Question:

How can I increase the strength of concrete slabs using waste materials?

Background research

Research points

- What are the biggest waste contributions to environmental waste, and why do they contribute
- What is concrete and how does it work
- How does the way you add the waste to the concrete affect its strength (weaving it vs randomly adding
- Has this been done before, and/or what are similar projects
- What type of concrete will be needed for use
- How can you predict which waste material will be the strongest
- What factors play into how strong the concrete will be?
- Cost Comparison
- How does this project itself impact the environment
- How are bricks useful? (housing crisis)

Notes

- Nzambi Matee builds plastic bricks by mixing small chunks of plastic and sand bits at a very high temperature and then compressing it
- How does plastic pollution affect the environment?
    - Every day 2000 garbage trucks filled with plastics are dumped into oceans, lakes, and rivers, and every year 19-23 million tons of plastic waste leaks into the ocean
- Products that take very long to decompose
    - Plastic
        - Why plastic is so difficult to decompose: most plastic bottles contain polyethylene terephthalate or PET for short (a synthetic resin used to make polyester fibers), PET contains chemicals that bacteria cannot consume and breakdown
    - Glass
    - Fabric
        - Why fabric is so hard to decompose: during the decomposition process, fabrics release greenhouse gasses and leach toxic chemicals into the soil
        - Synthetic fabrics like polyester and nylon are made entirely of plastic and face the same issues as plastics
        - While most natural fibers (cotton) are biodegradable, once they are combined with other synthetic materials (even if it is the slightest amount) they no longer become classified as decomposable

        - Jeans: even 100% cotton jeans contain problematic materials such as plastics, dyes, and metals
        - The textile recycling rate is one of the lowest compared to other materials
    - Aluminum
    - Disposable diapers
- What is concrete?
    - Concrete is an artificial composite material that is like a rocky material
- Different types of concrete
    - Lightweight concrete
    - Plain concrete
    - Reinforced concrete
    - Asphalt concrete
    - Precast concrete
    - Self-consolidating concrete
    - Ready mix concrete
    - Limecrete
    - Polymer concrete
    - Glass fiber reinforced concrete
    - Shotcrete concrete
    - Mortar
    - Portland cement
    - Roller-compacted concrete
- Concrete is 35 000 to 40 000 psi
- Biggest environmental issues
    - Deforestation
    - Pollution
    - Global warming
    - Natural resource depletion
    - Water usage
- Strength testing (Flexural strength)
    - Flexural strength test
        - Testing how the brick snaps/flexes
- Plastic chemical formula: (CH2-CHX)n

Research paragraphs

How does the way you add the material affect the strength of the concrete?

The concept of weaving, interlocking, or adding the material has a large effect on the strength of the binding. Especially when it comes to textiles, the way the material is weaved and if the textile is even weaved is an important factor. For example, in the world of fabrics, the difference between a plain weave (plain weaving is a basic way of weaving, where the horizontal yarn alternately passes over and under the vertical yarn) and a twill weave (a stronger version of the plain weave which causes the yarn to run more diagonal) is used can mean everything *(Patti, 2023)*. The strength of the weave is determined by the individual strength of the textile and the way the fabrics are placed together *(Balakrishnan, 2021).* Weaving makes breakage much more difficult and keeps things neatly together.

What materials cause the most environmental harm?

As it is commonly known, plastic is the number one cause of waste in the world, which derives from nonrenewable fossil fuels; electronic waste, the extraction of materials (lead, cadmium, and beryllium) for electronic devices can harm the environment, as well as the disposal of heavy metals like lead, mercury, and lithium for electronics; and textiles, which have high chemical and water pollution, with rapid production and disposal of these fabrics *(5 Gyres, n.d)*. A lot of these waste products are responsible for climate change, pollution, biodiversity loss, waste management, and other environmental problems by releasing greenhouse gasses, toxic chemicals, and taking up space in landfills.

How does plastic affect the environment?

According to CBC News and several other sources, plastic waste is Canada's number one problem, with most of the plastic coming from companies such as Tim Hortons and Nestle *(Chung, 2019)*. Plastic is not just a Canadian problem but a global one with 35 million metric tons of plastic wasted annually by humans *(Alves, 2023).* Plastic takes anywhere from 20 - 500 years to decompose, and even then the plastic never fully decomposes, it just gets smaller and smaller, creating microplastics *(UNEP, 2021).* To make matters worse, microplastics are not just harmful to the environment but to the human body. Microplastics release harmful toxins such as Bisphenol A that get absorbed into the human body and cause several diseases like inflammation, and genotoxicity. *(Med J, 2023).*

How does fast fashion affect the environment?

While plastic is the world's largest contributor to waste, many other waste materials sometimes go unrecognized. For example, the cotton and fast fashion industries (fast fashion products are low quality, high demand designs, that break quickly making an abundance of waste) impact the waste and water usage problem. Agriculture (especially the production of cotton), and fast fashion are responsible for 20% of global wastewater and 10% of global carbon emissions, that's more than flights and maritime shipping combined *(UNEP, n.d).* Fast fashion can be very harmful to humans as well, most fast fashion contains plastic microfibers, uses up a ton of water to make, and 57% of it ends up in landfills after use *(Le, 2020)*. Fast fashion and plastic still are not the only factors that play into waste.

How does the making and usage of glass impact the environment?

While plastic waste seems to be the most harmful waste product, things like glass have a higher environmental impact than plastic. Glass bottles take about 1 million years to break down and decompose. Not to mention the mining of silica sand plays a huge part in the loss of biodiversity, climate change, and waste. While glass can be recycled, the process isn't as simple as it seems. Glass has a higher melting point than waste like plastic and aluminum. During the melting process, tons of greenhouse gasses are released as a result, with 60 megatons of CO_2 emitted by glass-making industries every year *(Lee, 2023)*.

How does pollution affect the planet?

Landfills and pollution are often one of the major factors in environmental problems like climate change, air pollution, lack of biodiversity, and most of all land/soil pollution, as well as water pollution. Most water and soil resources become contaminated by a liquid produced from landfills called leachate. Leachate contains high levels of ammonia (ammonia is an inorganic gas that creates a pungent smell) which becomes nitrate through a process called nitrification (the biological process of oxidizing ammonia to nitrate), the nitrate then causes an increase of nutrients in the water which leads to an immense amount of algae which then leads to a decrease of oxygen, making a "dead zone". Dead zones are areas where animals cannot survive due to a lack of oxygen. Along with ammonia, other gasses such as methane, carbon dioxide, and water vapor, are released from landfills *(Vasarhelyi, 2023).*

What are some similar projects and what was the outcome?

In 2021 Nzambi Matee, a Kenyan environmentalist and engineer, started the company Gjenge Makers Ltd. Nzambi's company focuses on manufacturing paving stones (no cement). She does this by first grinding up the plastic into small chunks, and then adding sand to it to act as a binder. From there the sand and plastic are added to a machine called an "extruder", the extruder combines the mixture fully at very high temperatures converting it into a paste. The paste is then added to a mold where it is then compressed and ready for use. Her paving stones have a stronger compression strength than a normal paving stone since they use plastic which she says is "fibrous in nature". Nzambi Matee's stones are also half the weight of normal paving stones, making them cheaper to transport and install. Thanks to her invention, Nzambi Matee won the "Young Champions of Earth'' award and is planning to take her business even further *(UNEP, 2021)*.

Working with concrete

To begin using concrete, the required materials are the concrete mix, any aggregates (like sand and gravel), a wheelbarrow, a shovel, trowels, and molds if needed. First, mix the concrete and water according to the specific ratio, then add the aggregates and mix until combined. Afterward, the mixture can be placed into the mold, and trowels can be used to get rid of the air bubbles. During the curing process, the concrete needs to be kept somewhat moist and can be covered with a burlap of plastic for an extra measure *(Wallender, 2022)*.

Estimated cost comparison to make waste bricks

According to *Homeguide* normal cement bricks cost about $2.50 - $5.50 per square foot (materials only), and it costs about $32,320 on average to start up a concrete brick manufacturing business *(Walls, 2023)*. Material-wise, it costs $6.80 for a basic concrete at Home Depot, and all waste material can easily be collected for free. All the materials for "waste bricks' should cost relatively the same amount as normal cement bricks, or possibly even cheaper since waste bricks may not use reinforced metal and less cement. This does account for factors such as utilities, transportation, and labor. Plus, from a corporate perspective, it can seem very costly to change equipment to aid the new line of bricks, but that doesn't mean it is too late.

How are concrete bricks made?

To make concrete; water, concrete powder, and aggregates (such as sand and gravel) have to go through a chemical process called 'hydration'. The main ingredient, powdered cement, goes through a complex chemical reaction when it is mixed with water (hydration). During hydration, the silicate (a compound consisting of oxygen and silicon) and aluminate (a compound of alumina and metal oxide) in the cement combine with water to form calcium silicate hydrate (C-S-H) gel and calcium hydroxide. The gel helps reinforce the strength and durability of the concrete acting as a binding agent that solidifies the mixture. The hydration process usually happens over a long period and generates heat while doing so *(University of Illinois, n.d)*.

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<u>Hypothesis:</u>

If I make several bricks using various waste materials then the one including the fabric will have the highest breaking point, this is because the weaving and permeability of the fabric allow for a strong bond to the fabric as well as flexibility.

Variables
Independent variable- waste added in the bricks
Dependent variable- tensile strength
Controlled variable- type of concrete, dimension of brick, building method, testing method, wood, amount of concrete used, type of fabric, type of plastic

Materials:

- Concrete
- Plastic bottles
- Fabric
- Water
- Wood
- Nail gun
- Stir stick
- Heat gun
- Scissors
- Hot glue
- Strain gauge
- Clamps
- Chains
- Shackles
- Engine hoist
- Metal tube
- Metal L bar

Procedure

Prep:

Material prep

1. Take large plastic bottles and cut them into long strips (cut horizontally)
2. Since the plastic strips will be curved, use a heat gun set at a low heat to gently heat the plastic strips enough so that you can straighten them
3. Repeat the process for every strip
4. Take some fabric (jeans) and cut them into long even strips
5. Trim both the fabric and plastic so that it will fit nicely into the concrete molds (in this case they should all be about 6” long)
6. Separate the materials into groups (fabric, plastic, hybrid), and make sure the weight of each group is equal (ex. the weight of the two fabrics in the fabric bricks should be equal)

Mold

1. Using scrap wood make seven boxes that are even in size (6” * 3” * 2”)

2. Use hot glue to seal the cracks and hold them in place
3. Secure the boxes by sealing them with a nail gun
4. Mark the inside of the boxes indicating how much concrete should be poured until a new layer of material needs to be added

Concrete bricks

1. Mix the concrete
2. Fill one of the concrete boxes to the top (controlled brick)
3. Pour the first layer of concrete into six compartments of the mold
4. Add an even layer of fabric to four of the bricks (two for the fabric brick, and one for the hybrid), and add a layer of plastic to the final two bricks
5. Pour the next layer of concrete into the six boxes
6. Repeat step step four but add a layer of plastic to two of the bricks that currently have fabric in it
7. Pour a layer of concrete
8. Repeat step four
9. Pour a layer of concrete
10. Tap the side of the mold until the surface of all concrete bricks is smooth
11. Let the bricks cure in the mold for five days
12. After five days remove the bricks and leave them upside down for the bottom to cure

Testing:

1. Set the brick up in the engine mount rig with the strain gauge
2. Crank up the engine lift until the chain around the brick isn't loose anymore
3. Set the strain gauge to zero
4. Slowly crank up the engine lift until you get the first crack (the first crack should be when there is a split completely through the top of the brick, it does have to break completely)
5. Set the brick up for test two
6. Crank up the engine until the brick breaks 100% (how it is determined: the strain gauge should peak in kg of weight then suddenly drop drastically)
7. Repeat the process for every brick

<u>Diagrams</u>

[science fair sketch]

[Tensile strength rig - science fair]

<u>Data</u>

Observations

Control

Pre-test:

- The top isn't smooth but very rough
- No main visible cracks
- One small line on the front (towards the bottom)
- Lots of sediment on the bottom
- Smooth along the sides
- Very small air bubbles along the whole brick

Test:

- Crumbled and broke into 3 main sections
- Clean immediate break
- Some sediment split in half
- Fell apart as soon as it reached its limit
- Quick release of pressure when broken
- Vertical cracks
- Had a higher strength but split immediately
- Better for compression strength

Fabric 1

Pre-test:

- Layers of fabric are very crooked and vary in distance along the whole brick
- Only two main visible layers
- Layers have small horizontal cracks along where the layers are separated
- Rock chunks are barely visible
- On the right surface, large pieces of the jean are visible
- No major bubbles on the top
- Along the sides, there are minor air bubbles where the jeans are sticking out
- Areas with fabric exposed
  - The exposed parts are mostly hard, but the fabric can shift

First test:

- Stayed together after fracture
- mostly vertical cracks but a few horizontal cracks
- Two cracks on the bottom
- Most cracks stem from the main layer (the first layer)
  - Or just the jeans in general
- A chunk of the brick is moving but is held together by the jeans
- Jeans soaked up the concrete
- The largest fracture is along the top center
- Held together
- A lot of fractures

- Broke at the top first

Second test:

- Even though the brick did fully break, it never fully came apart
  - The main part of the chunks were held together by the fabric
- Most of the cracks stopped where the fabric was
- Bent the brick
- Three major vertical cracks along the whole brick
  - The center where the force was applied
  - Two cracks where the ‘L’ bar was holding the brick
- One major crack is split throughout the entire brick horizontally (front to back)
- The left and right sides had four major cracks
  - Formed in the shape of a plus
  - The horizontal lines were along the layers while the vertical lines were along the center
- Jean doesn’t rip in half

Fabric 2

Pre-test:

- Minimal air bubbles on the top
- Layers appear very even on the front (roughly 17mm between each layer)
  - The top layer on the back is very close to the surface (the top layer is tilted and is 8mm from the top on the back side)
- Air gaps along the layers
- Big gaps on the back left corner and the right side
- Jeans are very visible along all sides
- Small cracks on the layers
- Areas with fabric exposed
  - The exposed parts are mostly hard, but the fabric is

First test:

- Fewer fractures than the first fabric test
- Mainly vertical fractures
- Break was sudden
- No damage on the bottom
- Clean break on the top
- Four main breaks
- Held together
- Good for tensile strength since it holds together
  - Earthquakes
- This will allow the fabric to go through great amounts of pressure before 100% falling apart

- A lot of fractures

Second test:

- Only two main cracks on the top
    - Center and where one of the bars was holding it down
- Some of the larger fractures went through the layers
- One major fracture on the front
- Similar to the first, the bricks stayed together
- Layers are much more visible
- The bottom had four main cracks
    - One in the center vertically
    - One in the center horizontally
    - Two arcs where the ‘L’ bar was
- On the back, most of the cracks were stemming from the center bottom layer
- One major crack on the back down the center
- The left and right sides only had minor fractures around the layers

Plastic 1

Pre-test:

- Two main layers are visible
- Crack where layers are
- All three layers are close together (20mm from the surface on each side)
- A small bit of plastic is visible on the right side
- Gravels on the bottom
- Large gaps on the back of the brick

First test:

- Clean fracture across the top
- Very few cracks on the side
- Plastic is slightly visible on the front and back
- No breaks on the bottom
- No parts of the concrete are easily shiftable
- Held together

Second test:

- Crumbled apart
- After all the concrete crumbled off the plastic strips fell off
    - Concrete and plastic did not stick together
- Three main cracks on the top
    - Two vertically in the center
    - One stemming from the left crack horizontally
- The majority of the plastic stayed intact
    - Some plastic bits broke apart as well

- Crumbled more than the controlled
- Immediately after the test the brick was somewhat in shape and was able to sit together but after moving around a bit it collapsed completely
- All in small bits

Plastic 2

Pre-test:

- A few air bubbles along the brick
- Layers are hard to see
- Large gap on the back (underneath a plastic strip)
- Lots of air bubbles on the front
- Rock chunks are slightly visible on the bottom
- Open chunk on the bottom lots of air gaps on the front under the plastic strips

First test:

- One main fracture on the top
- Held together
- A few pieces of concrete surrounding the plastic strips fell off
- Mostly horizontal fractures on the sides
- Very few fractures
- Crumbled to pieces after breaking
- Lasted even longer than the first plastic

Second test:

- the plastic strips had more arcs in them which theoretically played a part in their strength
- Completely crumbled to pieces
- Exploded once the max amount of pressure was added
- Withstood the most amount of pressure
- Completely demolished

Hybrid 1

Pre-test:

- Many visible pieces of fabric
- Layers vary in distance but stay relatively within an equal distance
- Large empty chunk on the back right edge
- A large visible strip of fabric on the back
    - Air bubbles in between concrete and fabric
- There may gaps on the left side
- The large hole in the front
- A large visible strip of fabric on the front

- Fabric doesn't seem to have soaked up the concrete many small cracks around the whole brick
- A bunch of sediment sitting on top of the brick
- Almost no air bubbles on the top
- Areas with fabric exposed
    - The exposed parts are mostly hard, but the fabric can shift
    - No visible plastic

First test:
- Very small fractures on the bottom
- One tiny fracture across the top
- Smaller fractures compared to the other bricks
- Most fractures are vertical
    - Stop where the layer is
    - Held together

Second test:
- Three main fractures on the top
    - Center and on the sides where the bar was
- Held together (somewhat)
- The center of the brick completely crumbled and broke into several small pieces
- The bottom layer lost a giant chunk
- Curve into concrete brick
- Cracks in random directions

Hybrid 2

Pre-test:
- Very few bubbles on the top
- Distinct three layers
- The top layer sits very low (30mm from the top)
- Large crack on the back
- Many gaps in the back
- Plastic isn't visible
- Four main cracks along the whole brick
- Lots of visible fabric

First test:
- Most vertical fractures are around the middle layer (the plastic layer)
- One main fracture
    - Reaches over the front
- No damage on the bottom
- More chunks fell off around the fabric

- All in one piece
- Held together didn't break in the center

Second test:
- Two major cracks
    - Where the bar was holding it down
- A giant chunk fell off the top
- Curved
- Concrete around the plastic fell off
- The bottom has a lot of pieces missing
- Most of the damage is on the bottom middle
- Left and right side have major cracks where the layers are (horizontal cracks)

Notes:
- Angle iron
    - 1.5 inches on each side of the brick
- Metal tube
    - Diameter- 1 inch
    - Contact point- ⅛ of an inch

Photos:
[2024 science fair photos]

Table

	Length (inches)	**Width (inches)**	**Height (inches)**	**Weight (grams)**
Control	6”	3”	2.5”	1627
Fabric 1	6”	3”	3”	1651
Fabric 2	6”	2.7”	2.6”	1640
Plastic 1	6”	3”	2.6”	1633
Plastic 2	6”	3”	2.7”	1690
Hybrid 1	6”	2.9”	2.7”	1623
Hybrid 2	6”	3”	2.7”	1689

Brick measurements:

	Kilograms before fracture	**Kilograms before clean break***
Control 1	350kg	350kg
Control 2	420kg	420kg
Control 3	260kg	260kg
Control 4	260kg	260kg
Fabric 1	220kg	650kg
Fabric 2	190kg	650kg
Fabric 3	180kg	620kg
Fabric 4	150kg	580kg
Plastic 1	310kg	710kg
Plastic 2	290kg	890kg
Plastic 3	160kg	860kg
Plastic 4	200kg	950kg
Hybrid 1	170kg	640kg
Hybrid 2	180kg	510kg
Hybrid 3	200kg	770kg
Hybrid 4	230kg	790kg

*a clean break is determined by when the pressure peaks and then drops drastically right after

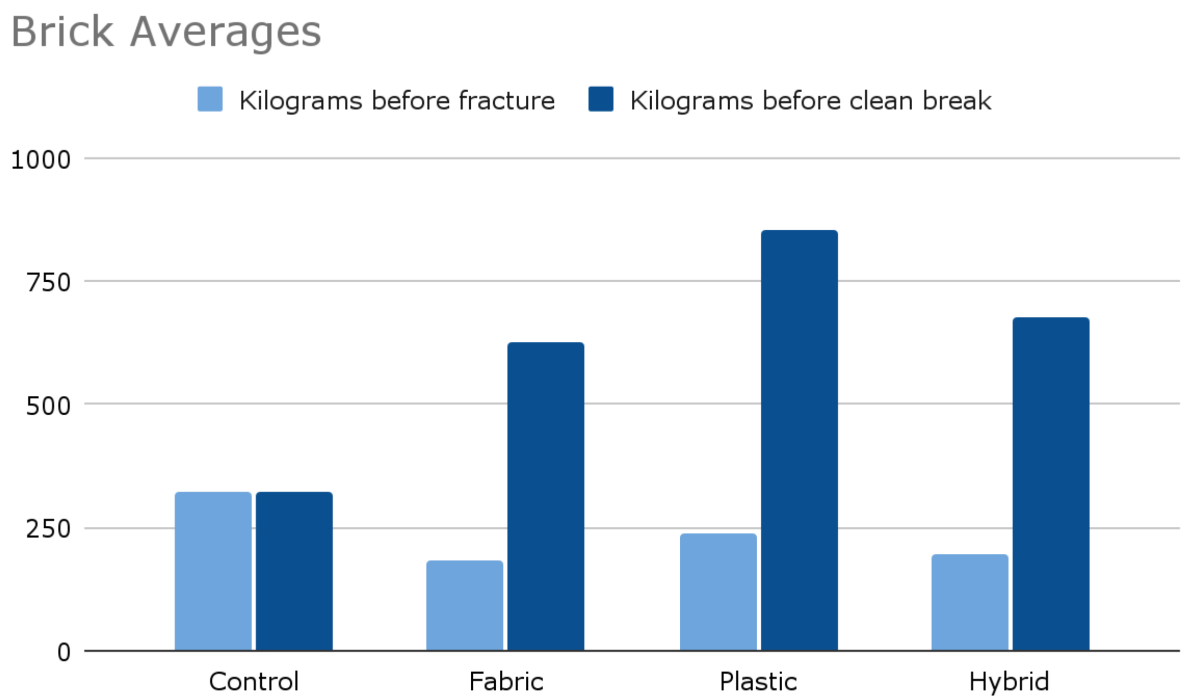
-all tests 3 and 4 were done as a separate batch and were made slightly different

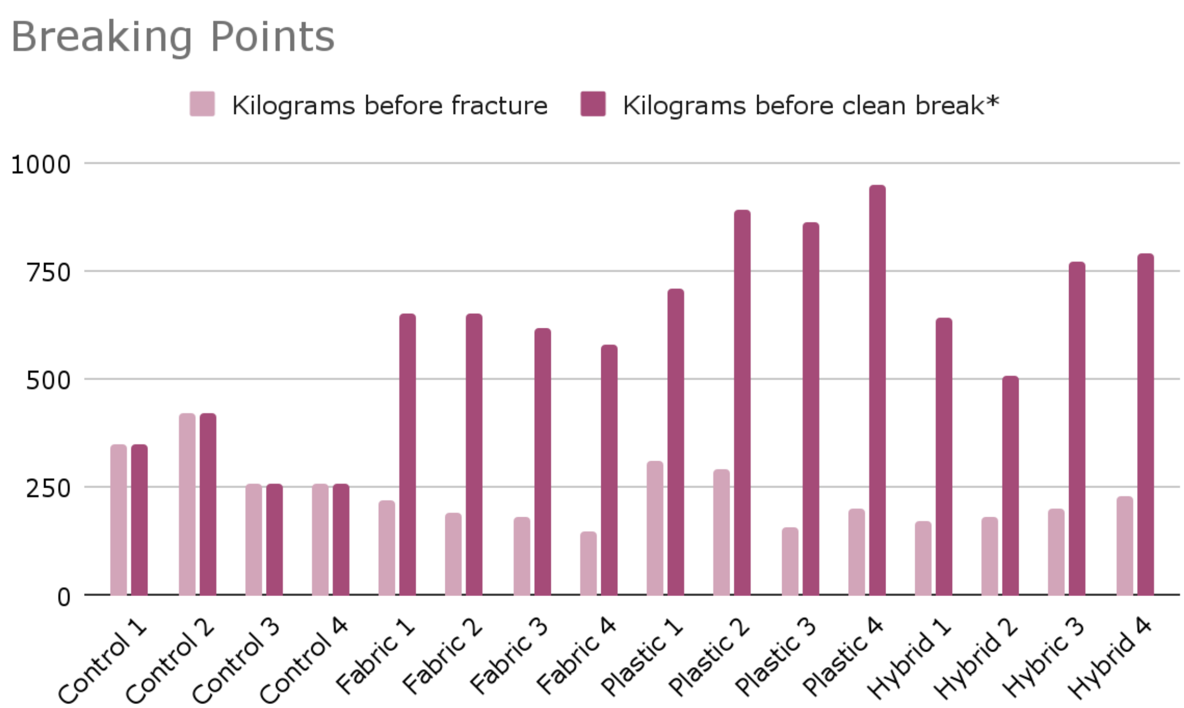
-all contain 2 layers (except for the hybrid bricks which contained 3)

Averages:

	Kilograms before fracture (average)	**Kilograms before clean break (average)**
Control	322.5kg	322.5kg
Fabric	185kg	624kg
Plastic	240kg	852.5kg
Hybrid	195kg	677.5kg

Graph


Brick Averages
Kilograms before fracture
Kilograms before clean break
1000
750
500
250
0
Control
Fabric
Plastic
Hybrid


Breaking Points
Kilograms before fracture
Kilograms before clean break*
1000
750
500
250
0
Control 1
Control 2
Control 3
Control 4
Fabric 1
Fabric 2
Fabric 3
Fabric 4
Plastic 1
Plastic 2
Plastic 3
Plastic 4
Hybrid 1
Hybrid 2
Hybric 3
Hybrid 4

Sources of error

- Material may not have been prepped evenly
  - Some pieces of fabric had more of an arch to them which could have impacted their strength
- Pouring concrete
  - Layers may not have come out even
  - One of the bricks does not have even layers (to ensure the same amount of fabric went into every brick extra fabric had to be added last minute)
- Some bricks weigh more than others (in the same category)
- The way the arches were placed (how they're facing)
  - Between the hybrid and the plastic
- Uneven distribution of materials (more plastic/fabric on one type to another)
  - Materials in the first batch were weighed to make them as close as possible to each other
  - The second batch was not weighed

- There were two sets of tests done separately which had a few major differences (it shouldn't matter since the two different tests were consistent among each other and had the same amount of bricks being tested so it won't affect the averages)
  - Some of those differences:
    - On the second test, all the bricks only had two layers (except for the hybrid)
    - The second test spent most of its time curing inside the house (temperature affected it??)
    - The way the bricks were manufactured

Analysis

Set up:

Introductory Paragraph	
Motivator - a sentence to motivate your reader to read forward - grab attention	Our hypothesis was that the fabric would work the best for bending strength, though the fabric bricks showed promising results, every one of the bricks displayed interesting results that could heavily impact the world of architecture.
Thesis Statement: a short statement that summarizes the main point of an essay	Despite the results having one clear "winner", the testing shows how different materials can be used for different purposes and different types of strength.

Topic Blueprint: Topic outline for 3 body paragraphs (supports thesis)	Different types of bricks are important since they can be used for different purposes like bending strength, compressive strength, durability, or even just aesthetics.
Body Paragraph	
Topic Sentence - sentence stating what this paragraph is about (supports thesis)	For reference to the other bricks, the strictly concrete brick broke all the way through once there was one fracture and stayed at 350 kg of force. While that is relatively good, it didn't compare to the other bricks.
• **support**	Out of all the tests, the plastic bricks were the strongest in both the fracture and the clean break test. This outcome was unexpected, especially after seeing how it took 890 kg of force to break on the second test. After the first test results were seen it was difficult to see why it had performed so well, it wasn't until the second test and the brick completely fell apart that it was easier to see. Once the plastic bricks had reached their limit they completely exploded and fell apart making the answer visible, inside the plastic brick were three layers of plastic strips that had straightened using a heat gun. In the process of heating the strips, if too much heat was added they would begin to shrink and curl forming arcs. Arcs and circles are some of the strongest used in both architecture and nature, by adding these simple plastic arcs to the brick, it allowed the strength to increase exponentially. While having a brick that withstands large amounts of strength seems like the obvious choice, there are some downsides. Because the concrete did not stick to the plastic, if there was a fracture or it completely broke, it became very flimsy and fell apart easily. In situations where you want something to stick together no matter what, this wouldn't be useful.
• **support**	On the other hand, the plastic brick showed promising results despite not being the strongest. Not only did the jeans hold the fabric together, but they also stopped the fractures from extending further than each layer. The major cracks, similar to the rest of the brick, they majorly stemmed from when the majority of the pressure was being applied (the bars holding it down and the bar pulling it). The most impressive thing about the entire brick was how it reacted at its breaking point. Instead of breaking it into two (or more) chunks, the brick stayed intact and was held together by jeans despite the

	concrete being completely broken. In a closer look at the layers of concrete, you could see that the fabric had completely soaked up the concrete making it almost fused and difficult to separate. This brick allows a generous amount of strength to be added to the concrete without it completely separating or breaking. This could be extremely useful for places with a lot of earthquakes, or structures that need a high bending strength.
• **support**	Based on the results of the plastic and the fabric bricks, it can be assumed that the hybrid brick would do incredibly well. Instead, the hybrid bricks showed the oddest results. The hybrid bricks consisted of two layers of fabric (one on the top and one on the bottom), and a middle layer of plastic for support. After looking at previous test results the hybrid bricks should have been just as good if not better, but instead, it showed a disappointing outcome. For an unknown reason, a mix between the two supports caused the bricks to become very weak and have fractures in all directions. Even though the brick stayed together due to the jeans, the brick still had several chunks that had fallen off.
Conclusion	
Reworded Thesis- reword the thesis in a new way	These results showed how most of the bricks can be repurposed for different architectural needs based on their results.
Clincher - final point to reinforce the idea	These bricks are important since they benefit not only the strength but also the cost, allowing for a stronger, eco-friendly, cheap alternative for concrete reinforcers.

Essay:

The hypothesis believed that the fabric would work the best for bending strength, though the fabric bricks showed promising results, every one of the bricks displayed interesting outcomes that could heavily impact or improve construction. Despite the results showing clearly which did the best, the testing shows how different materials can be used for different purposes and different types of strength based on how they react. Different types of bricks are important since they can be used for multiple purposes like bending strength, compressive strength, durability, tensile strength, or even just aesthetics. Most of these bricks showed a way to be used differently compared to the controlled brick which split immediately when it reached its limit.

Out of all the tests, the plastic bricks were the strongest in both the fracture and the clean break test. This outcome was unexpected, especially after seeing how it took a high or 950kg of force to break on the fourth test. After the first test results, it was difficult to see why it had performed so well, it wasn't until later on when the brick completely fell apart that it was easier to understand. Once the plastic bricks had reached their limit it had completely exploded and fell apart making the answer visible, inside the plastic brick werelayers of plastic strips that had been straightened using a heat gun. In the process of heating the strips, if too much heat was added they would begin to shrink and curl forming arcs. Arcs and circles are some of the strongest shapes used in both architecture and nature *(Building Big | Arch Bridge | PBS LearningMedia, n.d.)*. By adding these simple plastic arcs to the brick, it allowed the strength to highly increase, since all the force being applied to the brick was being pushed onto the top of the plastic archs, stability was provided making it withstand more. While having a brick that withstands large amounts of strength seems like the obvious choice when choosing what to build with, there are some downsides. Because the concrete did not stick to the plastic, if there was a fracture in the brick, it became very flimsy and fell apart easily, even crumbling to pieces in some scenarios. In situations where something needs to stick together, this wouldn't be useful.

On the other hand, the fabric bricks showed promising results despite not being the strongest. The concrete soaked up into the fabric due to the permeability (permiability: the state of a material which allows liquids or gasses to pass through it) of the fabric, which permitted the fabric and concrete to esencially bond together. Not only did the jeans hold the fabric together, but they also stopped the fractures from extending further than each layer. The major cracks, similar to the rest of the brick, mainly stemmed from where the majority of the pressure was being applied (the bars holding it down and the bar pulling it). The most impressive thing about the entire brick was how it reacted at its breaking point. Instead of breaking it into two (or more) chunks like the rest, the brick stayed intact and was held together by jeans despite the concrete being completely broken. In a closer look at the layers of concrete, it could be seen that the fabric had completely soaked up the concrete making it almost fused and difficult to separate. This brick allows a generous amount of strength to be added to the concrete without it completely separating or breaking. These types of bricks could benefit places with a lot of earthquakes, or structures that need a high bending strength.

Based on the results of the plastic and the fabric bricks, it can be assumed that the hybrid brick would do incredibly well. Instead, the hybrid bricks showed the strangest results. The hybrid bricks consisted of two layers of fabric (one on the top and one on the bottom), and a middle layer of plastic for support. After looking at previous test results the hybrid bricks should have been just as good if not better, but instead, it showed a disappointing outcome. For an unknown reason, a mix between the two supports caused the bricks to become very weak on the second test and have fractures in all directions. Even though the brick stayed together due to the jeans, the brick still had several chunks that had fallen off. The testing got even more unusual when a second test was conducted, when we began testing, we expected the bricks to do relatively similar to the first test, just as the other bricks had been. Instead the two bricks had drastically different results, while the first test reached a high of 640kg on the breaking test, the second test made it to a whopping 790kg, doing better than the fabric tests.Overall the brick wasn't able to withstand a large amount of force, breaking once it had hit 600 kg. The results of this brick were unexpected due to how the previous two bricks performed.

These results showed how most of the bricks can be repurposed for different architectural needs based on their results. These bricks are important since they benefit not only the strength but also the cost, allowing for a stronger, eco-friendly, cheap alternative for concrete reinforcers.

Conclusion

Set up:

Restate: -restate the lab experiment by describing the assignment	In this project, I worked towards finding a waste material that could go into concrete to increase its strength.
Explain: -explain the purpose of the lab experiment -what were you trying to discover? -procedure	This experiment would show which waste materials increased the bending strength of the concrete bricks, allowed them to break differently (eg. breaks but are still held together), and gave the different bricks new opportunities to be used for different purposes. To achieve this, the procedure had to be broken up into three sections (material prep, mold, and testing). To prep the materials you need first to take multiple 2L bottles and cut them into strips horizontally, use a heat gun to straighten the strips. Take a few jeans and cut them into strips roughly the same size. To make the mold take wood and nails to make seven boxes using hot glue to seal the edges. Finally, to conduct the testing, a make-shift rig made out of an engine lift is used (two bars clamped to the base of the engine lift, the concrete brick is then pulled against the bars when the engine lift is cranked up), and each brick is set up in the lift and cranked up until the first fracture is visible (the fracture is decided by when a crack goes through the straight through the top of the brick). Once the data for the fracture is recorded, the second testing begins, the brick with the fracture is once again placed into the lift and is cranked up until there is a clean break (a clean break is determined by when the strain gauge reading spikes the drops to a low measurement). Once all tests are conducted, observations are conducted.
Results: -explain the results, and confirm whether our hypothesis was correct or not	After the experiment was conducted, the results unexpectedly went against the hypothesis. In the hypothesis, the fabric brick was expected to perform the best since the fabric would hold it together making it difficult to break. Though it was correct that the fabric did allow the bricks to hold together causing it to withstand a great amount of force, the plastic in the end had the most bending strength, most likely because of the arcs formed in the plastic strips when heating it which gave it more structure. Even though the results clearly showed which brick was the strongest, the experiment also showed how different waste materials have different purposes in the building world (some can be used for compressive strength while others could be better for bending strength).
Uncertainties: -take into account errors	Despite the promising results from the experiment, many errors occurred during the testing that could have an impact on the making

	of these bricks. The biggest error was that the layers may not have come out even, with the thickness of the concrete it was difficult to pour accurately, meaning most of it had to be done by eye (though after measuring the bricks to see how accurate they were they came out fairly close in size). The size of the bricks could heavily impact how much force it takes to break, how it cures, and how the material interacts with the concrete.
New: -discuss new questions or discoveries that emerged	Following the experiment, new ways of executing it and more follow-up experiments came to mind. With further testing, the proper use for each brick can be looked at even closer, seeing how the different bricks react under different types of tests (compression, tension, etc.) to understand the different uses for each brick. As well, new types of waste materials can be experimented with, playing around with how to incorporate new waste materials in a way that can make it even stronger. A big one that could be looked at is using fine glass and/or other waste materials to replace sand in the concrete mix. This project allowed many future experiments to come out to better the environment and these bricks.

Essay:

The experiment would show which waste materials increased the bending strength of the concrete bricks, show how they break differently (eg. break but still held together), and give the different bricks new opportunities to be used for different purposes. To achieve this, the procedure had to be broken up into three sections (material prep, mold, and testing). To prep the materials, multiple 2L bottles are taken and cut into strips horizontally, using a heat gun to straighten the strips. Take a few jeans and cut them into strips roughly the same size. To make the mold take wood and nails to make seven boxes using hot glue to seal the edges. Finally, to conduct the testing, a make-shift rig made out of an engine lift is used (two bars clamped to the base of the engine lift, the concrete brick is then pulled against the bars when the engine lift is cranked up), and each brick is set up in the lift and cranked up until the first fracture is visible (a fracture is determined by when a crack goes through the straight through the top of the brick). Once the data for the fracture is recorded, the second testing begins, the brick with the fracture is once again placed into the lift and is cranked up until there is a clean break (a clean break is determined by when the strain gauge reading spikes the drops to a low measurement). Once all tests are conducted, observations are recorded.

After the experiment, the results unexpectedly went against the hypothesis. In the hypothesis, the fabric brick was expected to perform the best since the fabric would hold it together making it difficult to break. Though it was correct that the fabric did allow the bricks to hold together causing it to withstand a great amount of force, the plastic in the end had the most bending strength, most likely because of the arcs formed in the plastic strips when heating it which gave it more structure. Even though the test gave a clear result of which brick was the strongest, the experiment also showed how different waste materials have different purposes in the building world (eg. some can be used for compressive strength while others could be better for bending strength).

Despite the promising results from the experiment, many errors occurred during the testing that could have an impact on the making of these bricks. The biggest error was that the layers may not have come out even, with the thickness of the concrete it was difficult to pour accurately, meaning most of it had to be done by eye (though after measuring the bricks to see how accurate they were they came out fairly close in size). The size of the bricks could heavily impact how much force it takes to break, how it cures, and how the material interacts with the concrete.

Following the experiment, new ways of executing it and more follow-up experiments came to mind. With further testing, the proper use for each brick can be looked at even closer, seeing how the different bricks react under different types of tests (compression, tension, etc.) to understand the different uses for each brick. New types of waste materials can also be experimented with, playing around with how to incorporate new waste materials in a way that can make it even stronger. A big one that could be looked at is using fine glass and/or other waste materials to replace sand in the concrete mix. This project allowed many future experiments to come out to better both the environment and the building world.

Real-world application - why this matters

- Even though these current alternatives to stabilizers can compared to the most common types (like re-bar) they can work well enough for certain projects (such as driveways, normal bricks, etc.)
- While the cost is relatively the same as what it would cost to make a standard brick, this solution provides a low-cost alternative to make concrete stronger whilst being environmentally friendly
    - In comparison to rebar and wire mesh (all sources are from Home Depot, just material cost no manufacturing cost):
        - Rebar brick (two horizontal pieces) = $2.12
        - Wire mesh brick (two layers) = $3.02
        - Plain brick/eco-brick = $0.42
            - Waste supplies can be gathered for little to no cost, they can either be collected from a landfill (if legal) or donated
                - This cost comparison does not account for things like transportation, manufacturing, etc., the cost may vary depending on those factors
- Eco-bricks allow for a future of less waste in landfills, resulting in less pollution, and harm to the planet
    - Instead of these toxic wastes going into the environment, they get cleared up in use by the bricks on bottle and brick at a time.
    - Reduces waste in landfills by recycling and repurposing pollutants, thus preventing an abundance of waste in landfills
- These bricks save lives by reducing pollution and reinforcing building structures, in places with a high risk of earthquakes can prevent damage by putting things like fabric in their bricks

Essay

Every year, 2.12 billion tons of waste are dumped into landfills around the world *(World Waste Facts, n.d.)*, even if all waste production were to cease to exist, society is still left with the 2 billion tons of waste that can not be recycled. So how can we get rid of all this waste? While most plastics and other resources can be used to make more products, the process can be lengthy, expensive, and have no direct benefit to the companies who recycle their materials *(Romuno, 2021)*.

That is why this innovation works towards an alternative to deal with landfill waste that is affordable to manufacture, improves the product, and helps the environment. The plan for Eco-Bricks does all of that. Adding waste materials as layers for extra strength allows common waste to be repurposed, tackling the waste crisis one brick at a time. Using waste as a stabilizer in concrete structures can greatly increase the strength and behavior of the bricks. By adding these scrap pieces, the bricks now hold together and can withstand more tension. Though the waste bricks can not handle nearly as much psi as your most common concrete reinforcers (such as steel re-bar and wire mesh), they can still be used for structures where that much strength is not necessary. For example, a driveway needs to withstand 3000 psi to qualify *(Titan America, n.d.)*, for reference, the brick that can withstand the most (the second plastic brick) can take around 3924 psi. The fabric bricks also proved to be very useful in the sense that they hold the bricks together, this can allow for places with a high amount of natural disasters (such as earthquakes) to suffer much less damage. There would be fewer casualties, less fallen debris, and fewer resources poured into fixing the aftermath of these catastrophes.

Not only are these alternatives beneficial, but they are also low in cost. To build re-bar brick and a wire mesh brick it would cost around $2-3, whereas brick using waste resources only costs $0.42 to make (these prices do not include manufacturing or transportation). While these bricks do not perform as well as re-bar, the cost makes these bricks preferable.

Finally, the bricks also improve the health of the earth by making use of all the waste materials. While it would be difficult to use up all 2 billion tons of waste that is in the world, by executing this concept, the world could take one step closer to a waste-free planet. Several environmental problems would be solved, not just landfill waste. There would be more water resources since the landfill would cause less pollution, climate change would slow down, fewer habitats would be destroyed by landfills, and there would be less leachate production *(Vasarhelyi, 2021).* Even if we were to stop waste production, using up all the waste in landfills would be a very difficult feat to accomplish.

Ultimately, using waste as a stabilizer for concrete will allow for a stronger, more affordable, and improvement in the environment. These eco-bricks cost only $0.42 to make, can improve the manufacturing of buildings by making them stronger, and are not only eco-friendly but also improve the environment by using up waste thrown in landfills. Implementing the use of these bricks will enhance the construction industry.