BRIKI:
RE-BRICK YOUR DORM

Nicole Tschan
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Environmental Design Honors Project

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Nicole Tschan

University of Colorado Boulder, Environmental Design

Latin Honors Project

Elena Sabinson – Primary Advisor
Caitlin Charlet – Secondary Advisor
Case Lindberg – Honors Council Member

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SECTION 1

ABSTRACT

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Dorm rooms have always been notorious for being small, cramped and bland spaces that students have to accept as their new home away from home. What if there was a way universities could help the students easily transform this space into a well-designed oasis while also reducing landfill debris in the process? From this idea Briki was born.

Annually, a substantial 180 million tons of construction and demolition waste finds its way into landfills, alongside approximately 12,000 tons of furniture waste in the United States alone. Repurposing these highly landfilled materials presents an opportunity to extend their lifecycle and mitigate the strain on finite resources. However, challenges such as inadequate waste collection systems and a lack of defined end uses hinder effective recycling efforts.

This project proposes a fabrication process to transform construction waste materials into durable, customizable products, thereby diverting them from landfills. Leveraging discarded brick and clean wood abundant in Boulder, this initiative introduces a modular tiling system, Briki. Tailored for university dormitories, it provides personalized decoration solutions for residents who currently have limited space and personalization options. This research underscored the significance of individual expression, particularly for students transitioning to independent living. Building upon Kaya's concept of territorial expression, this study emphasized the psychological importance of personalizing living spaces, especially during critical developmental stages (2003, 401).

Through an iterative design approach, hexagonal wall-mounted tiles were developed using recycled crushed brick to reduce the amount of brick landfill waste. Integrating Y-shaped hooks and wooden shelves, this modular tile system facilitates versatile storage arrangements, empowering users to tailor their living environment to their preferences.

In conclusion, this study not only introduces a creative method for repurposing construction waste but also tackles the urgent demand for personalized living environments in university dormitories. By encouraging individual expression within limited spaces, this modular tiling system showcases how sustainable design can simultaneously improve environmental responsibility and enhance overall well-being.

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SECTION 2

CONCEPT

CONCEPT

Figure 2.1: Concept diagram of the goals

SECTION 3

INTRODUCTION

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INTRODUCTION

The BRIKI project's concept diagram outlines its ambitious triple aim to revolutionize dormitory spaces. The first goal is to transform building waste into a three-dimensional wall tile to create a modular storage system. The second goal is to create opportunities for personalization in the dorm room through the modular wall. By creating a pre-installed tile wall, this project aims to achieve a third goal, preventing furniture waste created through dormitory living, by reducing the need to buy cheap and disposable decorative furniture. This wall tile system offers a personalized solution for each student that can be adapted based on individual preferences and desires. In order to bridge the product with the CU Boulder campus aesthetic, selected tiles were produced with a red terracotta color. The tiles create a multifunctional wall where shelves and hooks can be attached and easily moved for functional storage purposes. Additionally it allows users to express their own aesthetic preferences and display objects that they feel are important to their identity.

The construction industry is a large contributor to the volume of waste that is landfilled. In 2017, the U.S. recycled 70% of all construction and demolition waste. Even though this percentage seems large, the remaining 30% that is landfilled creates 180 million tons per year in waste (Aslam 2020, 2). The western and specifically the north American society is based on a linear economic system, that starts at resource extraction and ends on products being thrown away ending in landfills. Historically our society believed resources were infinite, but we now finally have realized that this belief is incorrect. In the past buildings didn't have to account for their environmental impact on their production, their maintenance, and their demolition, but currently more regulations are being set in place to reduce the negative environmental impact.

One environmental change is the increase of carbon dioxide in our atmosphere. The IPCC has been tracking the carbon dioxide concentration in the atmosphere and found that since the year 1750 humans increased the carbon dioxide concentration by 35%. In just under 300 years this value has exceeded the natural carbon dioxide level from the past 650,000 years (Alley 2007, 2). The building industry needs to shift from a linear extraction heavy industry into a system with circular economic principles. For this reason, the author selected materials that currently are commonly landfilled to recycle them to extend the material lifetime and save new resources from being extracted for this product. Presently the four most landfilled construction waste materials from the EPA charts are: brick and clay tiles, asphalt shingles, gypsum drywall and wood (United States Environmental Protection Agency 2020, 23). After researching the potential to reuse each of these four landfilled materials, the author excluded asphalt shingles and gypsum drywall because of their potential toxicity. Therefore, bricks and untreated wood were selected as the two most viable recyclable materials for the tile product.

This project focused on building waste local to Boulder, Colorado, and considered the typical dormitory room design at the University of Colorado. In 2016 the University accepted 16,920 freshman students, most of whom were required to live in university residential housing (Sailor 2016, 2). This on-campus housing requirement still exists. Students in the Program for Environmental Design, who study architecture, product design, landscape architecture, and urban planning, reside in the Willard dormitory on main campus. Most of the dorm rooms have approximately 187 square feet of living space. Two students share each room, giving students around 90 square feet of personal space, which greatly limit the decoration possibilities. Within this space, each student has two narrow and one wide wall to decorate. In dorm rooms occupied by two people, research has found that it is often difficult to personalize physical surroundings (Kaya 2003, 400). Humans have a tendency for strong territorial behaviors, which are often expressed through personalizing features in the environment to create boundaries and a sense of control and ownership (Kaya 2003, 401). Existing dormitories often fail to provide an adaptable space (Tzuoo 1989, 1). This project aims to improve the experience of living in university housing by creating a dedicated personalizable space for CU Boulder Environmental Design freshman students.

When students want to decorate their space, they often buy furniture that is not very durable. Unfortunately, these cheap furnishings frequently end up in landfills after they move out of the dormitory. In the year 2018 across the United States, more than 12,080 US metric tons (accounting for 4.1% of created furniture) were sent to the landfill (United States Environmental Protection Agency 2020, 18). This project would reduce the need for students to purchase disposable furniture by offering a pre-installed wall decoration option that can be adapted for their specific needs and used for many years.

In the following passages the author identified recent academic literature on reuse projects addressing the recyclability of former waste materials. However, this concept of combining a personalizable wall with recycled brick and wood materials represents a new approach to circularity. Briki is a design exemplar that uses building waste materials to create a product that supports the University of Colorado Boulder student community.

Following that, the author describes the design process and research methods to demonstrate the development of the idea into a three-dimensional wall tile. This tile contains a high percentage of recycled products while it simultaneously creates an aesthetically appealing wall composition for both decorative and functional purposes.

In the results chapter, the author discusses the positive outcomes and the improvements undertaken. 3D printing helped determine the optimal hexagonal shape with a length of 9.3 inches and a height of roughly 3 inches. The experiment with the ratio in materials concluded that crushed brick to cement ratio of 0.9:1 is the most optimal mixture to reach the recycling potential and durability of the final tile product.

SECTION 4

LITERATURE REVIEW

LITERATURE REVIEW

The building industry in the United States annually produces 600 million tons of construction and demolition waste, as reported by the Environmental Protection Agency (EPA) in 2018. Of those 600 million tons 24% end up in landfills, equivalent to 143 million tons (United States Environmental Protection Agency 2020, 22). Materials ending in landfill are lost valuable resources. In addition, people often discard building waste without separating its toxic content, creating additional environmental harm. Beside the harmful influence landfills have on their surrounding neighborhoods, toxic elements in landfill have the possibility to create poor groundwater quality that poses a dangerous environmental issue for all living things in the environment (Blair 2021, 5). Because of these alarming numbers occurring in our landfills, our society and system needs to focus on reducing, reusing, and recycling (Aslam 2020, 3). This project aims to continue the lifespan of products with the goal of following circular economic principles.

Currently the four most landfilled waste materials according to the EPA charts are brick and clay tiles, asphalt shingles, gypsum drywall and wood (United States Environmental Protection Agency 2020, 23). Boulder County disposed roughly 9,000 tons of clean wood and slightly more than 1,000 tons of aggregate in the year 2019 (Boulder County, 2019, 15). Aggregate is the overarching name for material used mostly as a component of concrete and asphalt. After water, aggregate is the most used material in the world. In concrete and mortar, aggregate accounts for 70% of the volume. Across the world, most countries face sand and gravel shortages soon; the two most common aggregates used (Danielsen 2015, 41). Because of the brick material properties and durability, the author selected this material as the main material of reuse.

The second highest landfilled material is asphalt shingles with around 87% of the accumulated waste ending up in landfills. The main health concern of asphalt shingles is the potential harmful release of asbestos during the recycling process because it was used historically in the asphalt shingles (Townsend 2007, 3 - 11). While asphalt shingles are a frequent building waste byproduct of the construction industry, the toxic materials emitted during de-construction make it poorly suited for reuse, therefore they were not selected as a material for this project.

According to the Boulder County final waste composition data, untreated wood is the fourth highest construction and demolition waste material (Boulder County 2019, 10). Untreated wood has a high chance of reuse because of its natural properties. It is easy to cut, make a product and later be composted sustainably, reducing the need to landfill it. Concluding from the four original materials with a high percentage ending up in landfill, the most promising materials that have potentials for reuse are brick and clay tiles, and clean wood.

As previously mentioned, the problems with landfilling need to be addressed at their roots: the linear economic system we have set up in this country. The concept of circular economy was first mentioned in the 1960s by the environmental economist Professor Kenneth E. Boulding (Ghosh 2021, 11). The Ellen MacArthur Foundation defines circular economy as "restorative and regenerative by design and aims to keep assets, components, and materials at their highest utility and value at all times" (Heisel 2023, 167). A circular economy is a "system which maximizes the value of the materials and products that circulate within the economy" (Ghosh 2021, 11). The building industry can play a role in this circular economy by changing how it responds to used construction waste. Changing our society to a circular economic model would help to mitigate the effects of climate change, offer the possibility of preserving valuable finite resources and support green workforce development (Heisel 2023, 167). With circularity as the goal, this project adapts the principle of reducing the need for new resources and creating a product that can sustain over time (Heisel 2023, 167).

In the current linear economic system, the poor execution of demolition contributes to the overall problem. By changing the current methods, the industry could recover more materials for new builds. The Comprehensive Environmental Response Compensation and Liability Act (CERCLA) is the main legislation for construction and demolition waste. Under this legislation, contractors are responsible for managing their construction and demolition waste (Aslam 2020, 4). Having individual responsibility for each contractor (and each project) makes it difficult to create a uniform solution to reduce the large sums of construction waste.

One possible approach is to focus on designing for deconstruction (DfD), which addresses the problem from the beginning by considering the reuse and recycle of building materials after its disassembly. Specifically, DfD is a plan on how to individually separate materials for future use. Design for deconstruction follows five key principles:

1) a need for a good documentation about materials, components and methods of deconstruction;

2) design for easy dismantling of parts such as using screws and bolts for connections;

3) separation of items into recyclable, reusable and disposable items;

4) standardization of components and dimensions;

5) design that requires for appropriate labor, productivity, and safety practices (45, 993).

It has become more popular to *Reuse, Reduce and Recycle*, using building waste products as aggregate. One method that is particularly promising is the use of crushed brick as an aggregate replacement (Müller 2022, 4). Various studies have used old tiles as aggregate replacement, which reduces the need to produce, store and transport heavy aggregate that is necessary in concrete production (Bommisetty 2019, Abbas 2023). The study by Bommisetty used a water-to-cement ratio of 1:2 and the old ceramic tile aggregate replacement of 20% (2019, 875). This study proved to be the most efficient in fulfilling the required cement properties, while they used as much aggregate as possible.

"WasteBasedBricks" by StoneCycling, based in Amsterdam, is a startup using building waste to make new tiles. They utilize a ratio of 1:1:5 with Portland cement, lime and sand (StoneCycling n.d., 4). In another study by Abbas, researchers smashed clay brick waste into cement powder, and used 10% of the powder as replacement for cement, while maintaining the desired product properties (2023, 25). Other researchers are exploring the use of plastic waste instead of aggregate, a method that has been growing in popularity (Thorneycroft 2018). In a study by Thorneycroft, shredded plastic was used to replace sand that is typically used in concrete and found that the optimal concentration of sand replacement was 10% (2018, 63). In the United States a company developed the product Phasphalt to use plastic materials as aggregate in road pavement. The materials were in the millimeter range between 0 and 6 and replaced between 5-7% in the final pavement product (Müller 2022, 70).

Besides the reuse of existing waste products, the second problem this project tries to address is the existing lack of decoration and self-expression provided by the design of traditional dormitory rooms. As is common in the U.S., and at the University of Colorado Boulder, first-year students live in university-provided housing. For most young adults, this is the first experience of living outside the family home where they grew up. Navigating this new environment comes with new challenges, and dormitory space that students live in is an extension of one's personality (Kaya 2003, 400). One study found that some students prefer to set up their dorm space to mirror their room at home (Avalon 2020, 21). In the same study, the researchers found that students who did not recreate their home space did so simply out of convenience. Overall, students decorate mostly with important objects and symbols in their limited space (Avalon 2020, 27). The majority of students living in dormitories tend to decorate their space to some level, ranging from minimal to elaborate decorations.

Expanding the range of elements available for personalization in students' living spaces not only enhances their sense of ownership, but also helps to improve their academic success. Studies have underscored the significant correlation between the physical environment and students' motivation levels resulting in more success during their time at university (Meagher 2023, 2; Avalon 2020; Dazkir 2018, 252). In the research of Brown it shows that students who are able to develop a sense of belonging see higher levels of grade point averages (GPA) (2019, 270). The design of dormitory spaces plays a pivotal role in the satisfaction of first-year students with their university experience (Meagher 2023, 2). Creating a space for personal expression facilitates a smoother transition from home (Brown 2019, 270; Moore 2019, 263). Additionally having personal space is pivotal for the expression of oneself (Brunia 2009, 170). Establishing control over one's territory is crucial for differentiating personal items from those of others, contributing to a stronger sense of belonging (Kaya 2003, 401; Brunia 2009, 169). This concept aligns with the notion of a "sense of place", characterized as an experimental process influenced by both the physical setting and individual experiences (Dazkir 2018, 253). In a shared space, ownership is communicated through personal decoration and furniture arrangement (Meagher 2023, 2-3). Offering greater flexibility for decorative modifications in dorm rooms enhances students' satisfaction with their sense of place. Modular tile walls represent a valuable tool for customization, allowing students to express themselves in more than the existing decoration options and showcase meaningful personal belongings effortlessly. Being able to create a strong feeling of attachment to home has been associated with a higher feeling of well-being (Dazkir 2018, 254).

SECTION 5

METHODS

METHODS

SECTION 5

After the author selected the materials, the next part of the process was figuring out the shape of the product. The author had to figure out how the product would work three dimensionally and how it would fit into a space. Two criteria were applied for the final product: firstly to reuse materials that mostly end up in landfills, and secondly to determine a practical use for the product. Based on the criteria, the author selected a tile, a hook attachment, a shelf attachment, a survey, and renderings for the final product.

TILE MAKING

The author used two goals to find the best tile shape in order to have a continuous pattern that is still interesting enough that provides visual variation on a blank wall. Initially the author drew shapes that were triangular and circles that would be able to be connected to each other and look connected throughout the repetition of the product along a wall. After multiple sketches and iterations of shapes, the design evolved into a hexagon stretched out along the horizontal axis.

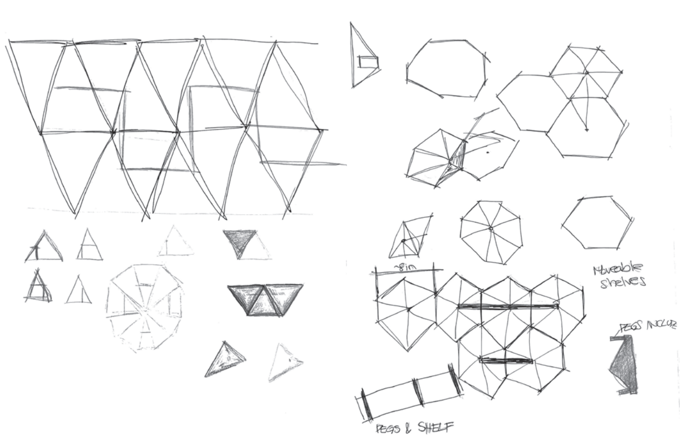

Figure 5.1.1: Process sketches of tile shape

The author made the shape three dimensionally to create more interesting visuals that also connect to one of the original ideas of a triangular form. The base of the tile is a hexagonal form that follows a pyramidal shape where all triangular sides join at one point at a height of three inches.

The shape was determined through multiple iterations of drawings and 3D printing of the entire shape. After fully determining the shape and form of the product, the author 3D printed the tile in a mold to be the shape for a silicone mold. The silicone mold was cast in which the final tiles were made. By creating a framing around the tile, the thickness of the silicone would suffice to be able to hold it all together. The print had a 15 mm thick spacing away from the tile, with a then 2 mm thick wall surrounding the tile to the top where the silicone was poured in. With roughly 28 mm of height from the tile to the top of the wall, this provided a solid base for the mold to be in.

Figure 5.1.2: 3D print before mold

Figure 5.1.3: 3D print before mold

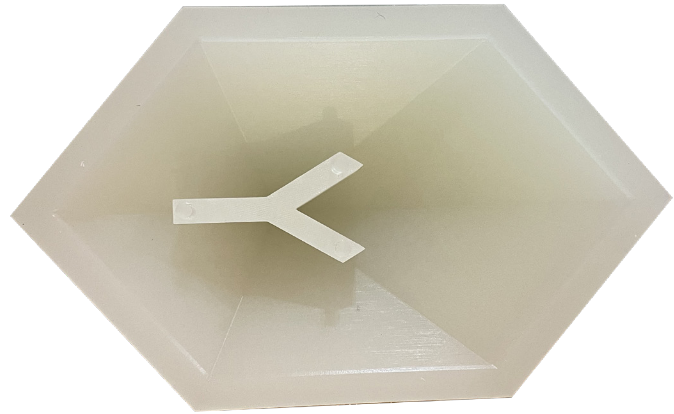

Figure 5.1.5: Empty mold top view

Casting the silicone mold involved prepping the 3D print and following the instructions to mix the silicone material. The important part was to make sure the room was well ventilated to reduce the exposure to fumes. The hardest part in the process was removing the silicone mold out of the 3D plastic print. With the help of pliers, the author was able to forcefully remove the plastic from the mold without damaging the piece so that it could be used for the prototyping stage.

Figure 5.1.4: Empty mold at an angle

Making the tile required many steps as there were three products prepared differently and mixed at various points in the process. Those three materials were the crushed pieces of brick, water and concrete, and in the cases of a red tile five tablespoons of terracotta red cement dye. With the help of a hammer, a KN95 mask, safety glasses and gloves the author smashed the brick in a bag on cardboard placed on a concrete floor in the garage. The cardboard helped to protect the concrete floor, and the bag helped to keep the small flying pieces in one place.

After breaking the tile into maximum 3 cm thick pieces, the author weighed them on a scale and put them in a large bucket where they were mixed with the remaining two materials. The dry concrete powder was scooped out of the bag in the next step, weighed and added into the bucket. Adding the water to the mixture and a bit of stirring changed the texture. With the help of a wooden stick the author was able to stir the aggregate pieces, concrete, and water together to attain the desired consistency.

The most important step in this process was the treatment of the mold before putting in the mixture. A mixture of one or two squirts of soap in water and applied to the mold walls with a silicon pastry brush reduced the concrete from binding with the mold. After applying the soapy water into the mold, the next step was to pour in the mixture.

The important part in this step was to make sure the top surface of the mixture was as flat as possible since it would be the back of the tile and would attach to the wall. The tile then sat for at least 48 hours in the silicone mold before being removed. Important in this step was to allow enough time, as it could possibly break if removed from one corner when the tile had not fully dried.


Figure 5.1.6: Back of the tile with uneven surface

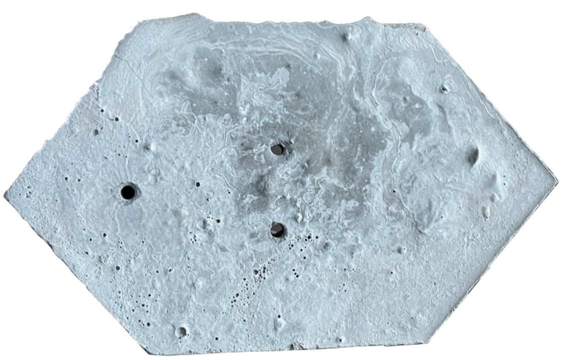
Figure 5.1.7: Back of the tile with even surface

It was important to first remove the section along the length of the tile to lift it out most evenly. When coming out of the mold, the tile still had considerable moisture and needed to sit for at least 24 more hours before being handled.

To test what material properties would be the most successful, the author did a drop test from 4 feet height onto the concrete floor for each piece to see which product material properties would hold together the best. This test was important to understand the durability of the product during the installation process. With the means accessible to the researcher, the drop test seemed the best suited to judge the product based on the possible installation problems.

Levels	Criteria
1	Pieces up to 1 cm removed, not yet impacting the function of the tile
2	Pieces up to 3 cm removed, not yet impacting the function of the tile
3	Pieces up to 5 cm removed, changing the weight distribution of the tile
4	Pieces larger than 5 cm removed, impacting the function of the tile
5	Tile falls into multiple similar size pieces, making the tile no longer functional

Table 5.1.1: Table of drop test criteria

Screws with a length of 1 ¼ inch provided the best support to hold up the tiles on the mock wall. The mock wall included a square 11 ¾ inch sheet of plywood onto which the tiles were screwed into. The ten tiles on the sheet of plywood were mortared for additional support.

ATTACHMENT PIECES

The second step in the process was making the shape and deciding the placement of the attachment pieces in the tile. Making the attachment was a simple process of creating a shape that could follow the outline of the three dimensionality of the tile along the six sides of the hexagons and where the height of the pyramid was located. As the hook attachment was aimed to be placed at the highest point of the shape, the Y shape seemed to be the best suited to hold well enough in the form while following the design of the tile. In total the author printed six different times until creating the perfect hook. In the first 3D printing phase, the author printed three different positions of the tip of the pyramid and changed the Y shaped placement according to the pyramidal shape.

The final shape of the hook piece was 3D printed with a tolerance of 0.5 millimeters of the tile along all sides for the optimal movement of inserting and removing the hook in the tile. Two pieces of hooks were printed: the first piece was a tapered Y piece with a hook, the second was an extended Y piece on where the shelf was finally placed. Each final piece was 3D printed out of wood PLA, a more sustainable solution than plastic.

The third component of the modular wall set, the shelf, was cut from reclaimed wood bought at the Resource Central in Boulder. It was placed on top of the extended Y piece. The dimensions of the shelf were 13 1/2 inches by 4 3/4 inches deep as they fit perfectly into the tile system.

SURVEY

The author sent a survey with fourteen questions to ENVD students who are current or former Willard dorm residents to determine their needs and design preferences. The fourteen questions were separated into three groupings: their personal demographics, users' needs and wants, and placement and color of the wall tiles. The demographic information helped in understanding the type and characteristics of those who answered the questions. The second part of the survey was stated generally to have the most diverse and honest answers from the students. This part included eight questions involving how students envisioned their room to be decorated and what type of objects they displayed in their room. This section helped to get a sense of the display needs and wants of the students.

The last part involved the opinion of students regarding placement of the modular tile wall and the color they would prefer the tiles to be. This involved three questions regarding: the placement in the room, the configuration of the tiles, and the final color of tiles. In the appendix the exact questions asked are written out for reference.

RENDERINGS

Renderings made it possible to represent the authors ideas of the direct application. Additionally, they helped to represent the possible executions in the survey questions. They were applied during design decisions, the survey creation and the final presentation preparation. The author used renderings as part of the iterative process to experiment with possible solutions for the tile wall composition and overall shape.

SECTION 6

RESULTS

SECTION 6

RESULTS

TILE MAKING

The tile prototyping was the most time intensive process and brought the most learning. Each step included the making of the tile as described in the previous chapter, the final weighing of the tile and a drop test to determine the stability and strength of each tile. The drop test was taken from four feet high onto a concrete floor. The drop test rating was on a scale of 1-5 with 1 being the best and having minimal breakage to 5 eliminating the function of the tile. Every tile process included the table of the data taken during the mixing of the products, observations, and the results of the tile drop test. The observations were sorted by the date they were created.

12.18.2023		
Crushed brick	1.047 lb	25.97%
Water	2.264 lb	56.15%
Concrete	0.721 lb	17.88%
Total	4.032 lb	
Total after mold	1.861 lb	48 days
Breaking scale	5	

Table 6.1.1: First tile information

This first tile had the highest water percentage of all the prototypes and had the lowest aggregate ratio for the prototyping process. The tile produced held together very well, but the backside of the tile was uneven because aggregate rose to the top of the mold. During this tile production the author had difficulty removing the piece from the mold, and had to break and glue it together again. The drop test was made 48 days after removing it from the mold and resulted in the tile breaking at the weak spots where it had previously broken during removal from the mold. On the breaking scale the tile received a 5.

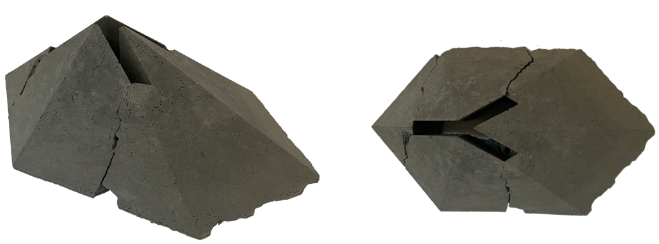

Figure 6.1.1: First tile (left) 3D view, (right) top view

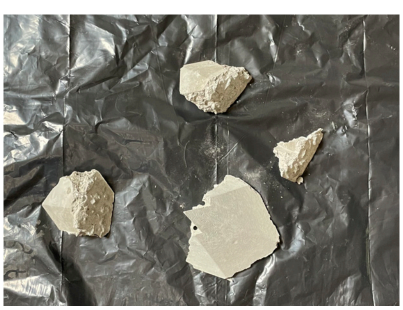

Figure 6.1.2: First tile drop test

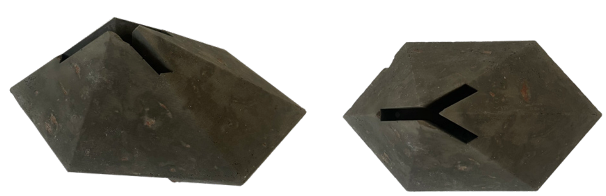

Figure 6.1.3: Second tile (left) 3D view, (right) top view

Figure 6.1.4: Second tile drop test

1.13.2024		
Crushed brick	1.687 lb	52.54%
Water	0.922 lb	28.71%
Concrete	0.602 lb	18.75%
Total	3.211 lb	
Total after mold	2.357 lb	22 days
Breaking scale	2	

Table 6.1.2: Second tile information

The second tile had a very watery consistency while making it. The cement looked very dark but lightened during the drying process. The backside of the tile was chipping off because of the amount of water at the surface in the mold. Because of the chipping, the aggregate protruded from the backside and was therefore very uneven. The drop test was after 22 days of drying and resulted in only a corner chipping off. This most likely could be because of the angle it landed at.

Figure 6.1.5: Third tile (left) 3D view, (right) top view

Figure 6.1.6: Third tile drop test

1.17.2024		
Crushed brick	1.451 lb	46.21%
Water	0.532 lb	16.94%
Concrete	1.157 lb	36.85%
Total	3.140 lb	
Total after mold	2.509 lb	18 days
Breaking scale	2	

Table 6.1.3: Third tile information

The third tile (Figure 6.1.7) had a very chunky consistency since the water percentage was the lowest compared to the rest of the produced tiles. The tile was less stable and looked more unique as it did not follow the shape of the mold. Because of its shape, the hook would not hold well in the form, as it would not be enclosed very well. The drop test occurred after 18 days of taking it out of the mold. Because of its bulky shape the tile broke off at the larger pieces on the edge. On the drop test the tile reached level 3 on the drop test scale.

Figure 6.1.7: Fourth tile (left) 3D view, (right) top view

Figure 6.1.8: Fourth tile drop test

1.23.2024		
Crushed brick	1.561 lb	43.95%
Water	0.838 lb	23.59%
Concrete	1.153 lb	32.46%
Total	3.552 lb	
Total after mold	2.646 lb	12 days
Breaking scale	5	

Table 6.1.4: Fourth tile information

The final gray tile of this sort had a good consistency and an interesting variegated mottled surface texture. This version of tile making was the first one to approach the final combination of crushed brick, water and concrete. The tile surface and strength were satisfactory and the process of making the tile created a better consistency than the previous ones. The drop test took place after 12 days of drying and resulted in the tile breaking into two large pieces and therefore received a level 5 on the drop test scale.

Figure 6.1.9: Fifth tile (left) 3D view, (right) top view

Figure 6.1.10: Fifth tile drop test

1.25.2024		
Crushed brick	1.236 lb	58.21%
Water	1.010 lb	26.30%
Concrete	0.595 lb	15.49%
Total	3.841 lb	
Total after mold	2.903 lb	10 days
Breaking scale	2	

Table 6.1.5: Fifth tile information

The first terracotta red tile, based on the CU Boulder campus aesthetic, included the highest percentage of crushed brick. To ensure a flat back for easier mounting, the tile was made in two layers. The bottom 95% of the tile was composed of the crushed brick, concrete, and water. The second layer was composed of just concrete and water to prevent crushed brick from making the back of the tile uneven. Unfortunately this method didn't lead to the desired result, and it wasn't continued. Five tablespoons of concrete red coloring were used to give the tile the red color. The drop test results were good as only the edge pieces of the tile broke off and it received a 2 on the drop test scale. Because the removal process was at an angle instead of a straight angle the top of the tile chipped off during the separation of the tile and the mold.

Figure 6.1.11: Sixth tile (left) 3D view, (right) top view

Figure 6.1.12: Sixth tile drop test

1.27.2024		
Crushed brick	1.243 lb	36.22%
Water	0.933 lb	27.19%
Concrete	1.256 lb	36.60%
Total	3.432 lb	
Total after mold	2.573 lb	29 days
Breaking scale	5	

Table 6.1.6: Sixth tile information

This tile was the second red tile made. The ratio between crushed brick, water and concrete was very successful. The tile had a uniform distribution between the materials, having the brick evenly distributed in the tile. This became the prototype for the rest of the shapes because of the maximized volume of crushed brick and the consistency of the mixture before pouring into the mold. The drop test result was not satisfactory and reached a 5 on the breaking scale. Nevertheless, the other criteria of maximized crushed brick content, even distribution of materials and smooth surface texture were fulfilled.

The rest of the tiles used in the final wall mockup were based on the ratios from the last tile. Four tiles were made with 5 tablespoons of concrete coloring and five were made without coloring to have a gray concrete tile. The complete wall assembly contained 9 tiles screwed into the plywood and supported by the mortar around it.

ATTACHMENT PIECES

Figure 6.1.13: Mockup wall at an angle

Three attachment pieces, hooks and shelves, were crafted for the final mockup wall, based on a series of seven distinct hook attachments that were influential in the iterative design process to determine the optimal attachment piece. Among the critical phases, the tapering of the attachment emerged as a crucial step, influencing the outcome.

The initial prototype, while robust, suffered from a blocky design that overshadowed the aesthetic between the tile and hook shape. The following iterations showed improvements. The second prototype featured tapered edges. However, the hook detracted from the overall cohesion of the existing shapes.

Figure 6.2.1: Seventh and final prototype attachment piece with "Swoop" hook

Figure 6.2.2: Eighth and final prototype attachment piece for the shelf

Inspiration drawn from hook designs from existing design precedents influenced the direction of the third iteration. Although the introduction of a rounded top added a contemporary element, it distracted from the existing hexagonal and Y shape. Similarly, the fourth iteration, with its sleek crossed design, offered versatility in orientation but introduced additional complexities to the assembly as it added a new shape to the constellation.

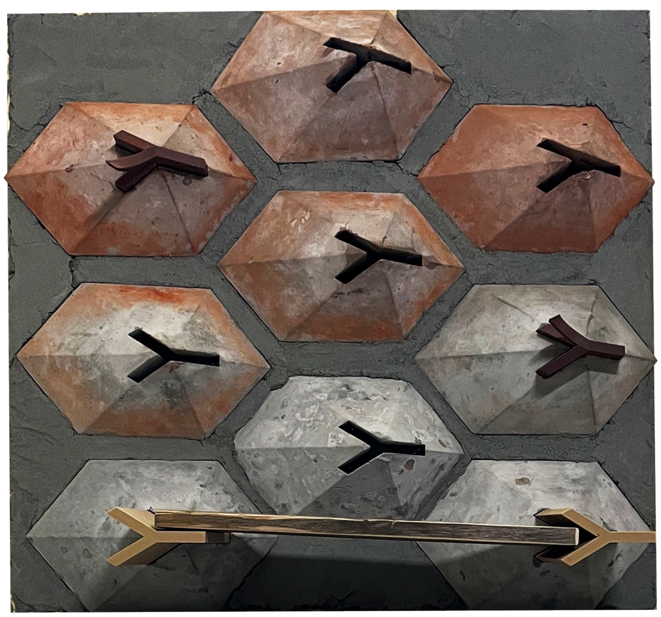

Figure 6.1.14: Mockup wall front view

Figure 6.1.15: Mockup wall top view

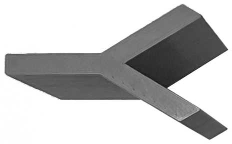

Figure 6.2.3: First prototype attachment piece

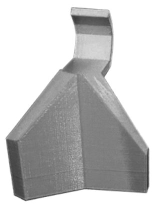

Figure 6.2.4: Second prototype attachment piece

During the fifth iteration, significant findings were uncovered by accident, suggesting the possibility of assembling different hook pieces within the tapered component. Amidst the iterations, the "Swoop" hook stood out as a triumph, seamlessly integrating with the attachment piece. From certain angles, it even assumed the role of decorative embellishment, further enriching the wall ensemble. While the wood PLA piece demonstrated promise in shape, the tolerance compromised its viability for the first wood print.

Figure 6.2.5: Third prototype attachment piece

Figure 6.2.6: Fourth prototype attachment piece

In summary, the iterative journey through multiple prototypes and hook attachments was instrumental in refining both form and function. Each stage of experimentation contributed valuable lessons, and paved the way for a more refined and cohesive final product.

Figure 6.2.7: Fifth prototype attachment piece

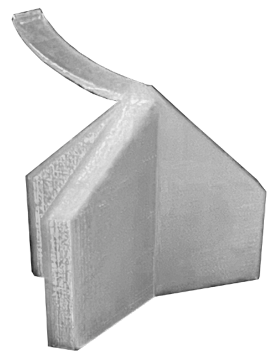

Figure 6.2.8: Sixth prototype attachment piece

The shelf was repurposed from a reclaimed fence and resized to sit perfectly on the attachment. It was cut to fit snugly between two tiles horizontally. The 3D printed "Y" attachment extends the shelf's length and ideally was one inches thicker to seamlessly blend with the tile piece.

SURVEY

This survey gathered responses from 55 Environmental Design students: 25 fourth-year students, 9 third-year students, 10 second-year students, and 11 first-year students. As seen in Figure 6.3.2 most respondents were Woman. And in Figure 6.3.3 the majority of students identifies as White or Caucasian.

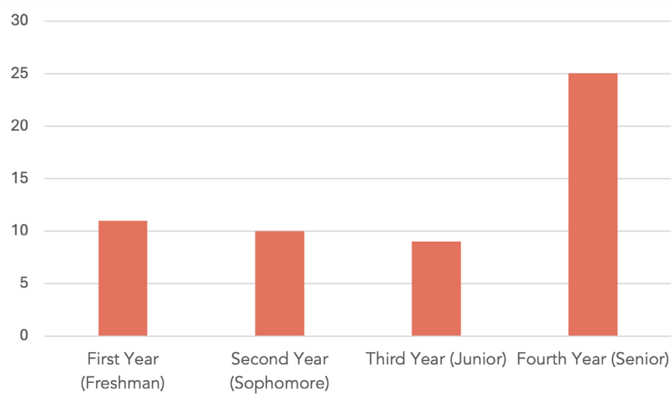

Figure 6.3.1: What year in Environmental Design are you?

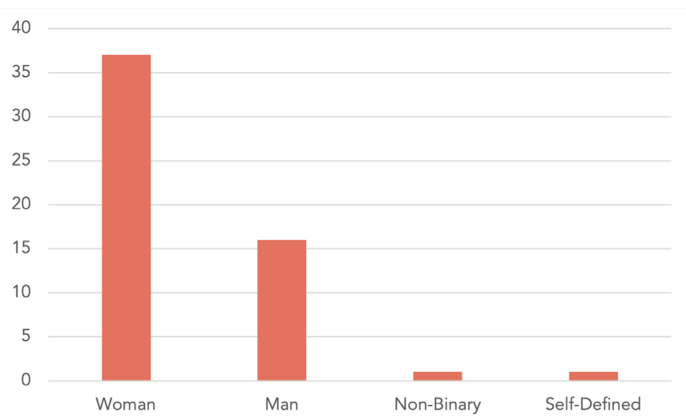

Figure 6.3.2: What is your gender?

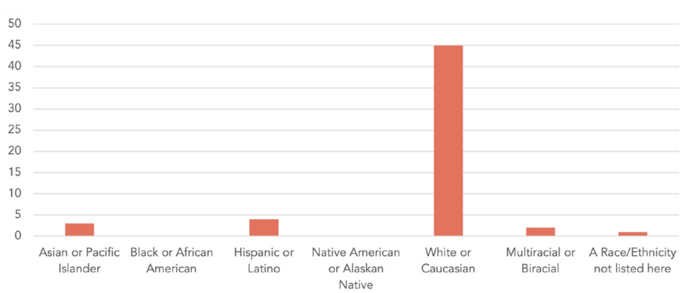

Figure 6.3.3: Which of the following best describes you?

The fourth question inquired about students' pre-move-in decoration visions. Among the responses, 23 responses envisioned posters hanging on their walls, while 20 imagined hanging pictures. Adding lighting received 7 votes, and adding plants to the dorm room received 6 votes. These 4 were the most popular choices for creating room ambiance.

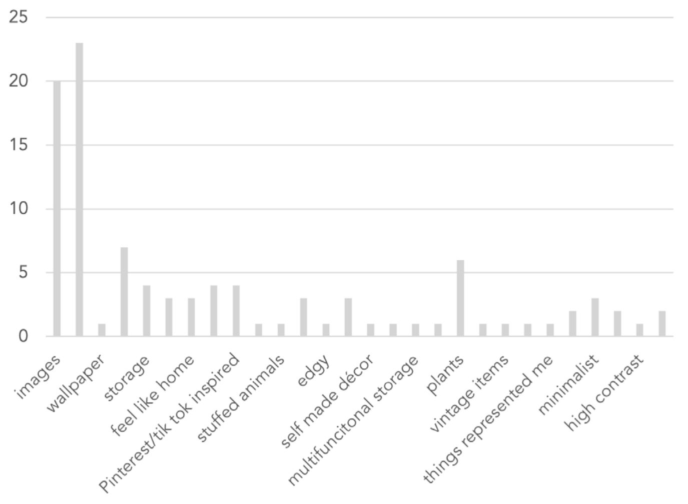

Figure 6.3.4: Before you moved into your dorm room, how did you envision you would decorate your dorm room?

The survey also shed light on the most commonly displayed items in dorm rooms after moving in. Pictures ranked highest with 51 votes, followed closely by posters with 48 votes. Plants were the third most popular choice with 30 votes, followed by souvenirs with 27 votes and LED lights with 26 votes. Notably, 20 students brought more than 10 items to display in their dorm rooms. Additionally, almost half of the respondents (47%) changed their room arrangement again during a semester, and 42 students felt their room reflected their personality.

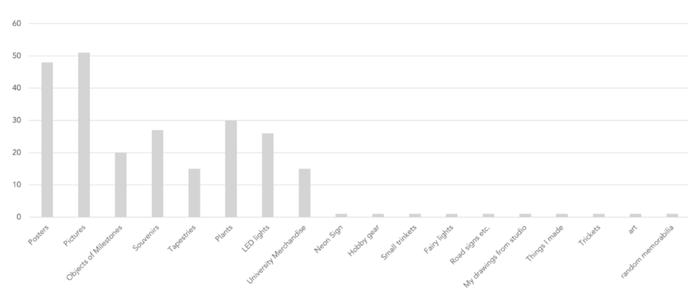

Figure 6.3.5: What types of objects did you display in your room? (Check all options that apply)

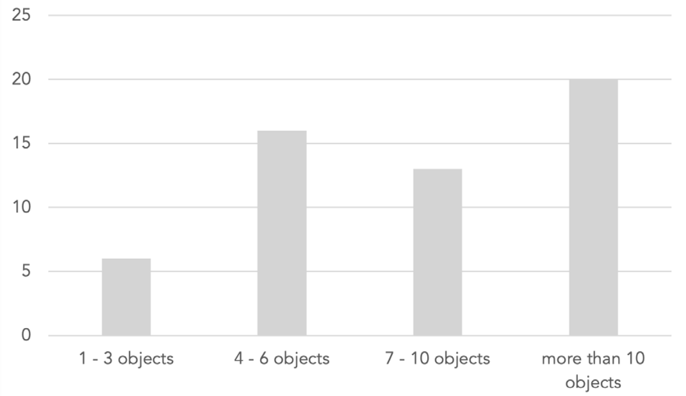

Figure 6.3.6: How many objects did you bring to display in your room? (ex. key chains, medals, picture frames, etc.)

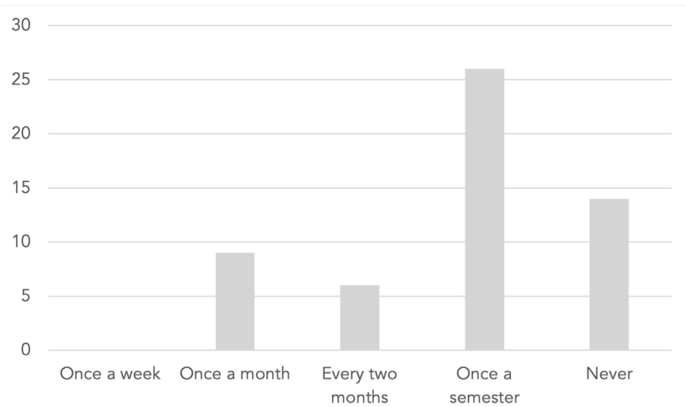

Figure 6.3.7: How often did you change the arrangement of your decorations in your dorm throughout the time you lived there?

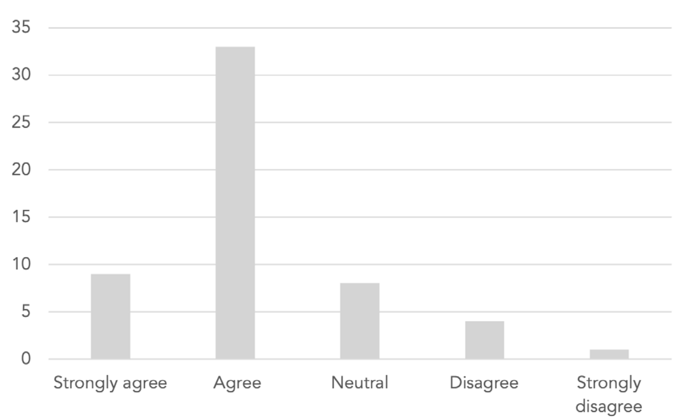

Figure 6.3.8: I felt like my room represented my personality.

Opinions were divided on the university's provision of decoration opportunities, with 47% feeling they weren't provided with enough opportunities to decorate and 53% students feeling they received enough. Responses to what students wished could change in their rooms were varied, but a common desire, expressed by 16 students, was for increased decor space.

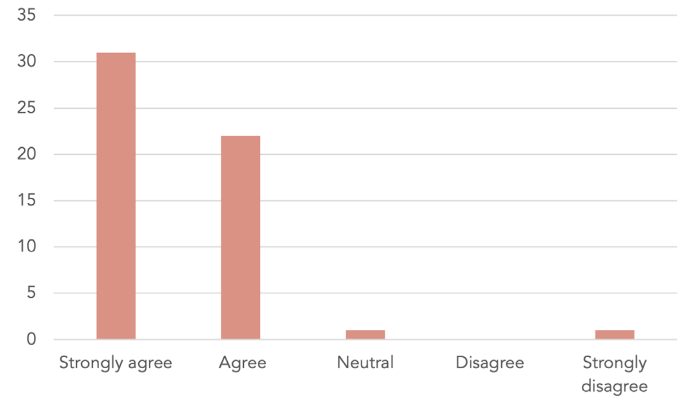

Figure 6.3.9: Having control over the design affects my satisfaction with my dorm room.

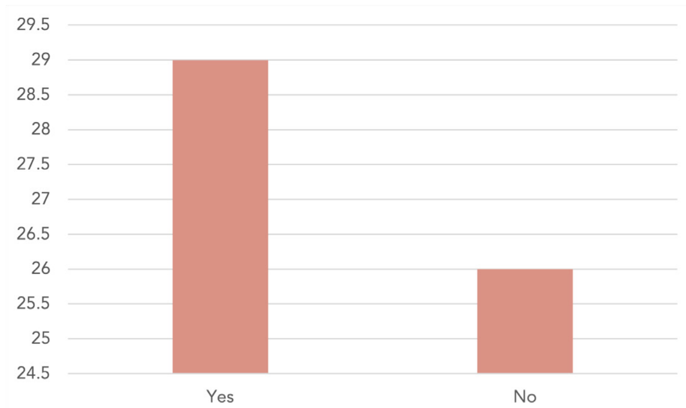

Figure 6.3.10: Were you satisfied with the opportunities the university gave you for the decorating your room?

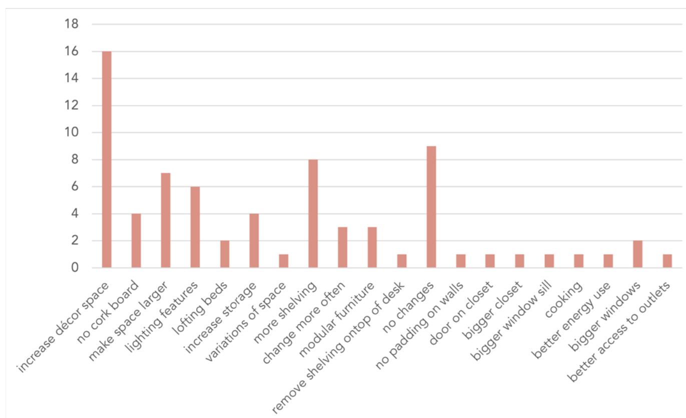

Figure 6.3.11: Thinking about the previous question, what would you have changed about the design of your dorm room?

Regarding the placement and design of a tile wall, preferences were nearly evenly split. Placing tile wall along the bed in the center of the room wall received the most votes, closely followed by placement beside windows and above beds. Arranging the tiles in an organic shape instead of rectangular was preferable, reflected in 69% more votes for organic formation. Gray tiles were favored over red, with one student noting a preference for a neutral color palette to allow their items to take center stage in the space.

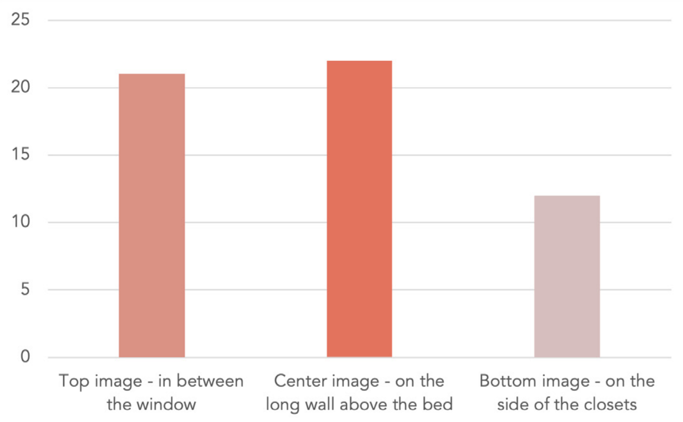

Figure 6.3.12: Please rank the tile arrangements in order of your preference from most preferred (1) to least preferred (3).

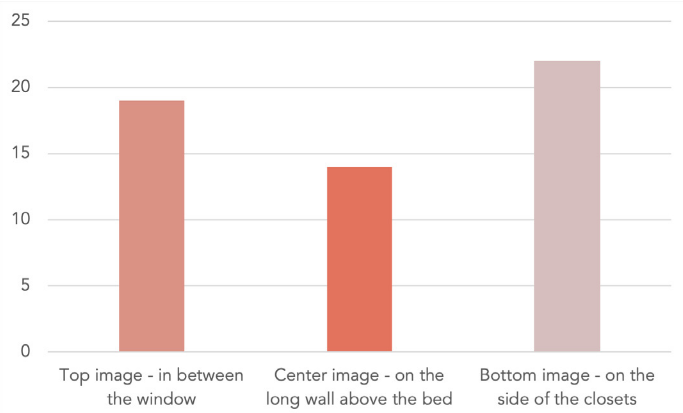

Figure 6.3.13: Please rank the tile arrangements in order of your preference from most preferred (1) to least preferred (3).

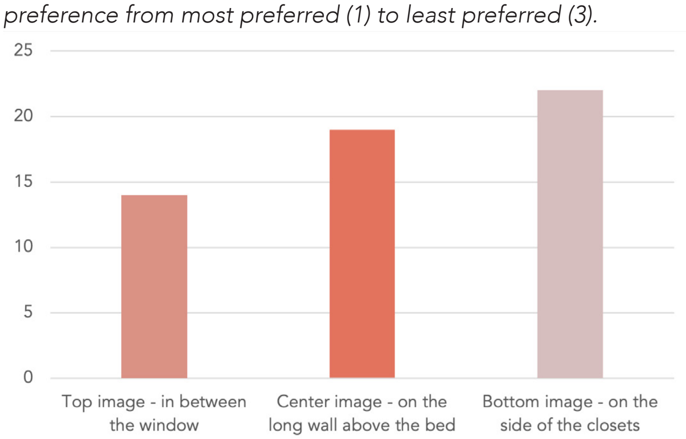

Figure 6.3.14: Please rank the tile arrangements in order of your preference from most preferred (1) to least preferred (3).

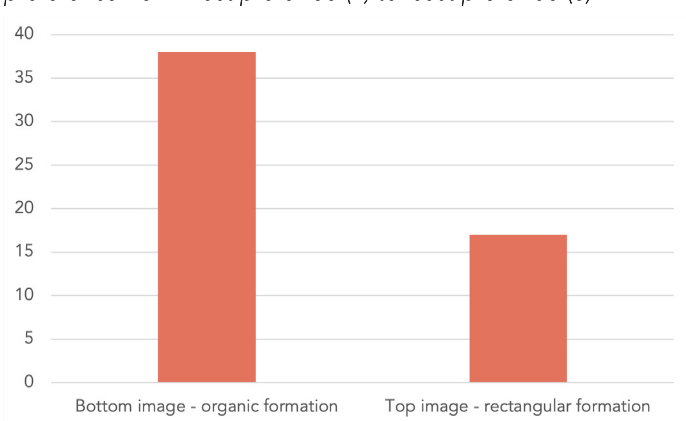

Figure 6.3.15: Which of the two arrangement do you prefer?

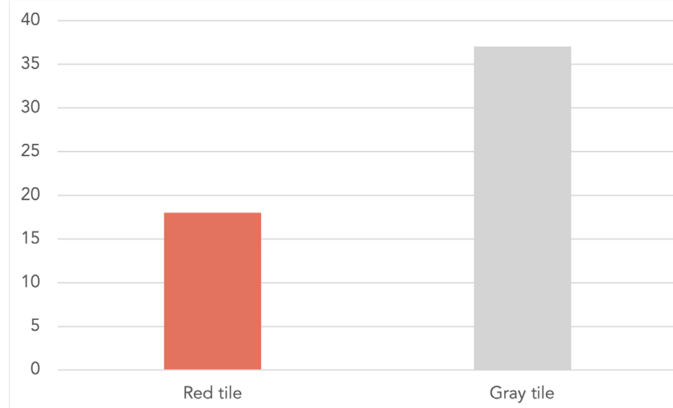

Figure 6.3.16: Which color do you prefer?

RENDERINGS

The axonometric drawing shows the complete wall composition with all the elements. The tiles were attached to the wall, Y attachment pieces slid into the tiles from where they were either a hook or a shelf.

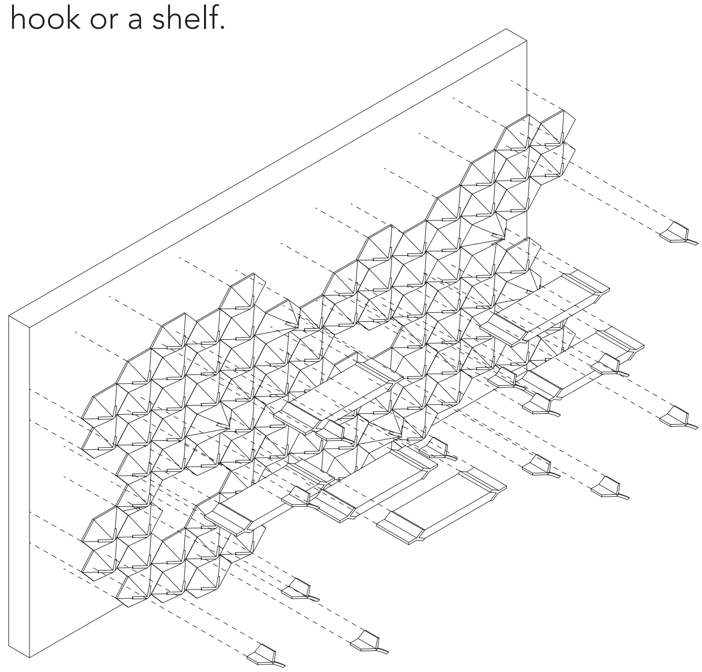

Figure 6.4.1: Axonometric wall assembly

Following are the final renderings to show a possible application of the modular tile wall in the dorm room. Based on the survey responses the organic formation was selected. Regarding the placement, these renderings show the first choice based on the survey responses: above the bed along on the long side of the wall. Both sides of the room received a modular tile wall, but with different tile colors to represent both options that were explored in this research project.

Figure 6.4.2: Rendering full dorm room

Figure 6.4.3: Rendering gray tiles

Figure 6.4.4: Rendering red tiles

SECTION 7

DISCUSSION

DISCUSSION

TILE MAKING

It took six attempts to determine the optimal material ratio, ultimately applying the ratio of the sixth tile to the ones made for the final mockup wall. However, the sixth tile scored a disappointing 5 on the breakage scale, which was created to gauge material strength during installation in case of accidental drops. This discrepancy raised doubts about the sixth tile's suitability for production, especially since half of the tiles received the poorest level in destructive drop testing. Nevertheless, if a tile would have fallen apart, it could have followed the product's intent of reuse and would have become aggregate for a new tile. Despite having the sixth tile break, key indicators such as the tile's flat back, final weight, and brick aggregate content were still valuable for final production.

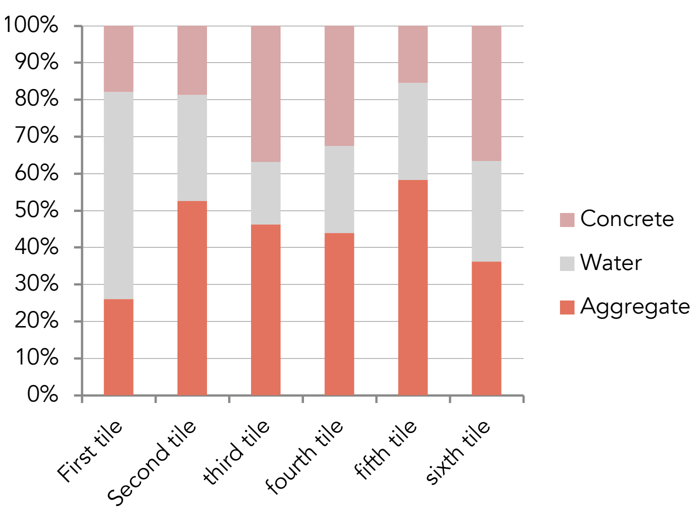

Figure 7.1.1: Ratio of materials

The initial tile strongly adhered to the mold, yet the author was reluctant to rip out the tile for fear of breaking the mold. Therefore the author took a hammer and broke the tile to remove it from the mold, then glued it together again. The drop test highlighted the weaknesses within the material, as the tile broke along the previous breakage lines. After comparing the six tiles with their different compositions, distinct traits emerged. The first tile exhibited the lowest aggregate and highest water consistency. In contrast, the second tile had a relatively high aggregate percentage but lacked concrete consistency. The third tile suffered from an imbalance, caused by too much concrete and insufficient water, which led to the formation of a chunky tile.

The fourth tile reached a balance with nearly 50 percent aggregate content and improved the overall cohesion and structural integrity. However, the fifth tile encountered challenges despite boasting the highest aggregate consistency. Issues arose as the mold was filled, leading to an uneven back surface of the tile and brick pieces lapping over. Notably, the most successful outcome was achieved with a balanced ratio of concrete and aggregate. This approach not only enhanced cohesion but also minimized water content, resulting in robust tile construction. This ratio was used later in all tiles of the mock-up wall.

This method proved effective in accommodating an increased amount of brick pieces, while having an easier production process. The optimized combination of materials and proportions ultimately ensured that the tiles were both structurally sound and visually appealing, marking a significant advancement in the production process.

The flat back of the tile served a practical purpose, as it facilitated easy installation by allowing straightforward screwing into the wall. In the experimentation phase, the flatness of the back wasn't considered and therefore there were multiple tiles with uneven backs. However, an issue arose during the manufacturing process, as the edges chipped away when the tile was removed from the mold. To address this, the back was made thicker by overflowing the mold to make the tile more durable. This solution introduced another challenge: the screw holes didn't puncture through the thicker back. The author then used a screw to break through the thin layer of concrete above the holes. For the newly produced tiles, a strategy was implemented to prevent this issue by allowing overflow of the mold and adding straws over the extension of holes, ensuring continuous, unobstructed holes for seamless installation.

Figure 7.1.2: Mold with straw supports

During tile testing, the lack of a weight-bearing mechanism within the accessible equipment from ENVD was notable, which deviated from the conventional method prevalent in other studies (Ansari 2023, 15; Bommisetty 2019, 876) that primarily concentrated on compression or strength testing. Besides product testing, if there would have been more time for additional product research, the author would have experimented with various binding materials to find a more sustainable binder than concrete that would align more with the project goal of reusing materiality. These limitations represented the challenges encountered by the author during the research process, which impacted the methodology and outcomes of the tile testing experiments.

ATTACHMENT PIECES

The design considerations for the hook piece were influenced by the existing shapes within the ensemble, the hexagonal tile and the "Y" shaped attachment. It was essential that the hook piece didn't overpower the overall aesthetic. To achieve this, the extension of the hook's arm was crafted with a more neutral shape. From a direct angle, the attachment remained discreet, seamlessly blending into the overall form, and ensured that it didn't dominate the ensemble but rather integrated harmoniously with it.

Exploring different pieces with additional personalization factors for design could have added an exciting dimension to the project. However, the time constraints posed a limitation, which prevented the full exploration of these possibilities. Especially using the fifth attachment piece, an additional personalization element could have been included. Secondly the length of the shelf piece posed a practical challenge as it didn't fit into the printer bed for printing at full length. To address this issue, either acquiring a larger printer or resizing the shelf dimensions would be necessary. These considerations highlight the need for balancing creative aspirations with practical constraints in design projects.

SURVEY

The desire among students to hang up items such as posters and pictures underscored the importance of incorporating features that facilitate easy hanging, such as hooks or shelves. This interest in hanging posters and pictures was obvious for the author having lived in the dorms. Additionally, the abundance of objects brought in by students highlighted the need for versatile display options, aligning with the modular nature of the tile wall system in addition to the currently existing decoration options. The survey also emphasized the significance of personalization in creating a comfortable living space, reinforcing the importance of accommodating a wide variety of decoration preferences. While modifying infrastructure was beyond the scope of the project, it was interesting to learn about the variety and contradictory changes students desired to change in their dorm rooms. For example, some students wished for a reduction in university provided pin board and shelves, and others would have liked an increase in decoration options.

The survey findings influenced decisions regarding the placement of the modular tile wall within the dorm room. The area above the bed was the preferred location, with the placement beside walls and above the bed a close second. It became evident that integrating decor options into this space was essential. The preference for an organic formation on the wall further emphasized the importance of creating visual interest while maximizing functionality. Additionally, the preference for gray tiles over red was given as a desire for a neutral backdrop that allows personal decor to shine. One student even noted that a neutral wall allows for individual items to take visual center stage.

These considerations guided the final design to ensure that it not only served practical needs, but also aligned with the aesthetic preferences and desires of the students. The mockup wall incorporated the desire for students to have gray over red tiles. A mix between the two colors shows the influence of the student's desires. If the survey answers would have been attained earlier in the process, the responses could have influenced the outcome of the project more drastically. Nevertheless, the amount of responses and the variety of questions were very helpful in highlighting the results and design decisions made along the way.

DESIGN GUIDELINES

- Make the back of the tile to be flat to insure a better installation
- Reduce the total weight while using as much crushed brick as possible to insure better installation
- Use the same weight of crushed brick and concrete for the best composition
- Design for the back of the tile to be thicker than 0.5 in to prevent chipping of the edges

SECTION 8

CONCLUSION

CONCLUSION

The project aimed to address two key challenges: the high content of building waste being landfilled and the need to enhance personalized living spaces, particularly crucial in small shared dormitory rooms. By repurposing building waste local to Boulder, Colorado, the project focused on creating a modular tile wall system to be implemented in the University of Colorado Boulder Environmental Design student dormitory rooms in Willard Hall. Utilizing data from the EPA, the research focused on identifying materials with significant landfill content that could be reused with minimal negative health impacts. The materials selected were bricks and untreated wood as they were among the fourth most landfilled materials and had the highest potential for reuse.

To address the first challenge, this project was designed to align with circular economic principles, with the aim to extend the used product's lifespan and potentially reintegrate it as aggregate in a new project. Building upon previous research by Bommisetty, which utilized crushed brick at 20%, this project achieved a higher aggregate content utilization, reaching 36% with the aim of maximizing the potential for reuse (2019, 875).

The second challenge addressed with this project was to offer flexible design options within dormitory rooms. Since personalization is a significant aspect of dormitory decoration, it has been widely recognized that the environment plays a role in academic success (Brown 2019, 270). Providing flexibility for the design of the space would contribute to the overall satisfaction with one's room. This assertion has been supported by the ENVD student survey responses. A majority indicated that the satisfaction with the dorm room is closely tied to the design possibilities available to students. Furthermore, respondents emphasized that the room serves as an extension of their personality. This project and the final product offer flexibility to the space. For instance, hooks can be placed in every tile on the modular wall and can be rotated depending on the direction of the tile. The shelf placements can be easily changed into any tile with a set distance from each Y piece. These modifications enable residents to tailor their living environment to their preferences and therefore improve their satisfaction with the space.

FUTURE CHANGES

This paragraph is dedicated towards improvements of this project if it would be continued or redone. Firstly, the author would begin immediately with the time consuming process of evaluating and testing binder material to identify the most sustainable and suitable options for execution. Ideally this would not include concrete, as by its nature concrete is not very sustainable.

To ensure that the design outcome aligns with user preferences, the survey should be conducted earlier in the process to gather valuable insights that can more strongly influence the project outcome.

Additionally, various iterations of hooks would be nice to experiment with to provide users with different options and possibly a hook that could adapt itself.

A testing phase of the product in a dorm room would have been effective to receive direct feedback from users. This would have been helpful in validating the product and evaluating the effectiveness of application in a real-life setting.

Regarding the construction and assembly process, it would have been helpful to consult a professional handy man and work together to refine the mounting process. Reducing the weight of each component would be needed to increase usability, as currently the tiles range from 1.8 to 2.9 pounds. This would imply that the tile would need to be reprinted with a new silicone mold.

In addition to reducing the overall weight, an important modification of the mold would need to be done. Currently the 6.65 mm thickness of the tile base is not thick enough. By increasing the thickness of the tile back, the issues of crumbling along the edges as the tile is removed from the mold could be reduced or mitigated. These steps underscore a comprehensive approach aimed at optimizing the functionality and sustainability of the final product.

This project, Briki, brings to light the possibilities for both reusing building materials currently being landfilled and creating simple but versatile options for decorating small spaces. Re-brick your dorm for enhanced living.

SECTION 9

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SECTION 10

APPENDIX: SURVEY

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1. What year in Environmental Design are you?

a. First Year (Freshman)

b. Second Year (Sophomore)

c. Third Year (Junior)

d. Fourth Year (Senior)

2. What is your gender?

a. Woman

b. Man

c. Non-Binary

d. Self-Defined

e. Other

3. Which of the following best describes you?

a. Asian or Pacific Islander

b. Black or African American

c. Hispanic or Latino

d. Native American or Alaskan Native

e. White or Caucasian

f. Multiracial or Biracial

g. A Race/Ethnicity not listed here

4. Before you moved into your dorm room, how did you envision you would decorate your dorm room?

5. What types of objects did you display in your room (multiple choice answer)

a. Posters

b. Pictures

c. Objects of Milestones

d. Souvenirs

e. Tapestries

f. Plants

g. LED lights

h. University Merchandise

i. Other…

6. How many objects did you bring to display in your room? (ex. Key chains, medals, picture frames, etc.)

a. 1 – 3 objects

b. 4 – 6 objects

c. 7 – 10 objects

d. More than 10 objects

7. How often did you change the arrangement of your decorations in your dorm throughout the time you lived there?

a. Once a week

b. Once a month

c. Every two months

d. Once a semester

e. Never

8. I felt like my room represented my personality.

a. Strongly disagree

b. Disagree

c. Neutral

d. Agree

e. Strongly agree

9. Having control over the design affects my satisfaction with my dorm room.

a. Strongly disagree

b. Disagree

c. Neutral
d. Agree
e. Strongly agree

10. Were you satisfied with the opportunities the university gave you for the decorating your room?

a. Yes
b. No

11. Thinking about the previous question, what would you have changed about the design of your dorm room?

12. Please rank the tile arrangements in order of your preference from most preferred (1) to least preferred (3).

a. Top image – in between the window
b. Center image – on the long wall above the bed
c. Bottom image – on the side of the closets

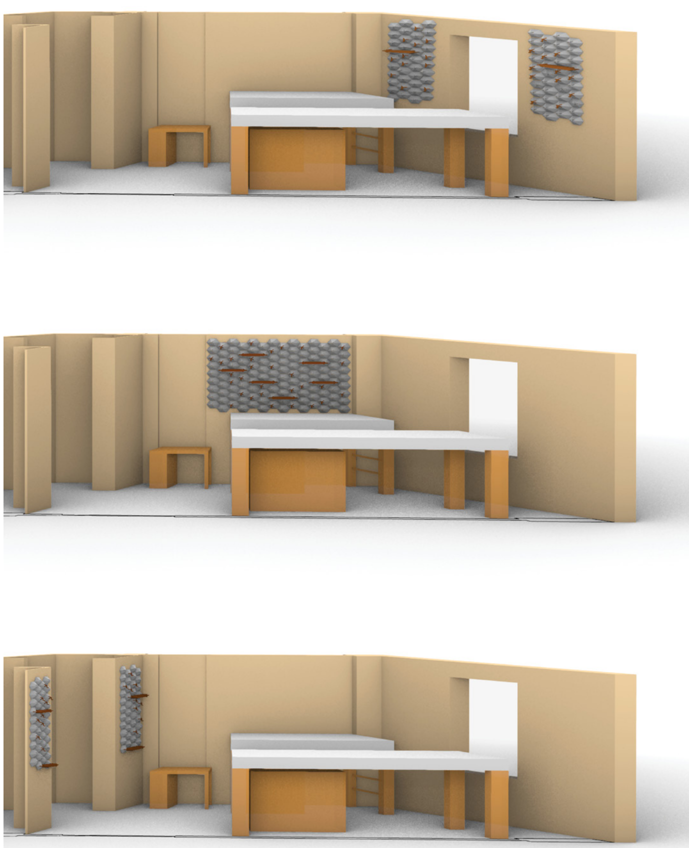

Figure 10.1: Three possible tile arrangements

13. Which of the two arrangements do you prefer?

a. Top image – rectangular formation
b. Bottom image – organic formation

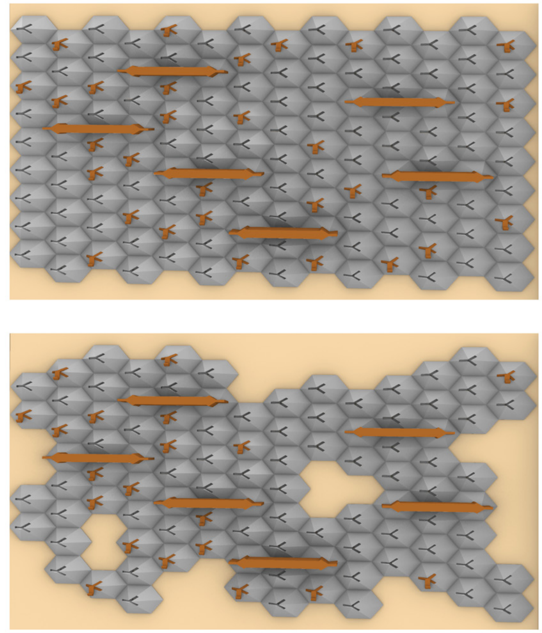

Figure 10.2: Two possible tile wall formations

14. Which color do you prefer?

a. Gray tile
b. Red tile

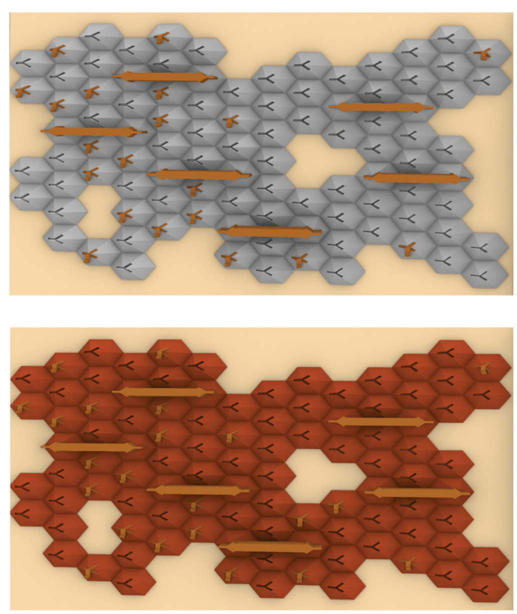

Figure 10.3: Two possible tile colors