooperative’s mission is focused on confronting the issue of ocean pollution by collecting found flip-flops and creating sellable art from the debris. Their work was less useful as a precedent for my design and more useful as a benchmark for how massive the problem of flip-flop pollution truly is; Ocean Sole claims to collect and recycle nearly 400,000 flip flops every year from the beaches of Kenya alone (Ocean Sole), but even
their international organization is hardly making a dent in the sheer volume of oceangoing flip-flops.

Another successful company, Vere Sandals, builds flip-flops which are nearly 100% closed-loop. This means that nearly every piece of each pair of their basic flip-flops is made from recycled material, which in turn may be re-recycled when the flip flops break and used again to make future pairs of flip-flops (Vere). Some of my initial concepts, which used frames and cork inserts that could be reused indefinitely, were inspired by the idea of a closed-loop system. However, I felt that Vere’s method of design was still not ideal; while their flip-flops were sustainable and could be recycled, they were also made of nearly 100% plastic products and certainly not biodegradable.

_A Better Flip-Flop’s_ exclusive use of natural materials is a unique approach to the issues of sustainability and biodegradability, and one which it was difficult to locate a precedent for. Two projects I encountered later in the design process came very close to what I was attempting to accomplish. The first, Cocoze, uses a unique material, coconut fiber, to build the soles of their sandals (Leafy Green). The packed coconut fiber is then coated with natural rubber and paired with a cotton strap. Coconut fiber is, in fact, a highly sustainable, durable, cheap, and healthy resource, perhaps even better than the cork I chose to use as the primary material. Access to cork mats and a method to fabricate with the material could have made _A Better Flip-Flop_ an even stronger project.

I discovered a similar sustainable flip-flop designer among Ball State’s Architecture faculty. George Elvin has been prototyping and building a sustainable flip-flop made from an extremely simple palette of materials; industrial grade felt, natural rubber, and metal snaps.
The process can be completed by hand with nearly zero embodied energy content; that is, the amount of energy expended in harvesting, transporting, processing, and assembling the end product is minimized as much as possible. Felt and natural rubber are both extremely sustainable, and his simple design is elegant and easy to produce. Like Cocoze, Elvin's production methods result in a minimal carbon footprint. Also like Cocoze, however, his flip-flops are far from being naturally biodegradable, and the integration of rubber into the felt and coconut fibers make both difficult even to recycle.

Still, I learned valuable lessons from each of these precedents in regards to the scale of the problem I was dealing with, about flip-flop design and manufacture, and about which material combinations might work and which were best to avoid. I learned, too, what the price point for similar flip-flops might be (roughly $30-$50). I established that precisely what I am attempting to do had never been done before, at least not successfully, and I began to think of ways in which I might change that.

Materials and Process

While designing A Better Flip-Flop I learned and relearned many of the design lessons my education in architecture had already provided; however, the most valuable lessons had to do with the choice and use of materials. In an architectural project it is easy to overlook specific materials; choices regarding assembly and sustainability are only considered in the broadest sense. In a project on the scale of A Better Flip-Flop, though, materials and assembly are critical, often driving the design. Through research and hands-on experimentation I discovered qualities of these materials with an intimacy I would never have fully realized in an architectural design.
In this way, I think that it is invaluable for anyone truly interested in excellent design to work at many scales, rather than just the one which they specialize in.

After thinking through and briefly sketching out my ideas, I realized the choice of a material palette was the necessary first move in A Better Flip-Flop’s design. These materials would dictate many of the decisions I made subsequently in the process, and had to accurately represent the environmentally conscious materials I intended to use in the final product from the very first prototype. I already knew that plastic products would not be an option; inexpensive plastics were unsustainable and sustainable plastics were too expensive. Instead, I focused on naturally occurring materials and settled on wood and cork. The cork, I imagined, would provide a flexible and comfortable sole, while the wood could act as a durable frame absorbing wear and tear.

Birch and cork, as can be seen in the materials study (Add. 1), are two of the most sustainable wood products. Birch is extremely fast-growing, is common in the Midwest and could be locally sourced. Cork is grown primarily in Portugal under strict government supervision to ensure sustainable harvesting and is naturally both quick-drying and resistant to rot and mold. My initial concepts utilized these materials in a way which would highlight each of their strengths; the cork would “float” as a flexible sole inside a rigid hoop or frame of birch (Fig. 2).

It is worth noting that my choice of materials was impacted in no small way by my access to CAP’s laser cutters. These machines were an invaluable tool in speeding the prototyping and assembly process, and greatly expanded the range of design possibilities. In fact, the perforated sole which came to define this project would not have been possible
without these laser cutters. They allow designers to push the limits and to innovate in novel yet practical ways at a scale which is highly tactile. The laser cutters have proved invaluable to my own progress in architecture, and critical to the success of A Better Flip-Flop as well.

To span between the birch and the cork I chose to use repurposed/recycled denim. Jeans consume immense amounts of water and energy in their production, and with our present technology this embodied energy is not truly reclaimable by recycling. Jeans typically go out of style or are discarded before they are completely worn out, and as the racks at Goodwill will attest, the supply of used jeans far outstrips the demand. While not sustainable in manufacture, by taking advantage of denim’s durability and biodegradability this project could provide a sustainable solution for recycling a previously wasted material.

Upon establishing which materials might be best suited for this project, I began to experiment within the basic framework of frame, denim, and suspended cork insert. I decided to cut the denim into strips and weave it through the frame to suspend the cork (Fig. 3). My hope was that this move would serve to simplify the stitching involved and to avoid the complexity and potential awkward design problems of using one piece of denim.

Unfortunately, the first draft of “A Better Flip-Flop” did not resolve itself as elegantly as I had imagined, but this is a general truth in design in architecture and in general. The first idea is almost never perfect, and is quite often terrible, but all projects are about learning from the mistakes as well as the successes. The jeans strips were too bulky and simply wrapping them around the cork insert, while effective structurally, was not aesthetically pleasing (Fig. 1). After some thought, it became clear that the major weakness of the initial study was both the method of weaving of the jean strips and the manner in which they connected to the cork.
However, I felt that my initial palette of materials was still the right choice. Therefore, I decided to think specifically about how the connection between the cork and denim might work in upcoming versions.

This refined connection took form in a series of perforations running around the outside of the cork for the second prototype (Fig. 4). Additionally, the denim strips were thinned and woven in a slightly more refined pattern derived from the weave used in traditional cane chairs, sometimes called a “shaker” or “plain” weave (McInnis). Rather than wrap the denim around the cork completely as had been done previously, I chose to keep the jean strips on the sole for this iteration. In this position the denser, more durable denim acts to shield the softer, more brittle cork, which provides a quick-drying and comfortable surface for one’s feet (Fig. 5, 6).

This new process also resulted in a more aesthetically pleasing product. In my work I typically aim to avoid deeply considering aesthetics until the functional design is resolved; however, this project demanded a certain degree of aesthetic design from the beginning. After all, a perfectly sustainable, durable, and biodegradable flip-flop does nothing to solve the environmental problem at hand if no one purchases them. In fact, an aesthetically unpleasant project could even be counterproductive; it may lead people to associate green technology and products with ugliness and make future designs with similar goals less likely to succeed. Therefore, one of the chief goals of my design was to accomplish an end design which would be both functional and aesthetically pleasing.

The second version was better in nearly every way, but it still had several major flaws. The chief issue was durability, or the lack thereof. Cork is a very flexible material, but the same traits which make it flexible also make it prone to cracking, splitting, and tearing. It can resist
bending and compression well, but the configuration of the jean loops were resulting in shear stresses beyond the limits of the cork. Additionally, many of the peers who I had try the flip-flops and offer an opinion criticized the way the jeans wrapped around the bottom of the plywood frame (Fig. 7); many felt that the contact with the ground at this point would compromise the denim’s long-term durability.

To correct this problem I thought to add a very thin layer of basswood veneer, or edging, to the cork. A second addition at this stage in the design was a system of gaps to the plywood frame, meant to correspond to the perforations in the cork. I had intended to keep this design simple from the start, but together the two systems added an immense amount of complexity to A Better Flip-Flop. The time spent on crafting the prototypes of these two pieces increased exponentially compared to previous versions, raising the potential production time to nearly 7 hours. While I completed the frame and laminated veneer-cork-veneer inserts, I realized that the process had become too complicated to suit the goals of simplicity and cost-effectiveness originally cited in my statement of intent.

I also realized that I had inadvertently created a simpler system at the same time; looking at the components (Fig. 8), I saw that the edging of the cork, if strengthened in some way, could serve as the frame itself. A separate “floating” frame of the style I had designed in previous prototypes was redundant. By eliminating the frame I could eliminate one of the most wasteful materials from my project. A frameless flip-flop, while more traditional, would also reduce the weight and bulk of the shoe, making it potentially more comfortable to wear and less expensive to produce.
Finally, the punctured frame was proving itself too brittle to be practical; the holes along the horizontal axis made it susceptible to cracking, delamination, and uneven bending, and other problems (Fig. 9). The frame had outlived its usefulness. A final variation incorporated in this third version was a slight change in the thickness of the denim strips. I thought that perhaps thinner strips could be more elegant and could result in a cleaner product. However, the use of thinner strips only exacerbated the existing fraying problem.

Working from the idea of an integrated frame/cork combination, I bought additional basswood and began laser prototyping a much thinner, simpler, and lighter flip flop than any of the others I had designed. This new version (Fig. 10,11) was the first fully functional and wearable flip flop since the very first rough attempt. With a clocked time of two and a half hours from raw materials to finished product, this iteration took much less time to assemble than previous versions. The friends I asked to review it also thought well of the design, saying A Better Flip-Flop(v.4) was surprisingly comfortable to wear, if a bit thin.

At this point I believed that the flip-flop might be ready for production with only a few simple tweaks, and decided to investigate my material palette more closely. Further research confirmed my suspicion that the materials chosen were, in fact, sustainable. Cork is grown and manufactured primarily in Portugal, from the outer layers of the Cork Oak. Harvesting of cork, when done properly, does not harm the oak tree itself, which may live for 150 years. Over this time, the same tree may be harvested up to 15 times. Cork Oaks are primarily cultivated alongside other crops as part of multi-product farms, and typically are not treated with pesticides (Cork Link). Cork itself is fireproof, waterproof, naturally nontoxic, and is one of nature’s most efficient mediums for sequestering carbon.
Balsa and basswood are both very quick-growing, sustainably harvested woods as well. In fact, basswood is the quickest growing of all hardwoods. Basswood is grown across North America, and can be found in Midwestern states, including Indiana. The use of locally sourced materials would reduce the amount of embodied energy in each pair of flip-flops, an environmental plus. Like cork, basswood trees are excellent at absorbing greenhouse gases, particularly nitrogen. Its relatively short biodegrade time of one year also makes basswood an attractive option as a material.

Unfortunately, this fourth version still had serious durability issues which needed to be resolved. After a few weeks of use by myself and by friends, including a week spent soaking wet in a plastic bag, the basswood was cracking and failing in its role of protecting the perforated edge of the cork. Basswood is highly flexible, and excellent at resisting bending, and is also able to resist shear and tension in the direction of the grain. However, it still tended to crack in the places where the grain did not run parallel to the direction of force, and it did not keep the cork from cracking as well as had been hoped. I still counted the denim as a successful material, and the cork could perhaps be saved, but if *A Better Flip-Flop* is to ever be marketable I still have many changes to make.

**Production and Marketability**

Precedent has shown that in order to succeed – in order to make a tangible difference in the world – environmentally sound projects cannot just be environmentally sound, or merely affordable. They must also be attractive. Any research I have done on this project, while useful
to me personally, is useless on a larger scale unless these ideas can be implemented. For this reason, marketability and makability were key considerations throughout the design process.

I have already alluded to some of the thought I gave to production during the course of designing a better flip-flop. Ideas of simplicity of process were key, as well as cost and availability of materials. I avoided using any processes or systems which could not be replicated in a small factory or accomplished with very little technical skill or expertise. Furthermore, I took steps to ensure a sequential method of assembly which was easily scalable, from prototype design by one individual to small factories of fifteen to twenty.

I imagined that the process of design might be broken up into three phases; first, the assembly of the frame and/or sole; second, the cutting and stitching of the denim; and thirdly, the weaving of the denim and frame together. This could be potentially be expanded to six categories; cutting the wood, gluing the wood, cutting the denim, sewing the denim, weaving the denim, and finishing (defraying and final stitching). By developing a series of parts that could be fabricated independently of each other, the process could be easily passed between one, two, three, six, or twelve individuals working independently.

Simplicity, both in material choice and in number of components, was also key. Materials had to be easily obtainable and mass producible, both to drive down costs and to focus on the design of the flip-flop itself rather than the complexities of a given material. One of the great weaknesses of the current design, in fact, is its focus on the cork. The cork itself, while central to the design, has dictated most of the decisions made since the design of the first prototype. Simplicity of process also played a role in the choice of weaving style which allows a minimal number of stitches without sacrificing durability.
As a business strategy word of mouth and social media would likely be the two most successful methods of marketing whatever product results from what I have learned in making A Better Flip-Flop. I have a consistent group of people who have been following my progress and asking for updates, and I could see this initial group of people as key to spreading the word if I was to start producing the flip-flops on a demand basis. On a larger scale, a Kickstarter campaign, perhaps paired with an Etsy store, may be a good way to raise money for further testing and prototyping and to spread awareness for the project and the cause it supports.

Beyond that, there are local flip-flop retailers in Fort Wayne who might endorse or sell a product like this. While production is unlikely to launch before the end of the school year, I still consider marketing and business strategy important considerations in future designs.

Lessons Learned

I had completed personal projects of this scale before, primarily working with wood, but this project took this craft-scale format of design to a new depth. The topic, footwear, was outside of my typical pattern of design, and together with the emphasis on sustainability forced me to think of materials and assembly in a deeper way. The emphasis on materials in particular was new to me. As I noted earlier, materials in architecture are often only considered on a broad scale; I had never taken the time to truly look into the potential strengths and weakness of a material from production to assembly through end-of-life.

The unique palette of materials present in this project also required me to learn new skills. For example, I learned a variety of basic stitches, as well as methods of preventing and encouraging fabric fraying. I even learned how to start and run a blog (Add. 3) I also learned
new methods of production and, as I mentioned, thought more deeply about assembly. The hands-on prototyping I did for this project encouraged me to think differently about my architecture; I realized how much of design truly relies on assembly. The difference between my worst prototype and the best model was defined mainly by changes, not in materials or form, but in assembly. Perhaps the same holds true in architecture; good buildings are defined by form and materials, it is true, but also by how those elements are combined.

A Better Flip-Flop also afforded me the opportunity to see the real interplay between design decisions, as I juggled issues of sustainability, comfort, style, and durability. In an architectural studio, or in a single-purpose project, it is easy to claim that all of these factors are in harmony. In this design I realized how difficult that balance is to achieve; even after four major prototypes and a dozen minor variations I have still not fully resolved all of these issues. Once again I was forced to realize that in any real-world design assembly is a critical factor if one is to truly ally form and function.

Beyond A Better Flip-Flop

Moving forward, assuming that I find a way to fund future prototyping, further experimentation with materials is a must. Specifically, I believe that a water-resistant paper product or leather-type material could be a better alternative to balsawood. In my research I saw a few innovative flip-flops using woven coconut fiber mats as a sole material, which has advantages over cork. It is more flexible, less likely to crack or tear, and yet also shares many of the ecological advantages of cork.
The result of the thesis project at this point is an environmentally sound, relatively inexpensive design I would be proud to wear, but I could not in good conscience move this project forward as a business until I am absolutely certain that the product I have designed will last. I have accomplished a significant amount of research within the bounds of this thesis, but I fully intend to continue to strive to complete it fully. I think the concept still holds promise; someday soon a sustainable and biodegradable flip-flop will exist, and I hope to be its designer.

*A Better Flip-Flop* is far from finished, yet I am proud to call this work my own, and I hope I have the opportunity to tackle similarly challenging projects in the future.
Sources


Addendum 1 – Materials

Cork
- Sourced from Cork Oak, primarily grown in Portugal.
  - Cork Oak can live for 150+ years, and may be harvested about 15 times
  - Grown as parts of multi-product farms
  - Regulated for sustainable production by gov.
  - Can be efficiently grown and harvested without pesticides
- Advantages of cork itself
  - Recyclable
  - Naturally non-toxic
  - Fireproof
  - Waterproof
  - One of nature’s most efficient methods of storing carbon
- Nearly a century to biodegrade in a closed, wet system; however, it is beneficial to many ecosystems.

Balsa/Bass
- Basswood
  - Growth Rate is faster than nearly every other hardwood.
  - Resistant to/ fast regrowth after clearcutting and harvesting
  - Grows primarily in Midwest, East, Canada
  - Absorbs high amounts of nitrogen
- Balsa
  - Probably not suitable anyways – too soft
- One year to biodegrade if exposed to water/air

Denim
- Ridiculous consumption of water and energy – 2500 gallons/pair of jeans
- New processes are cutting that number down dramatically
- Cotton
  - Vastly more energy efficient than synthetic fibers
  - Uses less land and needs less human intervention than wool/silk/other natural fibers
- Not easily recyclable – thus, this project is a big help
- Biodegrades in less than two years when exposed to water

Wood Glue
- Typically not environmentally friendly.
- Less than 0.5 oz. used/pair (less with v. 3.0)
- Alternatives for whey-based sustainable/nontoxic/biodegradable glues possible
Birch Plywood

- Birch is extremely sustainable
  o Easily grown
  o Rapid growth
  o Widespread
- Plywood is not as sustainable
  o Embodied Energy
  o Typically laminated with dangerous glues and chemicals
- 1 to 3 years to biodegrade in ocean

Plastic

- Typically not biodegradable
- Typically not sustainably produced (petroleum byproduct)
- Biodegrade time between 100 and 1000 years

Sources

Decomposition times: World Ocean Review, “Pollution”,

Cork Research: Cork Link, “The Amazing Natural Properties of Cork”,


Denim Research: American Chemical Society, “Sustainable Denim Manufacturing Process...”,
https://www.acs.org/content/acs/en/pressroom/newsreleases/2012.html
Addendum 2 - Images

Fig. 1 – First prototype of flip-flop. Note crudely woven jeans, frame, and cork insert.

Fig. 2 – Initial cork-in-frame concept.
Fig. 3 – Rough weave of first prototype.

Fig. 4 – Perforated cork sole for second version.
Fig. 5 – Top side and sole of the second version.

Fig. 6 – Second prototype, bottom side. More advanced weave pattern using perforations.
Fig. 7 – Connection detail on second prototype.

Fig. 8 – Third prototype under construction; note the basswood trim pieces. This is the moment I realized I had created an integral frame.
Fig. 9 – Frame with holes for version three. Note the tape where frame has cracked.

Fig. 10 – Underside of fourth prototype.
Fig. 11 – Sole side of fourth version.

Fig. 12 – Total glue used in the fourth version.
Fig. 13 – The detail of how the denim strips wrap the integral frame of the fourth prototype.

Fig. 14 – Wearing the fourth prototype
Addendum 3 – Blog

As part of my efforts to document my progress and garner interest and support, I started a Wordpress blog. Here, you can find more details about A Better Flip-Flop as well as my other ongoing design projects. Visit it at feltonthoughts.wordpress.com or by following the QR code below.