S U G A R S L A B

CONSTRUCTION WEEK 2022
UNIVERSITY OF EAST LONDON

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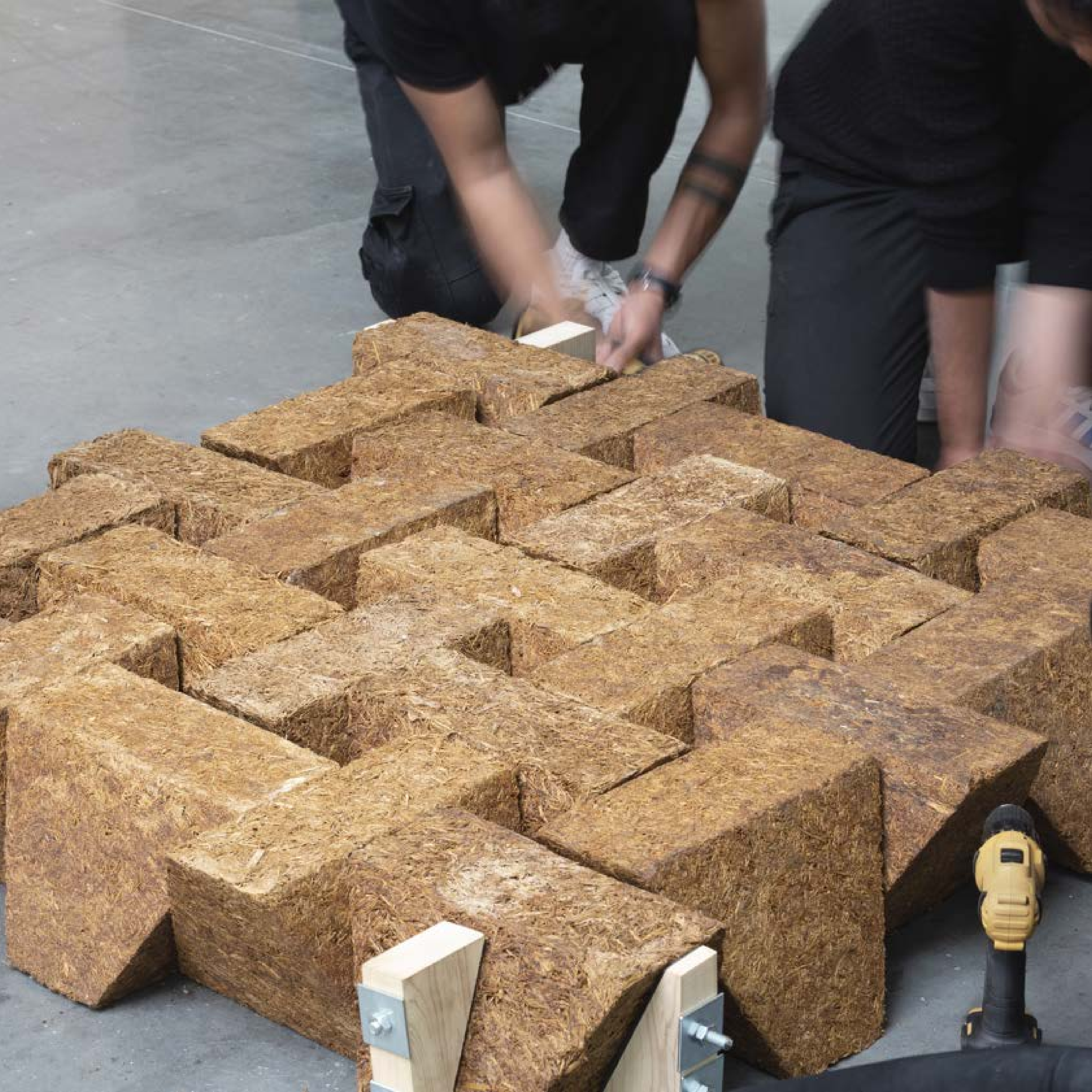

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01 INTRODUCTION

This report is a detail piece of research dedicated to bagasse as a building material. The idea was developed through the use if hempcrete in the construction industry. The purpose of this research is to inform interesed readers how a sugarcane by product can be used as a load bearing slab, structural wall or even as an isulation material with a carbon negative impact to the enviroment. Following our productive research of two weeks we have created and tested different ratios of bagasse using other binders and experimented u value, strength testing and fire testing on our prototype models. This report will give a detailed explanation and step by step guide on how bagasse could be used as a construction material and show the results of our testing. This experiment was undertaken by individuals with no prior experience in using bagasse as a construction material. We hope this report inspires you to expore the endless possibilities using bagasse and help impact the construction industry.

SPECIAL THANKS TO

It has been a great pleasure working on this project, and we are honoured to be a part of this field of research. We would like to first thank our Construction week workshop instructors, Armor Gutierrez and Alan Chandler for being so supportive and informative. We would like to extend our thanks to Bamdad Ayati for leading the research into this material, and helping us with the figures and scientific data.

We would also like to give a special thanks to Elena Shilova from Grimshaw Architects, who has been with us every day from start to finish, helping us and being passionate about the whole project! Thank you to Paul Nicholls, Sky Henley, Alina Klimenteva, Georgios Tsakiridis, and Philip Singer for helping throughout the two weeks.

An extended thank you to John from ASR Group for his informative presentation on sustainable raw sugar sourcing and giving us a detailed process of how sugarcane farming and importing opperates throughout Tate & Lyle.

Finally, a big thank you to Paolo Vimercati (Grimshaw Principle), and Andy Watts (Director of Design Technology at Grimshaw Architects), for research support and guidance.

02 PRECEDENT AND HISTORICAL CONTEXT

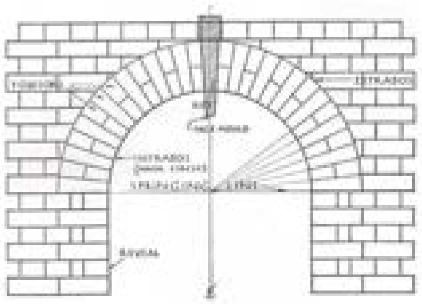


Fig.1 - Curved Vault

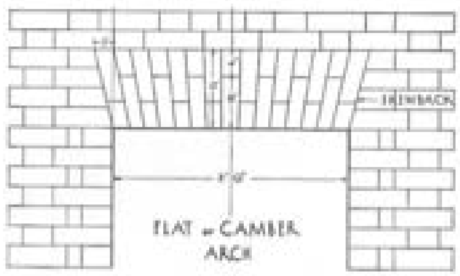


Fig.2 - Flat Vault

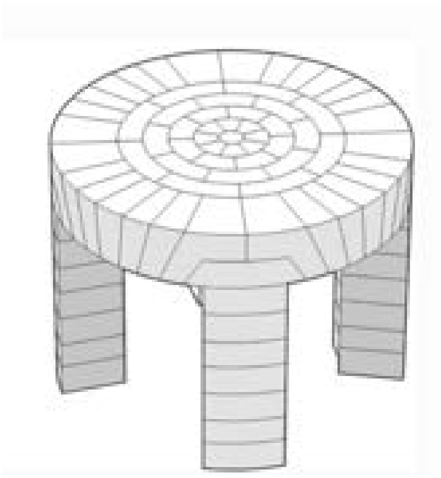


Fig.3 - Circular Flat Vault

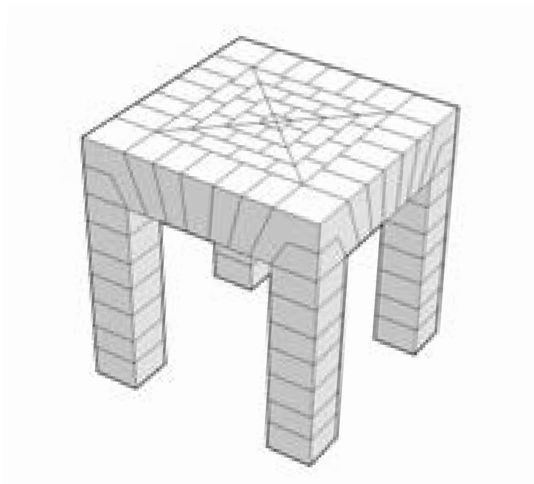


Fig.4 - Square Flat Vault

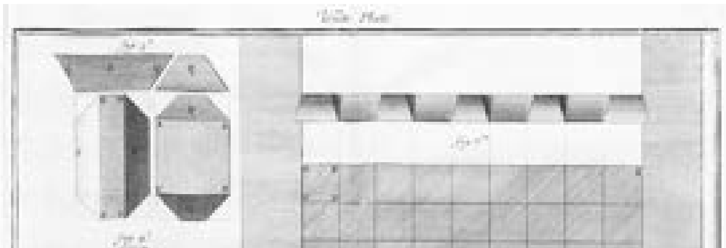


Fig.5 - Voûte Plate Sketch

Flat Vaults
Joseph Abeille's "Voûte plate"

The flat vault system was invented in 1699 by French Engineer Joseph Abeille. In his design a standard block has two orthogonal vertical sections, each with one pair of horizontal sides. These shapes range in variation from simple to complex, and their designs have been analysed by Engineers and Architects alike for many years.

This was truly the birth of a new type of structural engineering, and has formed the base of our own work and research. However, our design process follows a very different method than the one used by Abeille in 1699.

Whilst he utilised his drawing skills and mathematical tools, nowadays we can rely on technology to help us, (software such as Rhino and Grasshopper).

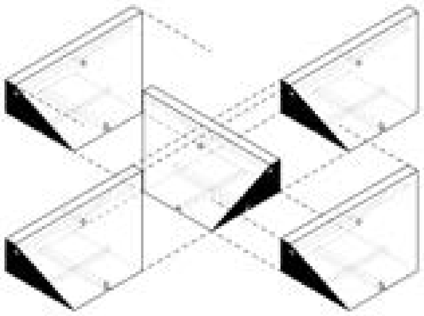


Fig.6 - Construction Sketch

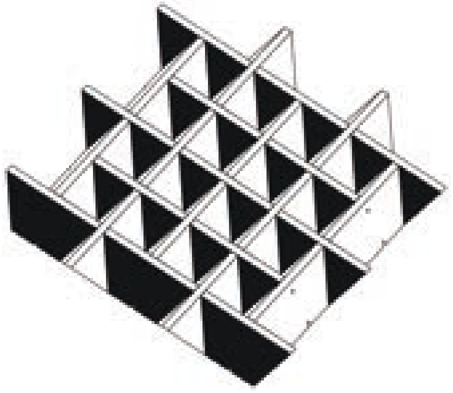


Fig.7 - Axonometric

Fig.9 - Interior View

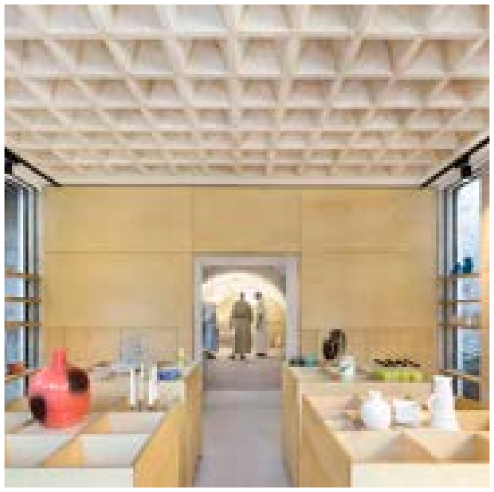


Fig.8 - Interior View

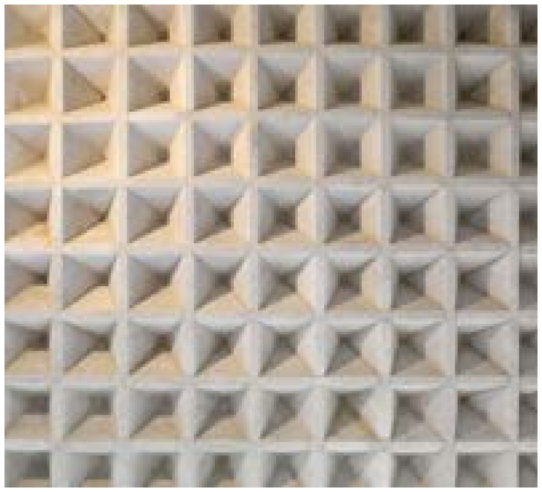


Fig.10 - Interior View

The Flat Vault, AAU Anastas

The church of St Mary of the Resurrection Abbey in Jerusalem was built in the 12th century by the crusaders in Palestine, however the newly built stone vault is an extension of the monestery's shop.

The design for the new shop is based on an innovative construction principle, literally weaving stones together to achieve the first reinforced at stone vault of such a scale. This vault is a great example of the quadrilateral plan vault.

The structure is built using just stone and holds itself together without any binder.This is quite impressive as it requires just a single material. However due to the blocks being made of stone it would mean each block was shaped to be exactly the same making that the longest process. Once all the blocks are cut the assembly would be quick as its the same shape in different rotations.

We would like to use this process when making our model as it would mean we use only bagasse and that would help reduce the carbon footprint for the process.

03 MATERIAL COMPARISONS

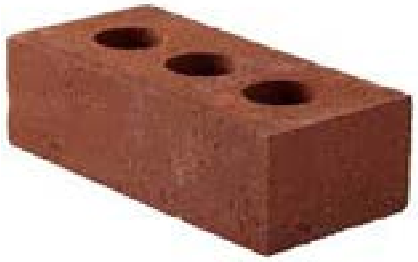


Fig.11 - Brick

Advantages Of Brick:
- Fast and Easy Building: Bricks are very efficient in building durable walls, very quickly
- Material Cost: Regular clay bricks are a cheaper alternative to most of the contemporary building mate
- Compressive strength: efficient in low-rise buildings.

Disadvantages Of Brick:
- Imported Bricks: In 2019 UK imported $33.4 M in Bricks, and became the 1st largest importer of bricks in the world
- Weight: Regular bricks are heavy to transport and carry during construction, and over a small surface area per brick.
- Layering: Contemporary brick walls are constructed using many layers that are required such as insulation, waterproofing and screening
- Energy Consumption: Brick production requires a lot of energy to heat up the brick, and this energy is mostly supplied from the primary grid electricty
- Construction Expenses: Regular brick wall construction is very expensive, rates reaching £40/hr.

Fig.12 - Steel

Advantages Of Steel:
- Reliability: has large elasticity and ductility.
- Industrial behaviour: rolled steeled sections are produced in the factory but the joining of components is carried out on site by bolts or rivets.
- Quicker construction time: steel construction is fast.
- High Strength: of steel per unit weight.
- Performance: if coated or painted, steel doesn't change with time.
- Elasticity: the steel doesn't crack nor tear before the ultimate load.
- Reuse: sections of steel can be reused after a disembled structure.
- Water-tight and Air-tight construction: oil and gas pipes are made from steel.

Disadvantages Of Steel:
- High Maintenance cost: extra cost and care is required when exposed to air and water.
- Fireproofing costs: steel is incombustible but their strength is reduced in prevailing fires.
- Buckling: if the members of steel is compressed, this will lead to buckling due to the collapse of the members.
- Cost: steels cost is higher to other structural materials.

Fig.13 - Timber

Advantages Of Timber:

- Versatility and durability: can be bent into its required shape and connected to other materials. Can stand harsh weather conditions.
-Cost: timber can be cheaper than a steel-framed or concrete building due to also the speed of construction being faster.
- Insulation: Timber is good for sound and heat insulation, it is also much better than steel or brick for cladding to keep the heat in, as well as creating a more enviromentally friendly structure.

Disadvantage Of Timber:

- Shrinkage and Swelling: as a natural material timber can have the ability to absorb water. It should be treated.
- Condensation: this can happen to a structure with a timber frame.
- Fire: a timber framed house cannot withsand the heat the way brick or steel would. Fire retardants can be a treatment to a timber house as it slows the spread of fire and reduces the amount of smoke.

Fig.14 - Brick Construction

Fig.15 - Steel Construction

Fig.16 - Timber Construction

03 MATERIAL COMPARISONS

Fig.17 - Hempcrete

Advantages Of Hempcrete:
- fast and easy building: Hemp bricks are very efficient in building durable walls very quickly.
- Thermal resistance: Hemp bricks have good thermal resistance, making them a grid choice for insulation purposes.
- Weight: Hemp bricks are lighter when compared to regular clay bricks as they are less dense.
- Bio-material: made out of hemp, being a plant based product, resulting in a carbon negative end product.

Disadvantages Of Hempcrete:
- Material cost: hemp bricks are up to 16 times more expensive than a regular brick, resulting in contractors avoiding it.
- Compressive strength: hemp bricks don't have enough compressive strength to make them a suitable and effective construction material.
- Main issue: hemp is grown only to make hempcrete put of it. Entire fields are occupied with hemp plants.

Fig.18 - Concrete

Advantages Of Concrete:
- Avaliability: concrete is easily avaliable.
- Durabiltiy: of concrete is very high, is free from deflects or flaws and can be manufactured to the desired strength.
- Construction: can be casted on site making it economical and can be cast to any shape.
- Cost: low maintenance
- Fire: concrete can withstand high teemperatures
- Performance: concrete is resistant to water and wind and deterioration is low and is a sound proofing material. Concrete becomes stronger and more durable with time.

Disadvantage Of Concrete:
- Performance: strength of concrete is low and is less ductile
- Weight: is high compared to its strength
- Climate: it is prone to water and feezing temperatures. Water can go into cracks and damage the concrete.

Fig.19 - Sugarslab

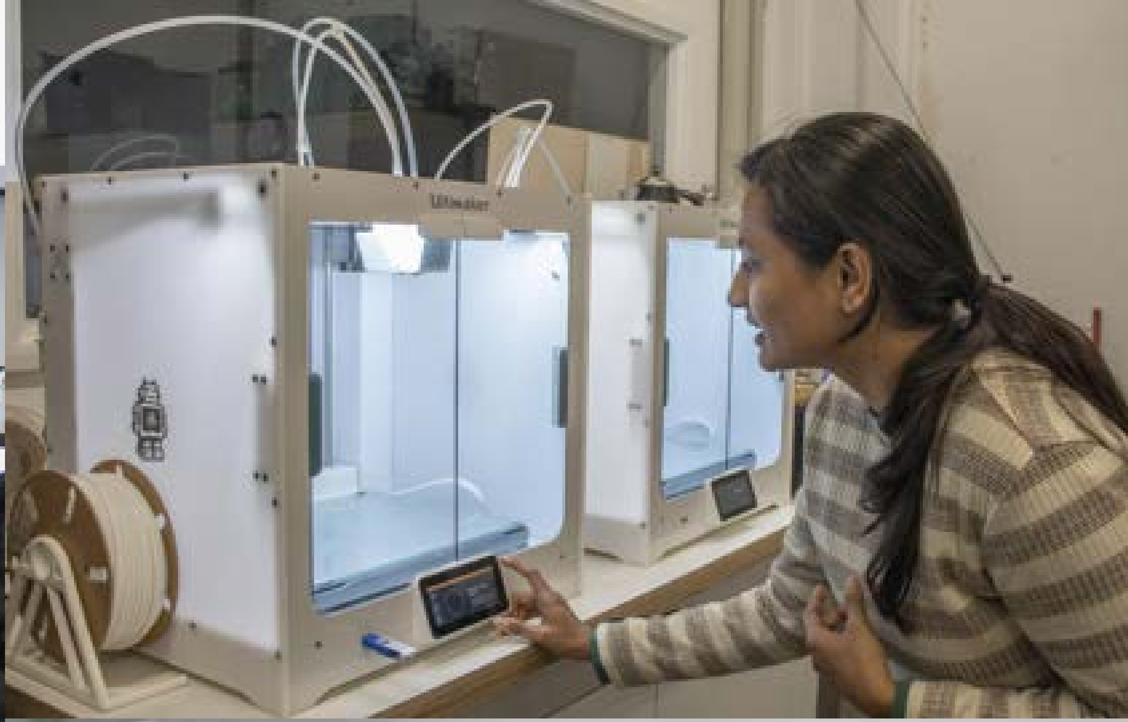
<u>Advantage Of Sugarslab:</u>

- waste product: Sugarslab is made using Bagasse which is a byproduct of Sugar Cane processing.
- Bio-material: like Hempcrete, Sugarslab is a plant based product and has a negative carbon footprint value.
- Weight: has a very low density, resulting in light bricks that can easily be transported, making it very efficient in building.
- Bio-material: Sugarslab is made from sugar cane, a plant based product, resulting in a carbon negative end product.
- Compressive strength: making Sugarslab bricks suitable for low-rise construction.
- Thermal resistance: Sugarslab bricks are good for insulation purposes.
- Ease of manufacturing: easy to manufacture on or off site, making them suitable for an efficient brick substitute.
- Circular economy potential: bagasse is a by product of Sugar Cane production, Sugarslab has a potential to create a circular economy in the counties that grow sugar cane.

	Regular Brick	Hempcrete	Sugarcrete
Dimensions (mm)	65 x 215 x 102.5	120 x 600 x 300	100 x 100 x 100
U Value (W/mK)	0.025	0.071	0.065
Fire Resistance (min)	60 - 240	60	60
Compressive Strength (kN/m2)	11200	1000	2760
Carbon Footpri (kgCOe)	0.63	-0.165	-0.161
Weight: Amount (kg)	2.60	10	0.445
Unit Cost (£)	0.54	8.76	-

Fig.20 - Material Comparisons


ABB


Ultimaker

04 SMALL SCALE PROTOTYPE

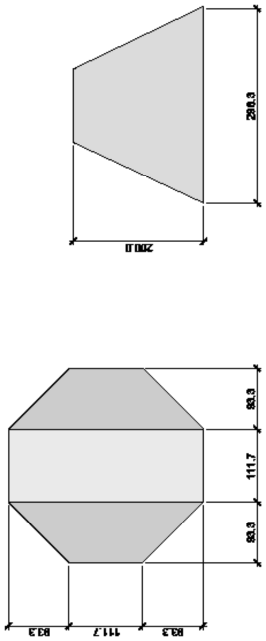


Fig.21 - Plan

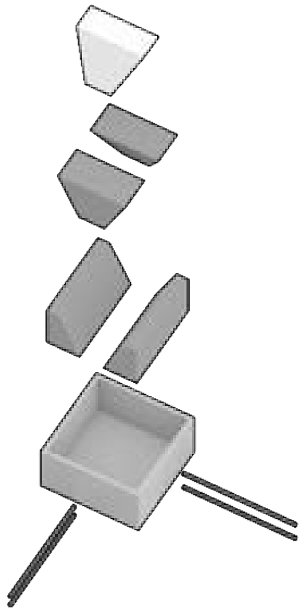


Fig.22 - Module Design 2

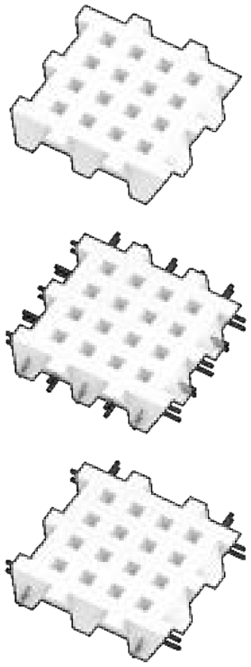


Fig.23 - Base Geometry 1

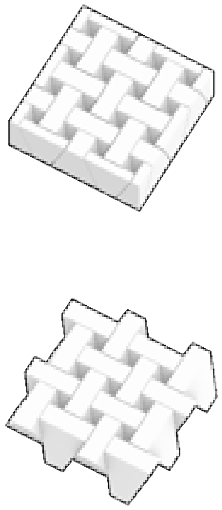


Fig.24 - Base Geometry 2

05 CONSTRUCTION

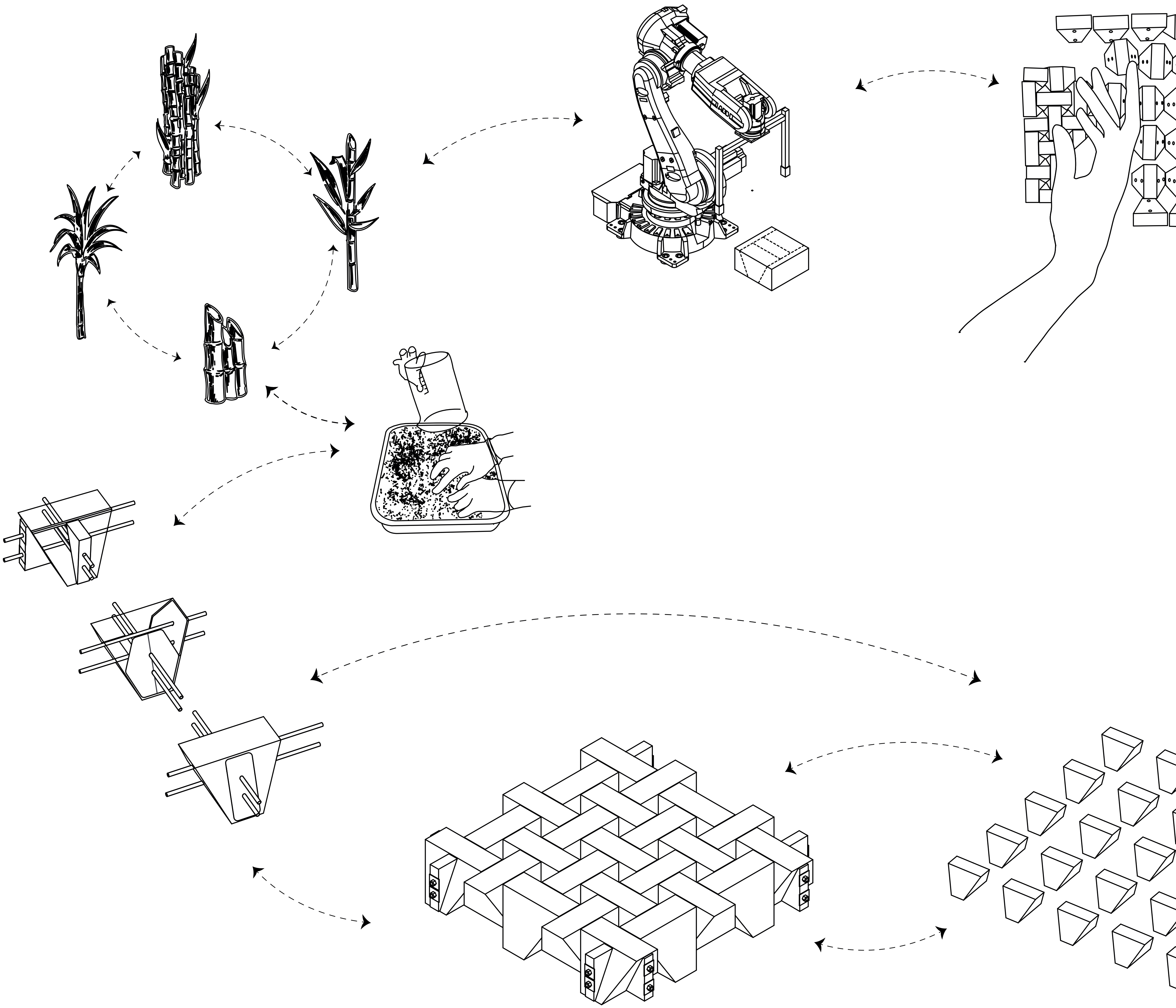
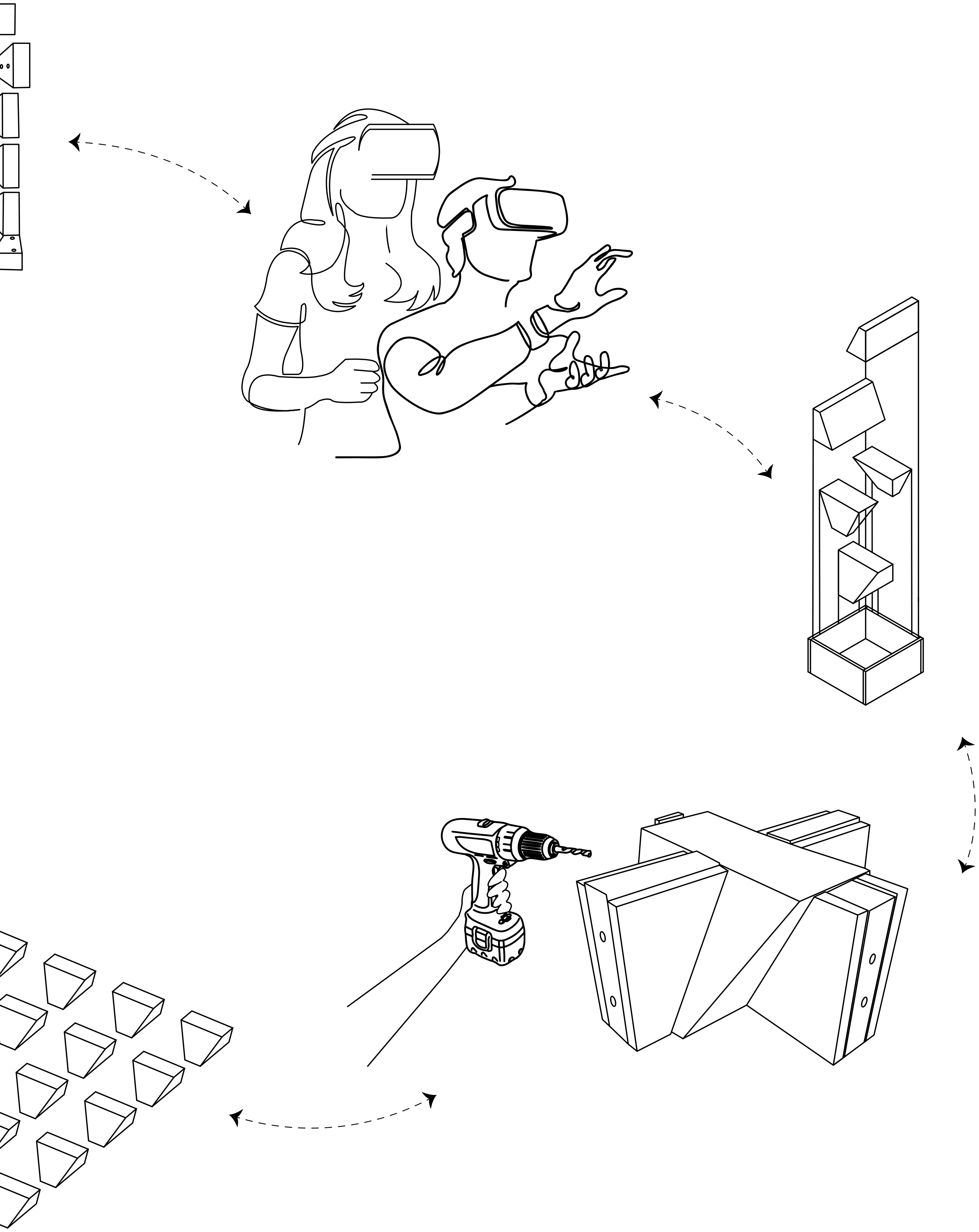


Fig.25 - Construction Process



1. Sugarcane is harvested and bagassae is a by-product.

2. Bagassae is combined with a mineral binder to create a building material.

3. Using advance digital modelling, a geometric form is created and the robotic arm is used to cut out the mould for this form.

4. A 3D printer was used to create a prototype of the proposed slab to see the concept of interlocking system.

5. VR technology is a process of virtual assembly.

6. Once a design was chosen the blocks were moulded within a wooden box, using the foam mould cut by the robotic arm.

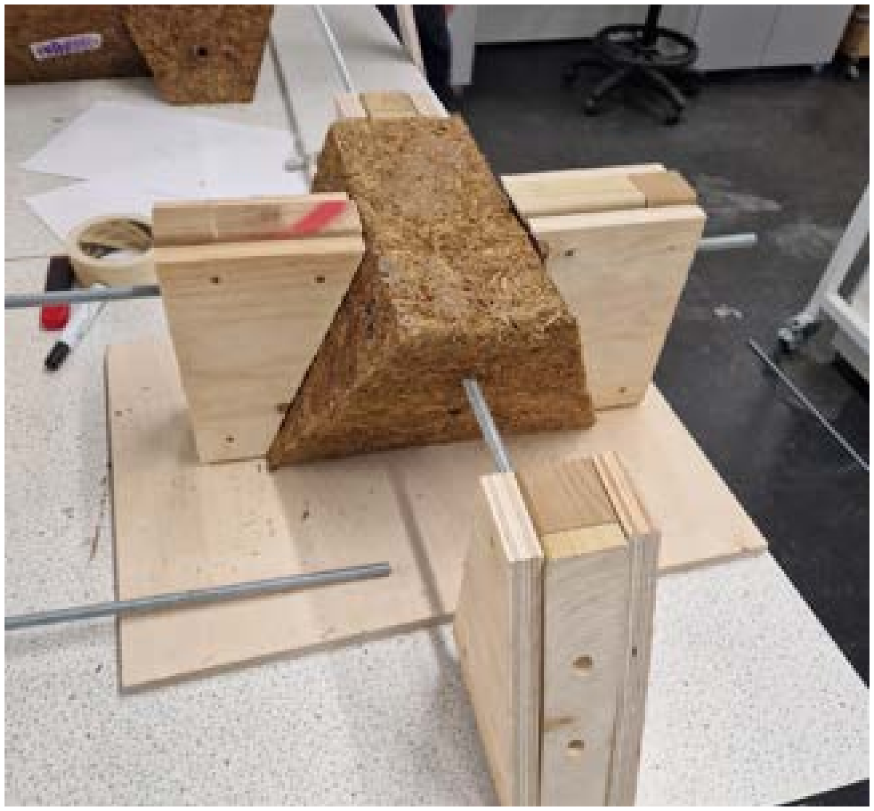
7. To ensure the drill holes were aligned equally a jig was created and used.

8. Once every piece was prepared they were aligned and ready for assembly.

9. The blocks were interlocked together using steel rods creating tension on the outer frame. Due to the geometric form and tensioning of the frame no binder was used in the interior of the slab.

10. Detail of frame tensioning.

06 Tension and Compression



Whilst the geometric pattern is designed to be interlocking and self-supporting, there is still a limit to the stability of the structure without the addition of tension rods.

In a section with the area of 0.1x0.1 = 0.01SQM there is a compressive capacity of 0.01*5000 = 50kN. This means that we can allow for up to 50kN of tension before we see compressive failure.

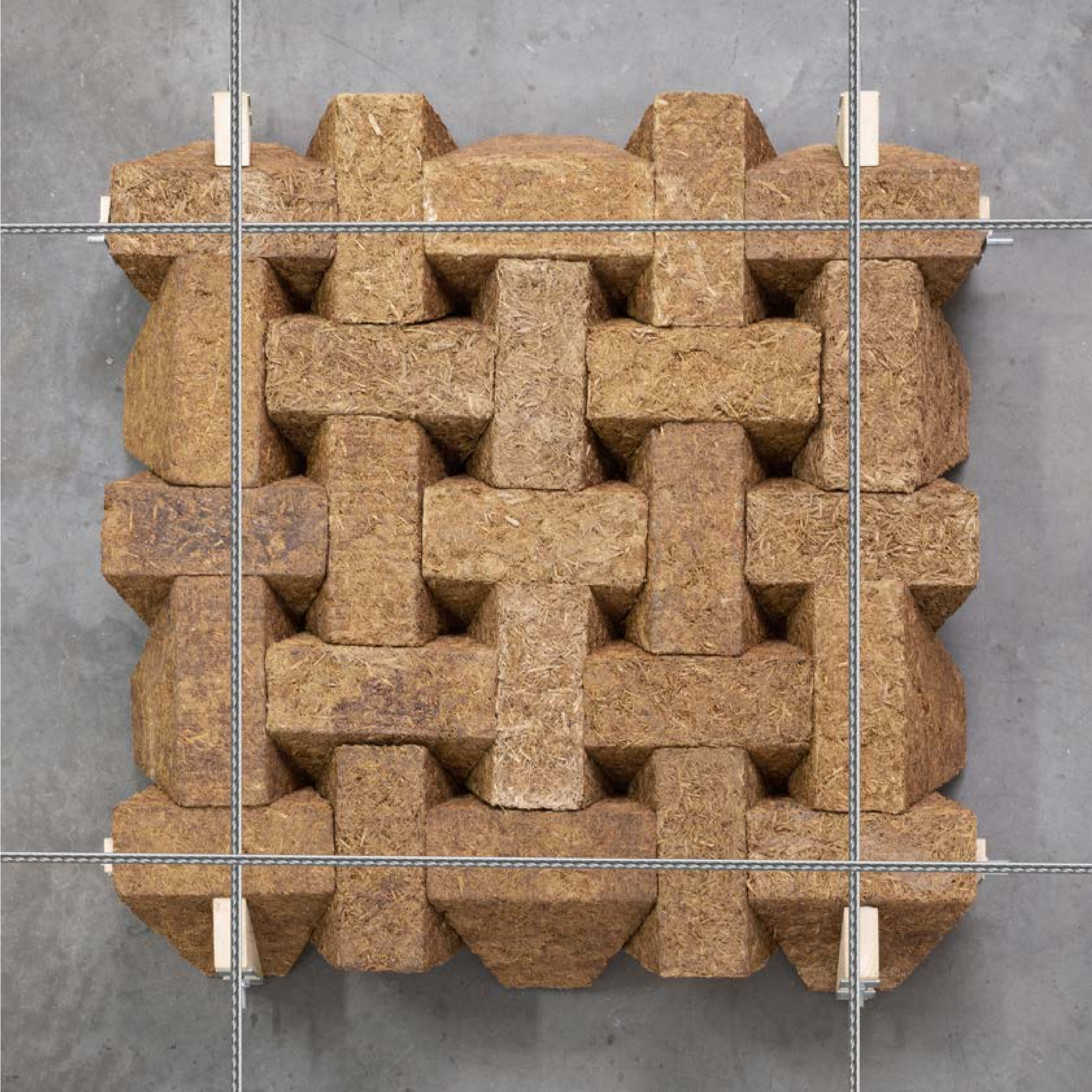
To create a slab spanning 3x3m that would support the weight of a person (100kg), we would need a support rod that has the tensile strength capacity of over 10kN. Therefore the capacity of the rod would need to be calculated on the base of:
Tensile strength required to support a person x Rod tension applied to the system

Assuming this tensile strength is around 10kN and the maximum amount of tension we can achieve is 5-10kN, then the rod tensile capacity would be around 15-20kN.

	Cross section	Breaking load (KN)	Breaking load (Kg)	Weight	Carbon footprint 4x1m	Price	Carbon footprint per unit of strength*
Blue Ocean nylon (recycled marine plastic) 450kg/t CF	6mm 8mm 10mm	12.5 23.1 33.1	1,390 2,560 3,690	110 g 190g 300g	+0.005kg +0.08kg +0.13kg	£5.6 £7.8 £11.8	+0.3
Dyneema Rope 7,000kg/t CF	6mm 8mm 10mm	31.3 51.9 77.4	3,200 5,300 7,900	104g 160g 220g	+0.7kg +1.12kg +1.54kg	£9.8 £13.5 £19.6	+0.01
Hemp rope -1,000kg/t CF	6mm 8mm 10mm	3.4 5.34 6.9	350 545 705	100g 180g 296g	-0.4kg -0.7kg -1.184kg	£1.52 £2.36 £2.88	-17.1
Steel cables/threaded rod 1,850kg/t CF	6mm 8mm 10mm	20.00 35.60 55.60	2,039 3,630 5,669	380g 550g 970g	0.7kg 1 kg 1.75kg	£8.2 £11 £19.5	+3.1
Carbon fibre 29,500/t CF	2mm	50	5,098	5g	0.2kg	£5	+9.8

*Carbon footprint/breaking load *100

Fig.26 - Comparison of Reinforcement Types



06 Tension and Compression

To test the structural stability of the slab with the tension support rods we gradually loaded with weight in the form of people.

The first person stood directly in the middle, with a more even distribution of weight as each person climbed on.

The average weight of a person is 75kg, and our prototype fit 8 people giving it a final load capacity of 600kg.


P&J Dust Extraction Ltd





07 FIRE TESTING

(a)

Fire Testing involved manually applying heat onto two 100x100x100mm sample blocks of different bagasse mixtures using a flame torch at 1,000 degrees for 1 minute.

The mixture ratios of each block in terms of volume were as follows:

Sample 1:
1 part Non-sieved Bagasse, 3 parts Sodium Silicate

Sample 2:
1 part Sieved Bagasse, 3 parts Sodium Silicate

In summary, the blocks exhibited a very strong resistance to the flame, as well as exhibiting strong thermal resistance. The direct area of contact turned black and showed some degredation on first look, however on further inspection the material became stronger. Usually you would expect to find an ashy residue left behind that would transfer if rubbed, however there was no such residue here. Immediately after testing, while the block was still very hot, the reverse side was completely cool to the touch, and the effect of the fire had only penetrated around 7mm in depth.

Fig.27 - Microscoping Image at X100.00 of Sugarslab after Fire Test

Fig.28 - Microscoping Image at X50.00 of Sugarslab after Fire Test

Fig.29 - Burn at 15 Seconds

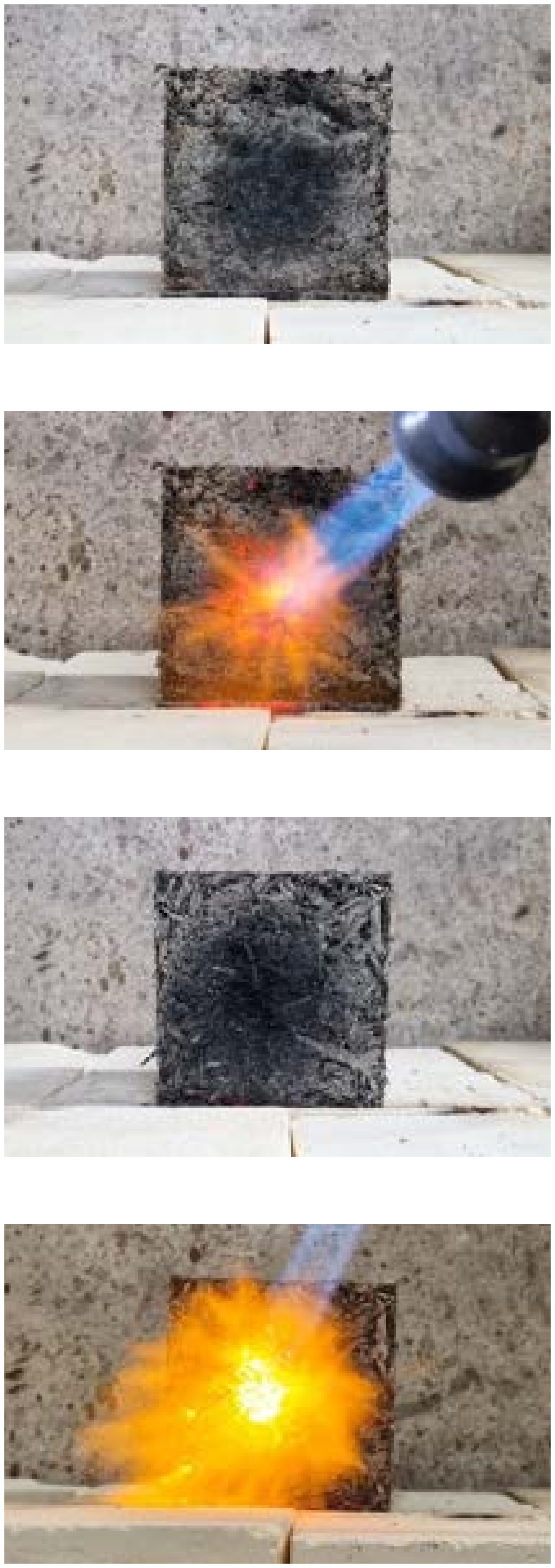


Fig.30 - Burn at 30 Seconds

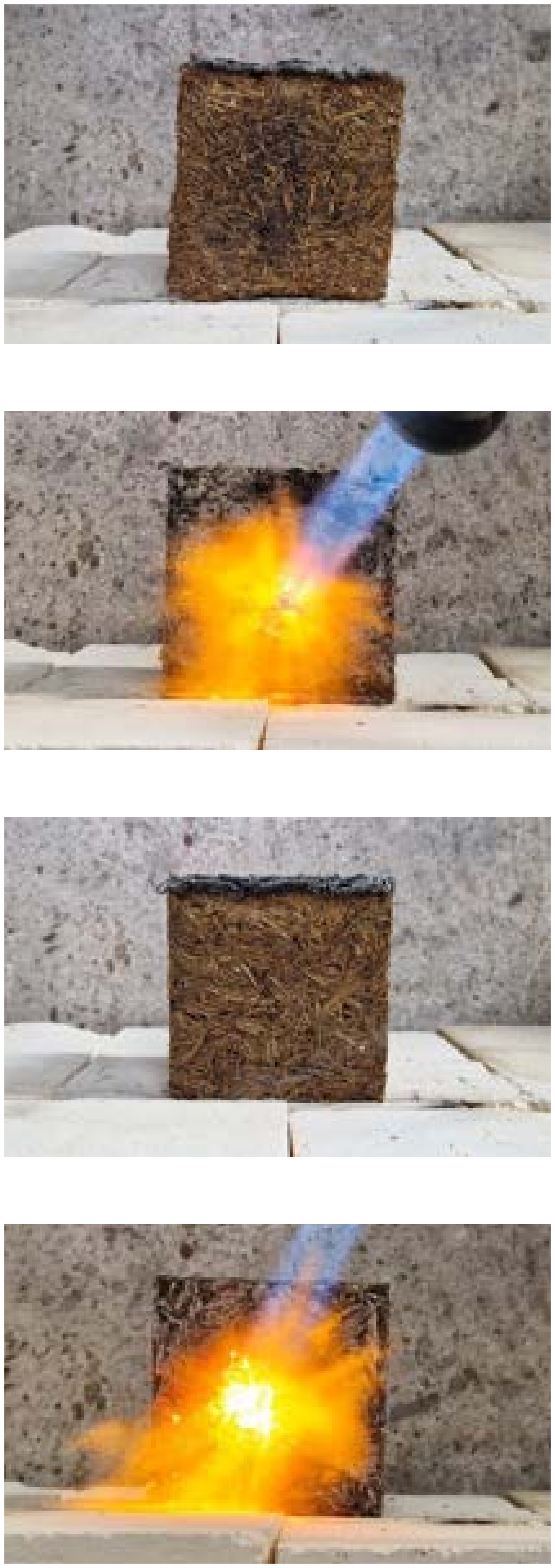


Fig.31 - Burn at 45 Seconds

07 FIRE TESTING

(a) Lime Bagasse Samples

Previously we had tested four 100x100x100mm blocks however the blocks were made using bagasse, water and lime. These blocks were burnt using a flame torch over a 7.5 minute period.

Sample 1:
1 part water, 2 part lime, 2 part bagasse

Sample 2:
1 part water, 2 part lime, 3 part bagasse

Sample 3:
1 part water, 1 part lime, 4 part bagasse

Sample 4:
1 part water, 1 part lime, 3 part bagasse

The fire resistance for a standard brick 215x102x65mm is between 60-240 minutes.

The fire resistance for Sugarslab block 100x100x100mm is approximately 60 minutes.

Fig.32 - Before Burn

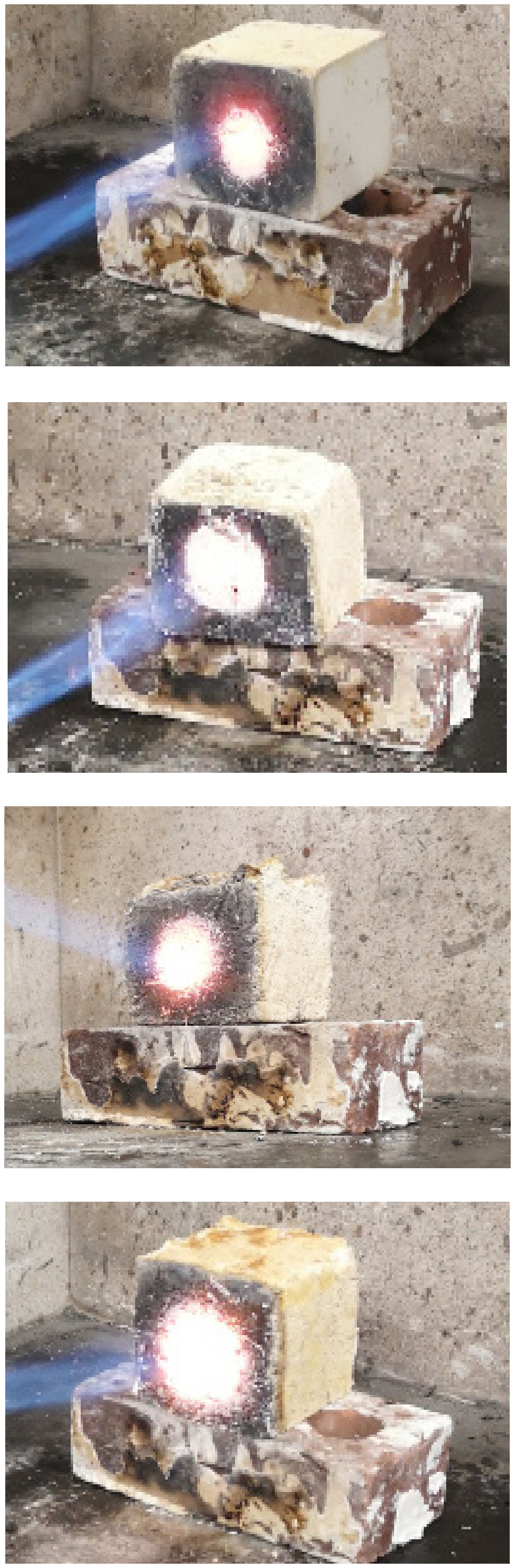


Fig.33 - After Burn

Results from Lime Bagasse Samples

	Sample 1	Sample 2	Sample 3	Sample 4	Summary
Burning description for Minute 7.5	The surface slowly turns black. There is no crack developed. It takes 1 minute for a white mark to be seen. The heat was not spread eas-ily.	The surface gradually turns black. There is no crack develop. It takes 45 seconds for a white mark to be seen. The heat was not spread eas-ily.	The surface instantly turns black. There is no crack develop. It takes 30 seconds for a white mark to be seen. The heat was not spread eas-ily.	The surface immeadiately turns black. There is no crack develop. It takes 15 seconds for a white mark to be seen. The heat was not spread easily.	The prototype with more lime was harder to burn.
Diameter of burnt spot	3cm. The smallest burning spot	4cm. A small burning spot	5cm. A big burning spot	7cm. The biggest burnt spot	The prototype with more lime have a smaller burning spot.
Condition of opposite surfaces	The opposite surface of burnt spot was at room temperature				The prototype does not spread heat easily.
Strength of the proto-type (Refer Chapter 6 : The compres-sion test on)	Easiest to break (break at XX kN)	Medium to break (break at XX kN)	Hard to break (break at XX kN)	Hardest to break (break at XX kN)	The prototype with more lime breaks easier.

In conclusion bagasse lime does not combust in high temperature and high heat. The combination of bagasse and lime can withstand heat even at 900 to 1200 degree celcius. It is suitable to use as insulation material in construction.

Sugarslab with sodium silicate is also a great fire resistant material which can be used as insulation as well. When the sodium silicate binded block was burnt it created an almost crystalised surface which slowed down the burning slightly. It would be interesting to see how the block reacted if more heat was applied at a longer time period.

0.7 COMPRESSION TESTING
(b)

Compressive strength is the ability of a certain material or structure, to withold loads applied to it. This is calculated by measuring the force also Newton (N) per unit area (mm2) - resulting in Mega Pascal (MPa) also defined as N/mm2=MPa

Compression tests involved manually applying compression onto four 100x100x100mm sample blocks of different mixture ratios, determining the force at which the blocks crack and at which they lose 20% of their volume.

The mixture ratios of each block in terms of volume were as follows:
Sample 1:
3 part sodium silicate, 3 parts Bagasse
Sample 2:
3 part sodium silicate, 3 parts Bagasse
Sample 3:
3 part sodium silicate, 3 parts Bagasse
Sample 4:
3 part sodium silicate, 3 parts Bagasse
Sample 5:
3 part sodium silicate, 3 parts Bagasse
In summary, the blocks exhibited bearing capacity lower than typical commercially availabe bricks and concrete blocks blocks. It appears that the the higher the lime to bagasse ratio, the better compressive strength the block would have.
The strongest mixture ratio, although lower in strength than a typical block, can still be considered comparable to blocks. Further research and experimentation may produce blocks of strenghts equal to typical blocks.

<u>Waste Bagasse:</u> We believe that the waste Bagasse could be used for more productive and environmental solutions rather than just burning it for electricty. In order to do shift from the current use to our vision, we have to make sure it is more efficient to use in construction rather than burning it.

Dimension(mm)	-	100x100x100
U Vaule(W/mK)	-	0.065
Compressive trength(KN/m2)	-	60
Carbon Footprint(KgCoe)	-	-0.061
Weight:Amount(Kg)	-	0.445
Unit Cost	-	_

Fig.34 - Compression Test Machine With Proving Ring

	Material Comparisson		
	Material	Cracks at	20% Volume Loss at
	Typical Bricks	15.0-70.0 N/mm2	N/A
	Typical Concrete Blocks	2.8-10.0 N/mm2	N/A
Sugarslab	1L/2W/2B	1.84 N/mm2	2.76 N/mm2
	1lL/2W/3B	0.58 N/mm2	1.15 N/mm2
	1L/1W/3B	0.23 N/mm2	1.27 N/mm2
	1L/1W/4B	0.28 N/mm2	0.58 N/mm2
	4B/15SS	4.905 N/mm2	N/A
	4B/17SS	4.905 N/mm2	N/A
	1B/5SS	4.905 N/mm2	N/A

Fig.35 - Material Comparison

<u>Comparison to other building materials compressive strength:</u>
Steel- ranges from 275 N/mm2 to 900 N/mm2
Timber- softwood- 6.8 N/mm2, harwood 12.5N/mm2
Brick - ranges from 5 N/mm2 to 25 N/mm2


Fig.36 - Cracks


Fig.37 - Shrinkage

Test Sample 1

3SS / 3B

Cracked at 1.84N/mm2

20% volume loss at 2.76N/mm2

Test Sample 2

3SS / 3B

Cracked at 0.58N/mm2

20% volume loss at 1.15N/mm2

Test Sample 3

3SS / 1CC / 3B

Cracked at 0.23N/mm2

20% volume loss at 1.27N/mm2

Test Sample 4

4SS / 2CC / 3B

Cracked at 0.28N/mm2

20% volume loss at 0.58N/mm2

Test Sample 5

3SS /1 CC / 4B

Cracked at 0.28N/mm2

20% volume loss at 0.58N/mm2

07 COMPRESSION TESTING
(b)

Fig.38 - Before Compression

Fig.39 - After Compression

Test Sample 6

820ml Water - 1200g Quick Lime

41:60

2.5MPa

Test Sample 7

1200ml Water - 1200g Quick Lime

1:1

1MPa

Test Sample 8

1200ml Water - 1080g Quick Lime - 120g Bagasse

10:9:1

Test Sample 9

800ml Water - 1140g Quick Lime- 60g Bagasse

40:57:3

0.32MPa

Test Sample 10

1000ml Water-1140g Quick Lime-60g Bagasse - 520g Sodium Silicate

50:57:3:26

0.32MPa

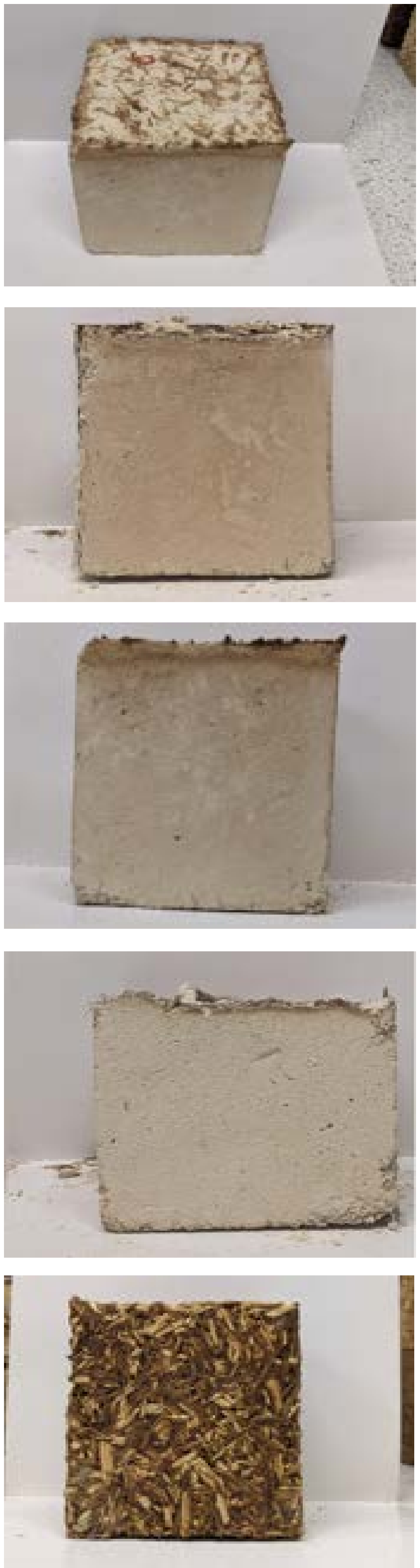


Fig.40 - Before Compression

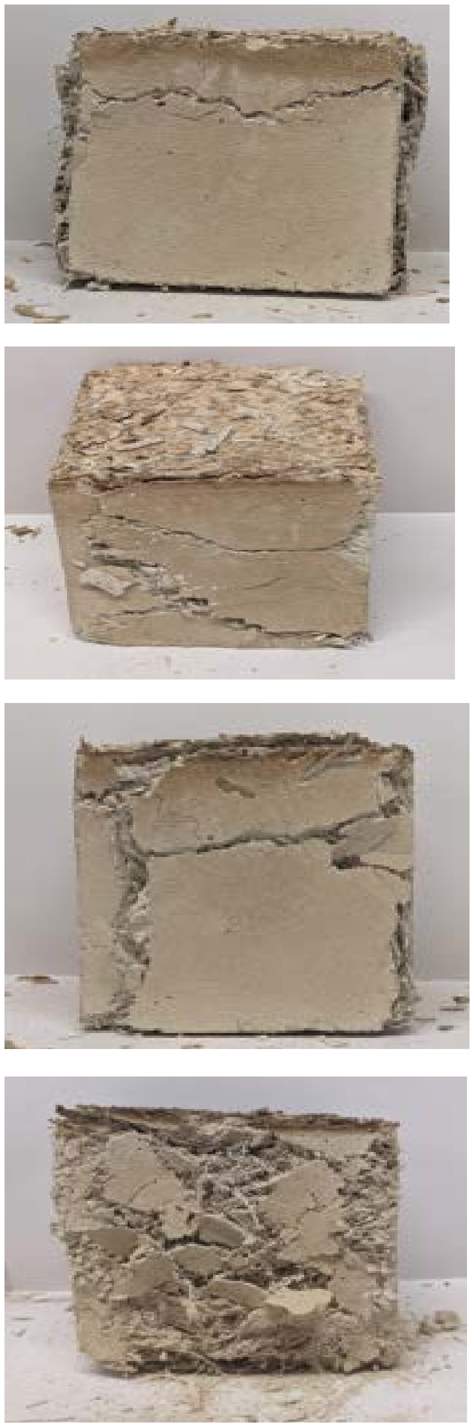


Fig.41 - After Compression

Test Sample 11

700ml Water - 570g Quick Lime- 70g Bagasse

70:57:07

0.086MPa

Test Sample 12

750ml Water- 1200g Quick Lime - 240g Ba-
gasee

25:40:8

Test Sample 13

750ml Water- 1200g Quick Lime- 120g Bagasse

25:40:04

2.3MPa

Test Sample 14

650ml Water- 325g Quick Lime- 140g Bagasse

130:65:28

0.5MPa

Test Sample 15

80g Bagasse- 80g Hemp- 500g Sodium Silicate

4:4:25

3.1MPa

07 COMPRESSION TESTING
(b)

Test Sample 16

40g Bagasse- 120g Hemp- 600g Sodium Silicate

1:3:15

Test Sample 17

160g Hemp - 450g Sodium Silicate

16:45

3.1MPa

__Waste Bagasse:__ We believe that the waste Bagasse could be used for more productive and environmental solutions rather than just burning it for electricty. In order to do shift from the current use to our vision, we have to make sure it is more efficient to use in construction rather than burning it.

Dimension(mm) - 100x100x100
U Vaule(W/mK) - 0.065
Compressive trength(KN/m2)- 60
Carbon Footprint(KgCoe) - -0.061
Weight:Amount(Kg) - 0.445
Unit Cost - _
Comparing to other materials -
Steel 275 N/mm2 to 900 N/mm2
Timber, softwood 6.8 N/mm2, hardwood 12.5 N/mm2

Test Sample 18

200g Bagasse - 750g Sodium Silicate

4:15

4.905MPa

Test Sample 19

200g Bagasse- 850g Sodium Silicate

4:17

4.905MPa

Test Sample 20

200g Bagasse- 1000g Sodium Silicate

1:5

4.905MPa

Fig.42 - Before Compression

Fig.43 - After Compression

Fig.44 - Lime Block Being Tested for Compressive Strength

Fig.45 - Bagasee and Sodium Silicate Block Being Tested for Compressive Strength

Different samples including different ranges of materials were tested including water, quick lime, hemp, bagasse and sodium silicate. After numerous tests and compositions, our winners were made simply by using bagasse and a natural binder - sodium silicate only, resulting in a high compressing strength of 4.905MPa. This is due to the fact that sodium silicate was used to bind this, which made the material as a whole stronger, compared to other compositions which used lime.

There were 3 compositions with this great result,samples 18, 19 and 20. They all had a range of bagasse and sodium silicate. This only leads to further research and testing into these compositions to potentially work on achieving a higher compressive strength. This result is closest to the lowest range of a brick's compressive strength and softwood's compressive strength, however with all the other great qualities of this material that others do not hold, it only suggests how much potential it holds as a whole.

07 (c) THERMAL RESISTANCE TESTING

Tests were carried out in order to assess the material's thermal resistance properties, when compared to a manufactured 50mm thick expanded cork board with known thermal resistance properties.

The tool utilised was a bespoke plywood box with insulated walls, floor and cover. The test materail is placed as a barrier in the middle of the box - separating the interior into a hot and a cold chambers. The hot chamber is equiped with 4no. 100W incandescent light bulbs, controlled via dimmer swithces externally. The temperature in each box is measured with wired thermometers.

As the light bulbs are turned on, increses in temperature in the hot and cold chambers are measured and compared, in order to evaluate the thermal conductivity of the test material.

A 75mm thick testing Sugarslab Board (325g Lime / 675g Water / 80g Bagasse) was used in this experiment. It can be summarised that the board has a comparable thermal resistance to the 50mm cork board. Further tests need to be carried out in order to determine the precise thermal resistance of the board and the overall thermal conductivity of Sugarslab as a material.

Fig.46 - Thermal Testing Rack

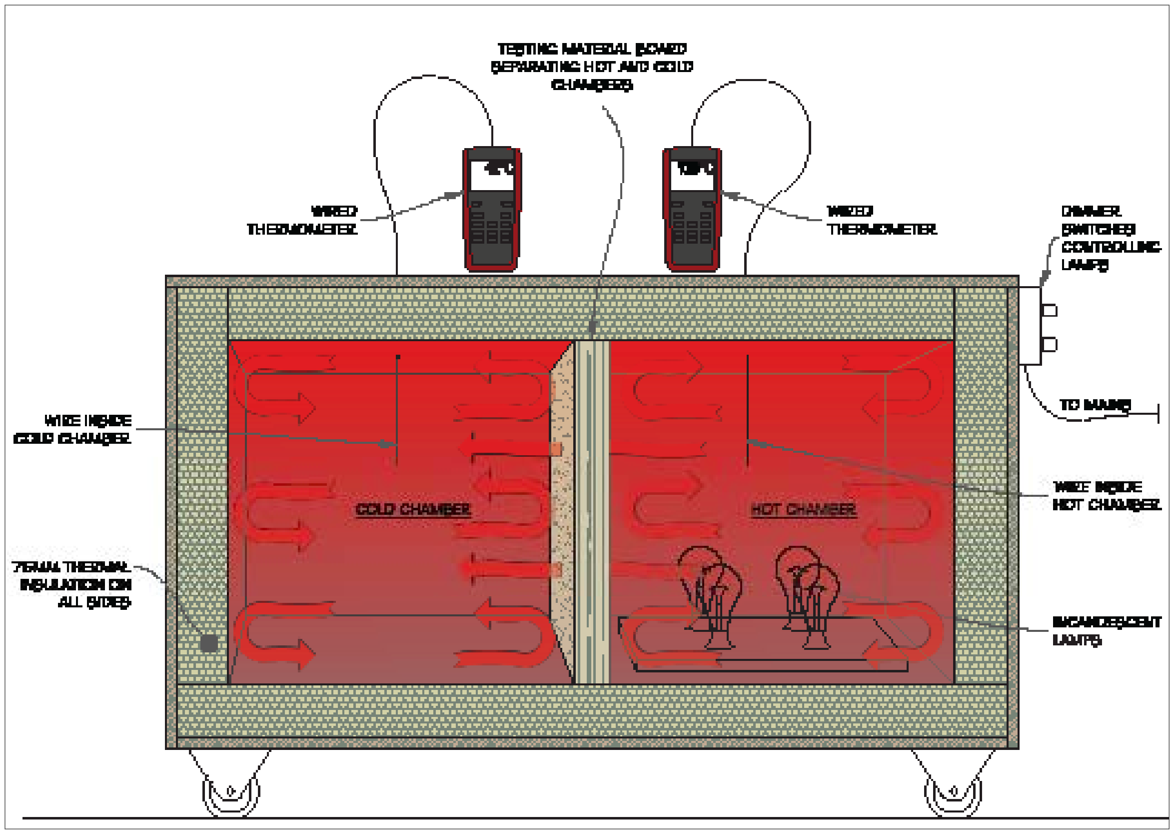


Fig.47 - Thermal Testing Rack Diagram

50mm Cork Board Testing Results

U Value = 0.043W/m*K

d=50mm

K=Q*d/(A*ΔT)

Solve for Q at t=40min
Q=K*A*ΔT/d
Q=0.043*0.185*95/0.05
Q=15.11W - heat transfer to the cold chamber

R=L/K

R=0.05/0.043
R=1.16m2*K/W

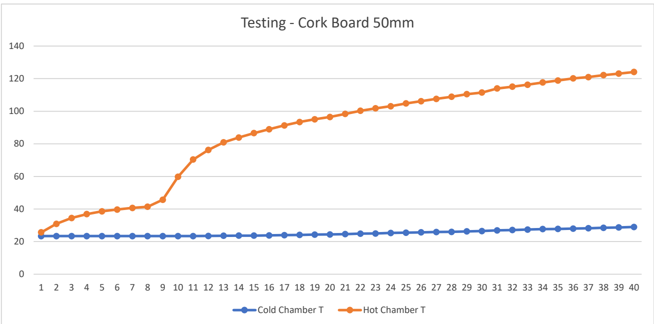



Fig.48 - Cork Board

75mm Sugarslab Board Testing Results

U Value = 1.5 * 0.043W/m*K = 0.065W/m*K

The denser Sugarslab board absorbed and

stored some of the heat energy, hence lower

temperature was reached when compared to the cork test. At 100oC in the hot chamber, the Sugarslab passed a similar amount of heat energy (+1.6oC) into the cold chamber, to the cork (+1.5oC). This suggests that the two have similar thermal resistances. The sugarcrvate board is 50% thicker than the cork board, hence it can be assumed that its thermal conductivity is 50% higher.

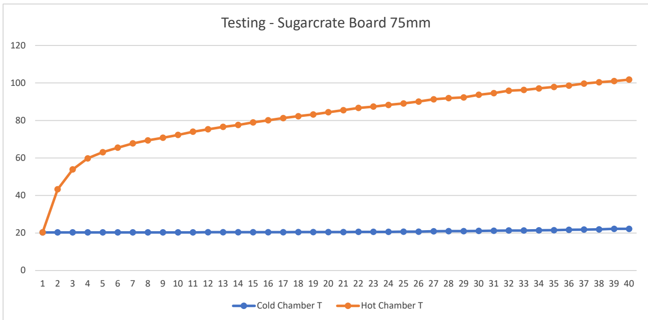



Fig.49 - Sugarslab Board 75mm

50mm Sugarslab Board Testing Results

U Value = =0.268W/m*K

d=0.05m

K=Q*d/(A*ΔT)

Solve for Q at t=40min
Q=K*A*ΔT/d
Qc=22.3
A=0.4x0.45=0.18
ΔT=29.3

K=Qd/A ΔT
22.3x0.05m/0.18m2x(51.6-29.5)
K=1.115/4.158

U Value = 0.268W/m*K


Fig.50 - Sugarslab Board 50mm

07 Carbon Footprint Calculations (d)


Fig.60 - Brick Factory

The current rate of production for brick is 1,500 billion bricks per year.

1 traditional brick has a carbon footprint of **0.904kgCO2/brick.**

The carbon footprint of the brick trade for one year is **1,356 billionkgCO2.**

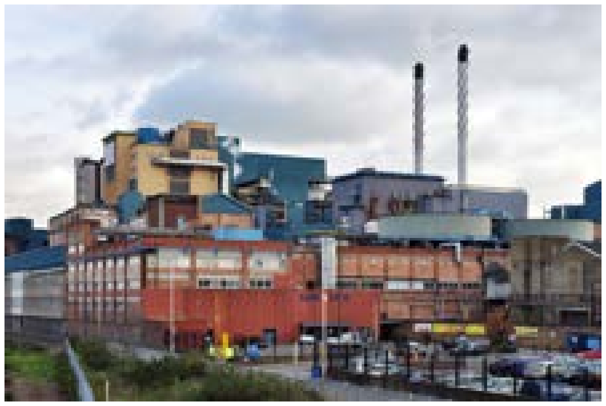


Fig.61 - Tate & Lyle Factory

According to World Sugar Production, **1,949,310,108 tonnes** of sugar are produced worldwide each year. Bagasse accounts for 32% of this at **623,779,234 tonnes.**
Using our Sugarslab formula the amount of Bagasse needed to create a brick of **215x102.5x65mm is 0.14kg.**
Therefore in theory, the equivalent of **4450 billion** bricks worldwide could be produced from the current Sugarcane production each year.


Fig.62 - Sugarcane Farm, Thailand

Considering the sugarcane industry in Europe; Spain, Portugal, and Morocco are our local growers, producing approximately **520,000 tonnes** of sugarcane a year. This could enable the construction of **1,200 million** Sugarslab bricks a year, (in comparison to the 1,800 million standard bricks the UK produces each year).

Potential Carbon Footprint Reduction:

Steel: The average carbon footprint of steel production is 1.85 tonnes of CO2 per tonne of steel.
Timber: A tree can ***store*** roughly 167kgCO2 per year, or 1 tonne of CO2 per year for 6 mature trees.

Sugarslab: The sugarslab carbon footprint is equivalent to 0.192kgCO2/brick, which is ;
- 20% less than a standard brick
- 25% less than steel

According to the Global Status Report for Buildings and Construction 2019, “The buildings and construction sector accounted for 36% of final energy use and 39% of energy and process-related carbon dioxide emmissions in 2018, 11% of which resulted from manufactoring building materials and products such as steel, cement, and glass.“

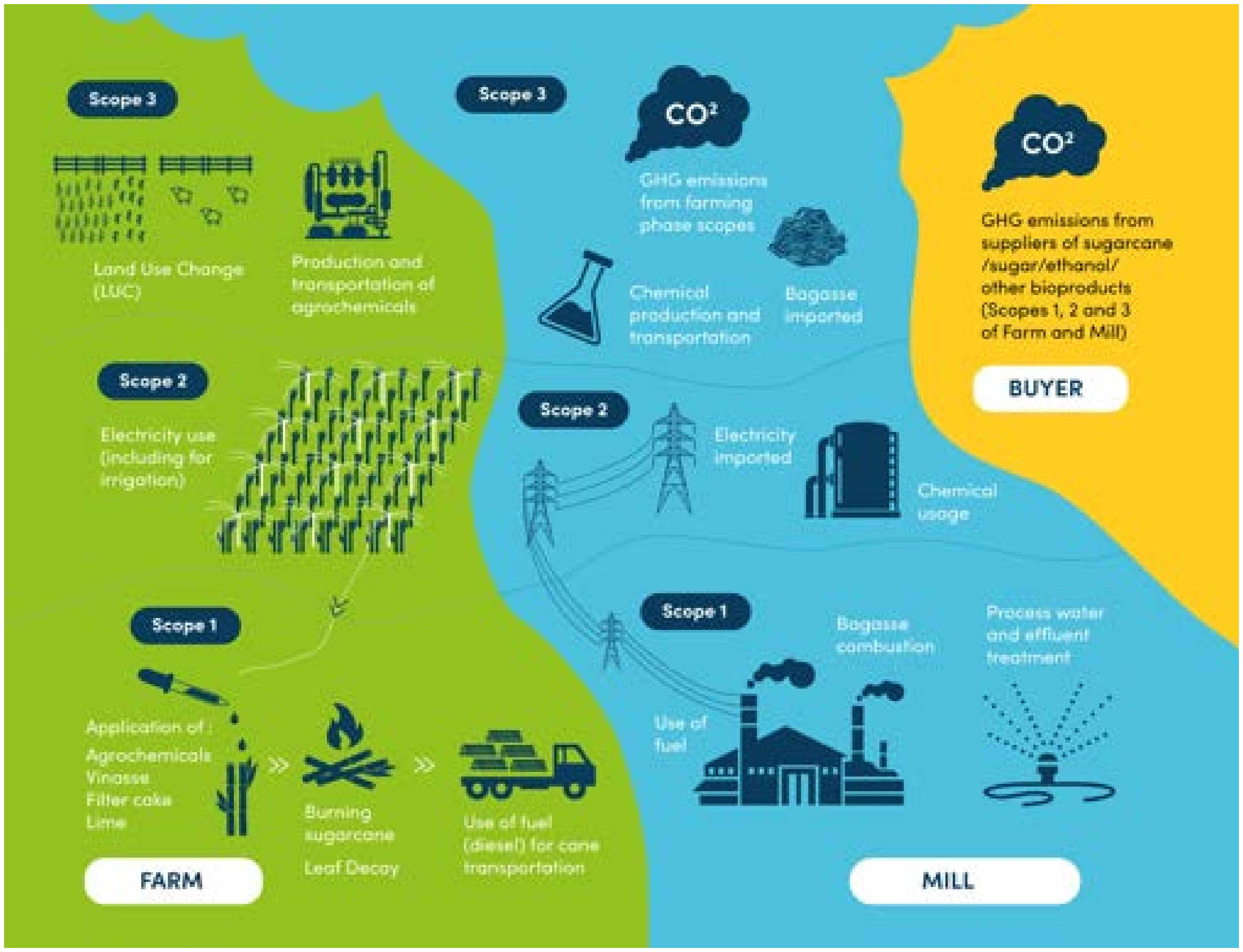


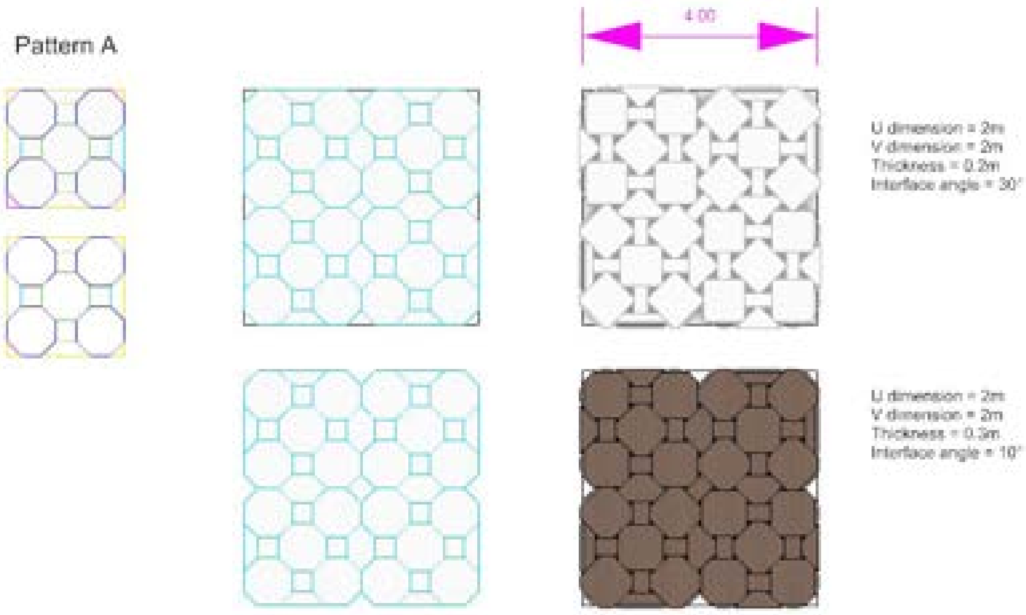
Fig.63 - GHG Emissions in the Sugarcane Value Chain

Farming the sugarcane contributes 77% of the total carbon footprint of the material, whilst the processing phase contributes 23%.

During this processing phase emissions are produced by processing and transporting the chemicals, processing the material, treating the water, and burning the bagasse.

By utilising the bagasse as a building material we can reduce the carbon footprint of the sugarcane industry by approximately 5.75%.

08 Digital Geometry Exploration

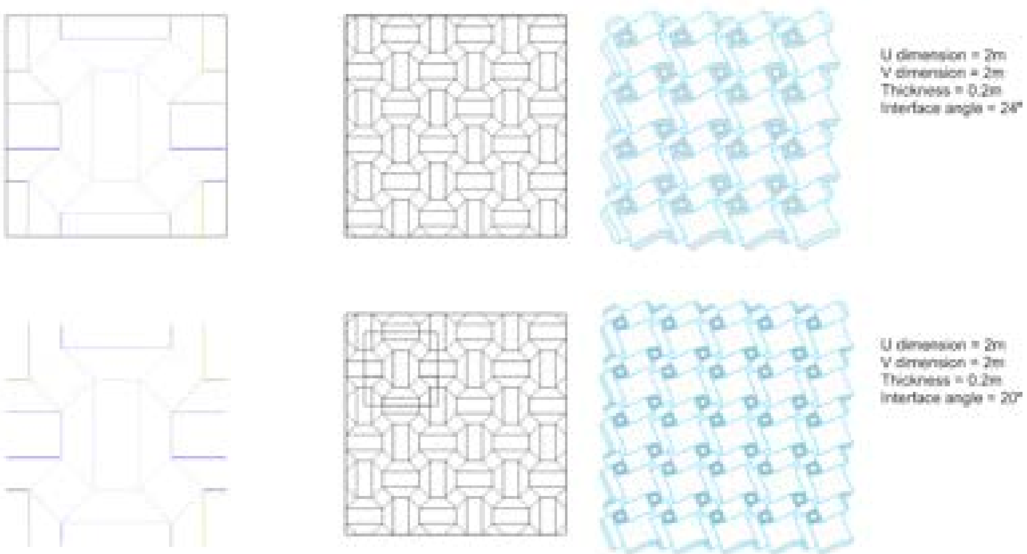


Team Wildfire's Rhino Pattern:

We had two main concerns when designing this pattern: to keep the geometry simple, and reduce any nooks and crannies in the pattern that could become perfect homes for venomous creatures.

Achieving simplicity was the most challenging element. It was integral to the proposal that the pattern was easy to be made by local, untrained workers.

The size of the blocks can be adjusted to change the basic geometry, which is beneficial for different environments. For example, you can create some space between blocks for ventilation. More relevant to our Brazil and Australia proposals, the thickness of the blocks can be changed for their uses.



Team BFA's Rhino Pattern:

The design had to be multifunctional, as the proposed ideas were for water collection to address drought and also air purification. We addressed this by coming up with a simple interlocking design. The two main concerns with the design were that there had to be enough gaps to allow water flow also having 2 different size blocks to create a better surface.

The design could then be structured into a slope form allowing natural flow down from the form to reservoir tanks. Allowing the locals to reuse the water during dry seasons for plantation.

A disadvantage of this design was that there were a lot of pieces to assemble it and also would be time-consuming.

Team HM's Rhino Pattern:

Fig.64 - Grasshopper Script

09 BRAZIL

(a)

Location: Brazil is the largest country in both Sou-th America and Latin America. It has a to-tal population of mora than 210,000,000 people, occupies an area of 8,515,767 km2, and bor-ders Argentina, Bolivia, Colombia, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela.

Climate & Precipitation: Brazil has a humid tro-pical and subtropi-cal climate except for a drier area in the Northeast. Much of the country recei-ves 1,000-1,800 mm precipitation annually, but this often is much heavier in parts of the 9.2aA-mazon basin and the sea-facing rim ofthe Serra do Mar. Temperatures below the equator are high, averaging above 25 °C, with little seasonal va-riation near the equator. Average temperatu-res below the Tropic of Capricorn range from 13 °C to 22 °C.

Industry Location & Production: Brazil supplies 50% of the world's sugar cane, making it the world's top producer and exporter of sugarcane. Annual production currently stands at 654.8m ton-nes of sugarcane per year

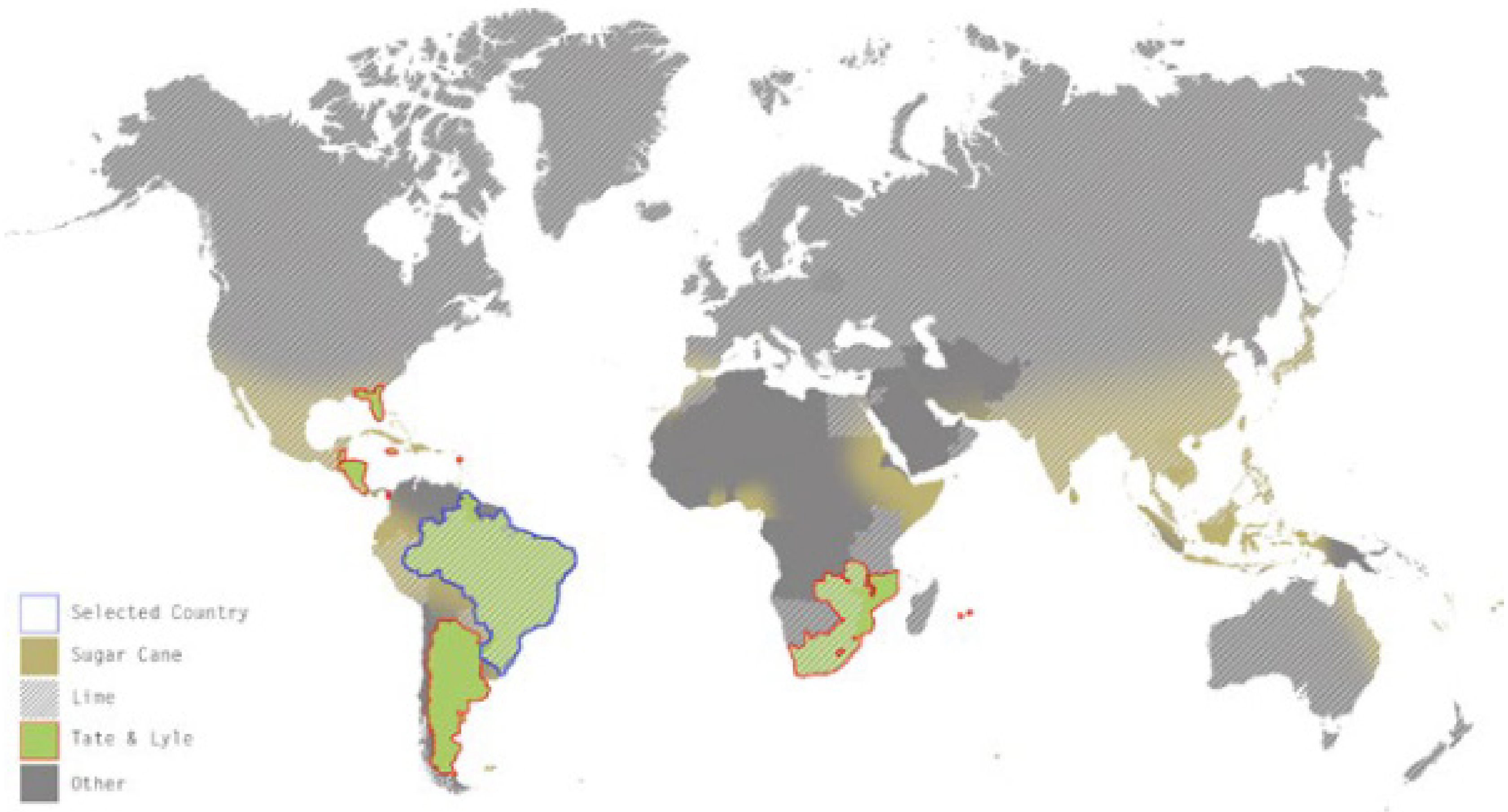


Fig.65 - Brazil in World Map

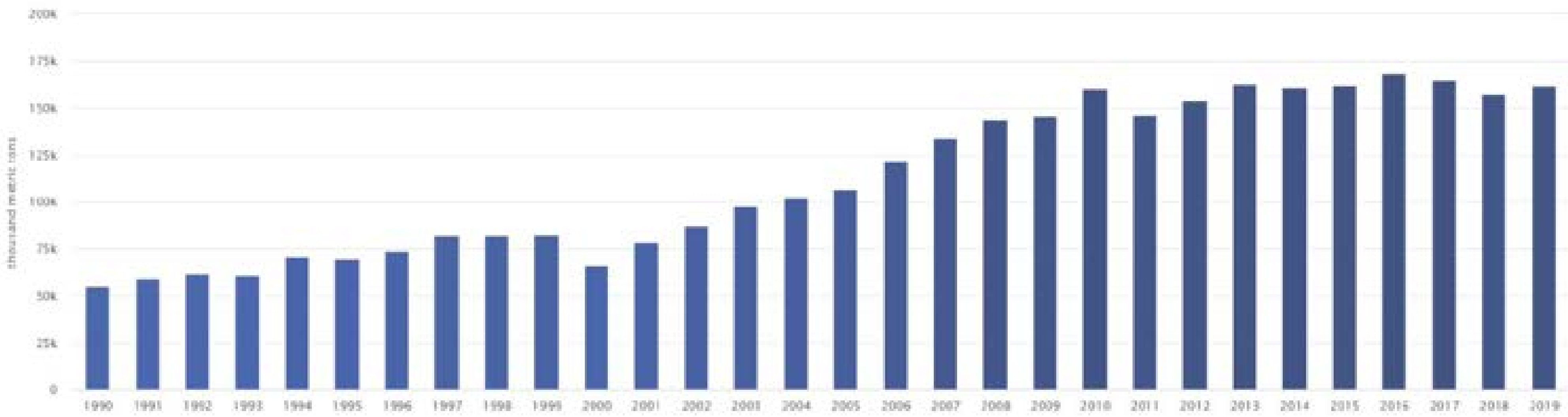


Fig.66 - Bagasse production in the world by year

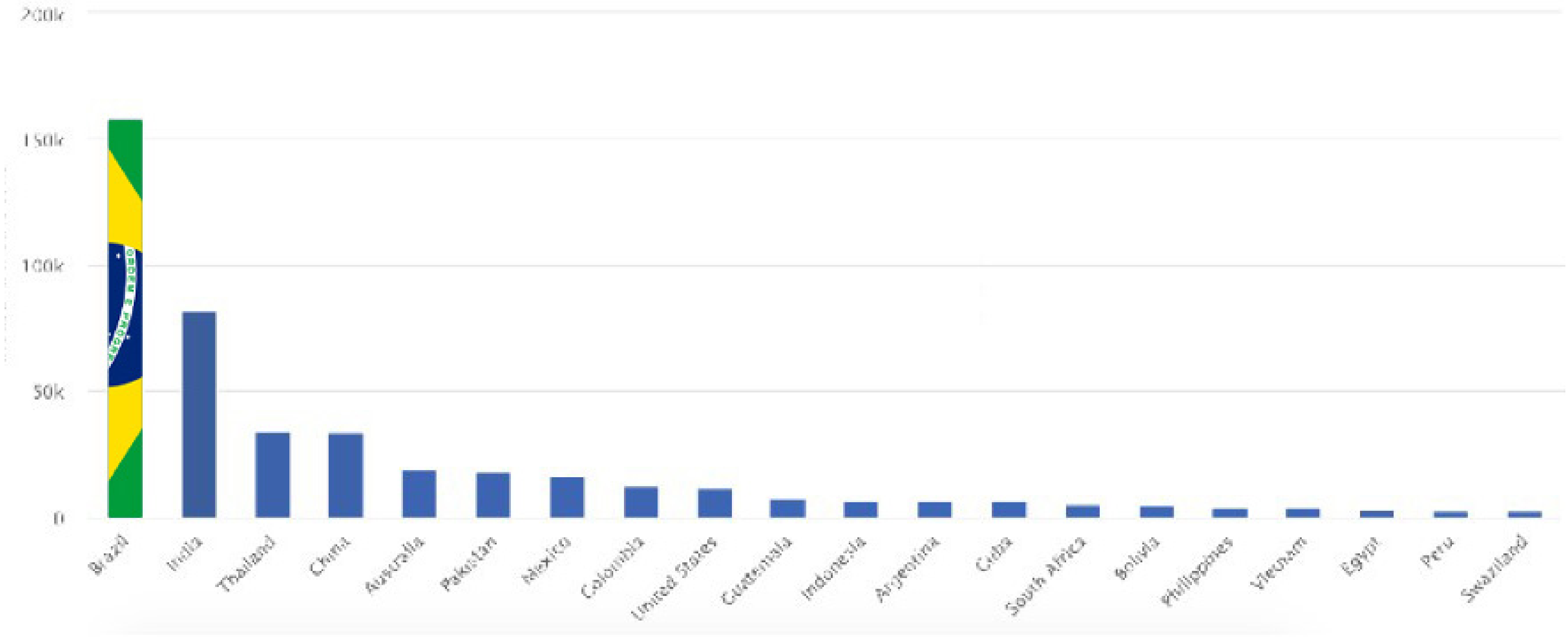


Fig.67 - Bagasse production in the world

09 THE PROBLEM
(a)

There are some great architectural buildings in Sao Paulo. These buildings represent the rich beautiful side of Sao Paulo. On the other hand we have basic design which brings us to favelas which are made by poorer people using any material they can find.

The main materials used intially were corrugated metal sheets, concrete, brick, timber and even cardboard. These materials are just locally sourced from either left over

Most of the plantation workers live in rough conditions and usually commute from the favelas to work. They work very hard just to come back to a small room which is barely holding together. They take years to build their homes as they don't have enough money to renovate their homes. They wait till they find the right materials to build with. Most buildings in Favelas are left incomplete so that when the time comes around they can add to the existing.

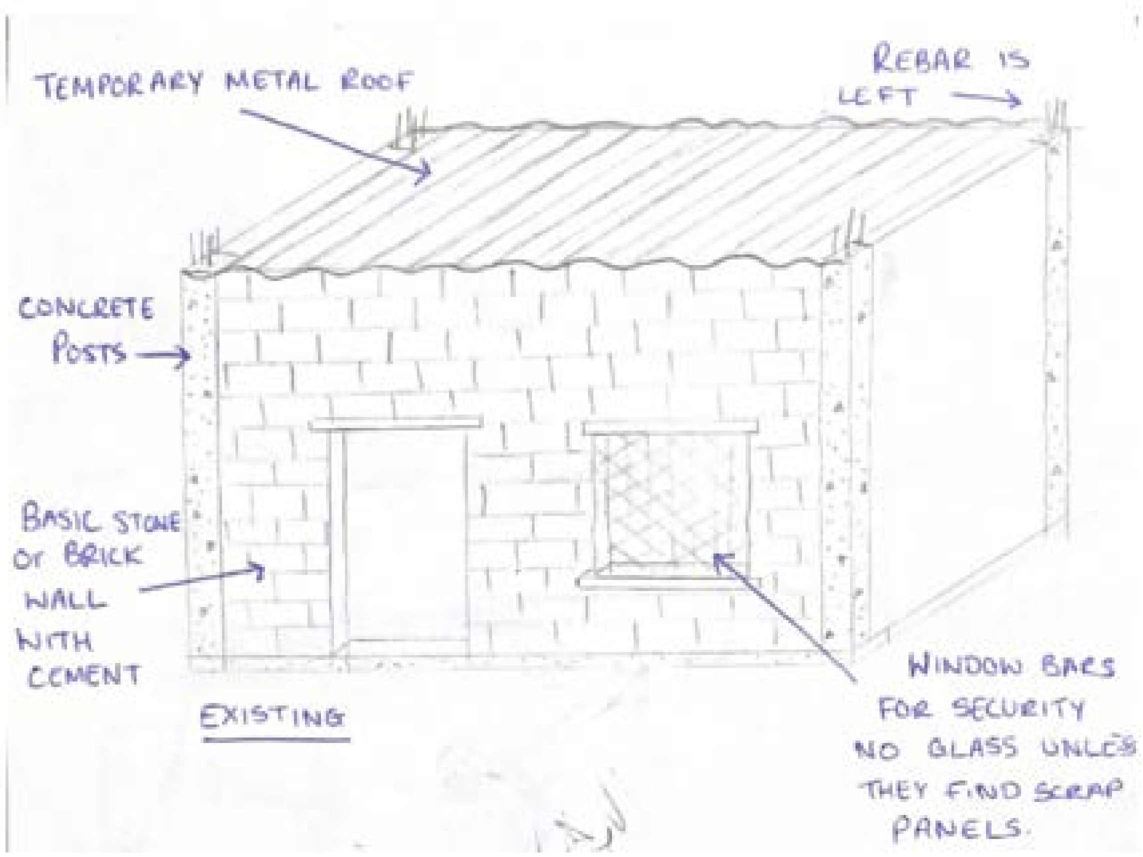


Fig.68 - Existing Structure of Unit

Fig.69 - Existing Environments

From looking in favelas we can see why the system works. Its very low in expenses and provides the basic shelter required.

Using the existing blueprint we can use it to develop a new structure using bagasse. The initial sketches show a rough example of how the unit will be reconstructed,

The bagasse will be used to create building blocks with a sloped geometry to allow the blocks to interlock with eachother with out the use of bonding. The bagasse posts will need to be casted similarlly to concrete posts and possibly include a rebar to be able to build upwards.

The floor/ceiling would be constructed similarly to the floor slab we created at 1:1. It would be tensioned and would be able to be load bearing.

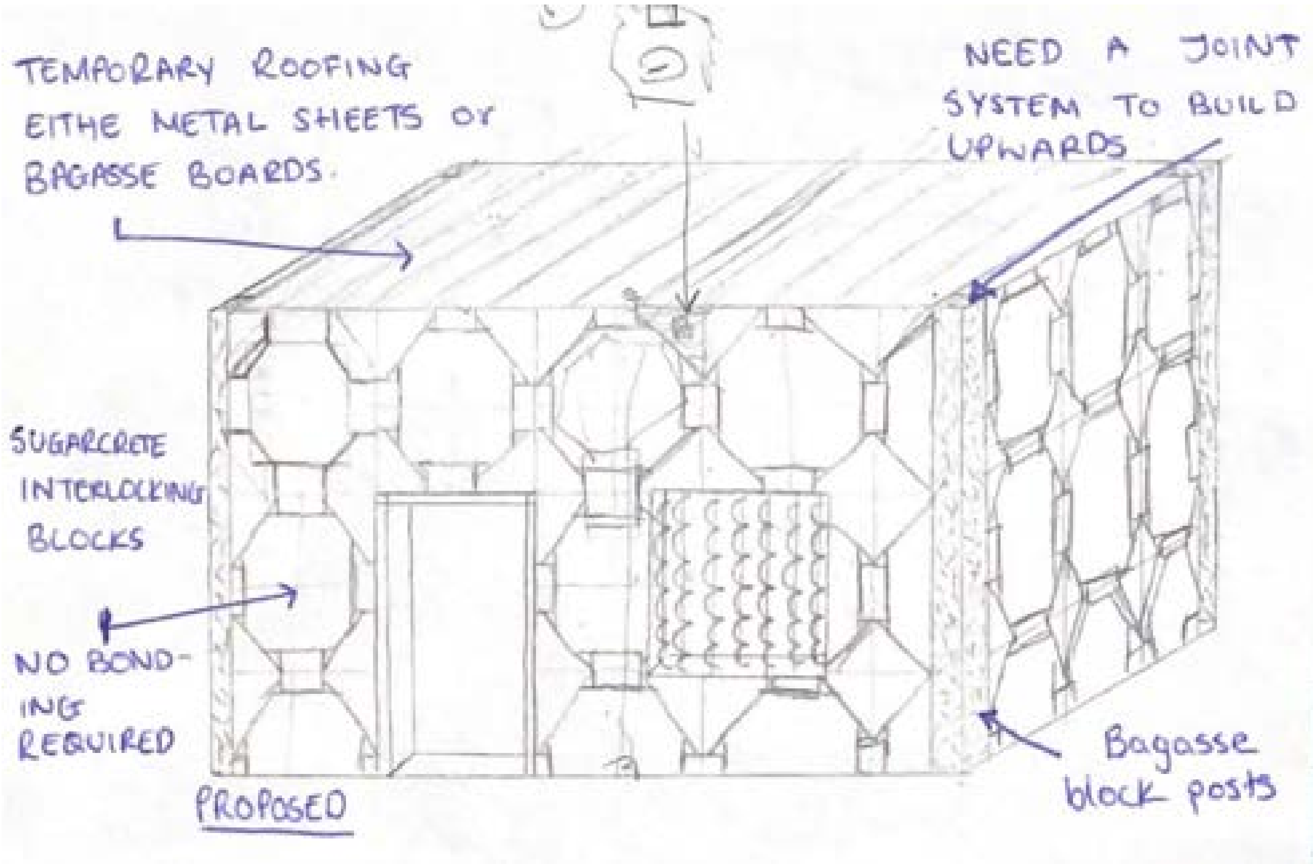


Fig.70 - Existing Structure of Unit

By designing housing units that can be placed on the plantation it completely removes the travel from the favelas to the plantation. The workers will have to use the bagasse to build their own homes as well as help the plantation create Sugarslab during the off season. This would work as a cycle where the workers harvest sugarcane and then switch to material moulding when the harvest is over. This will help to increase the skill set of these workers and provide them with the stepping stones to move to construction.

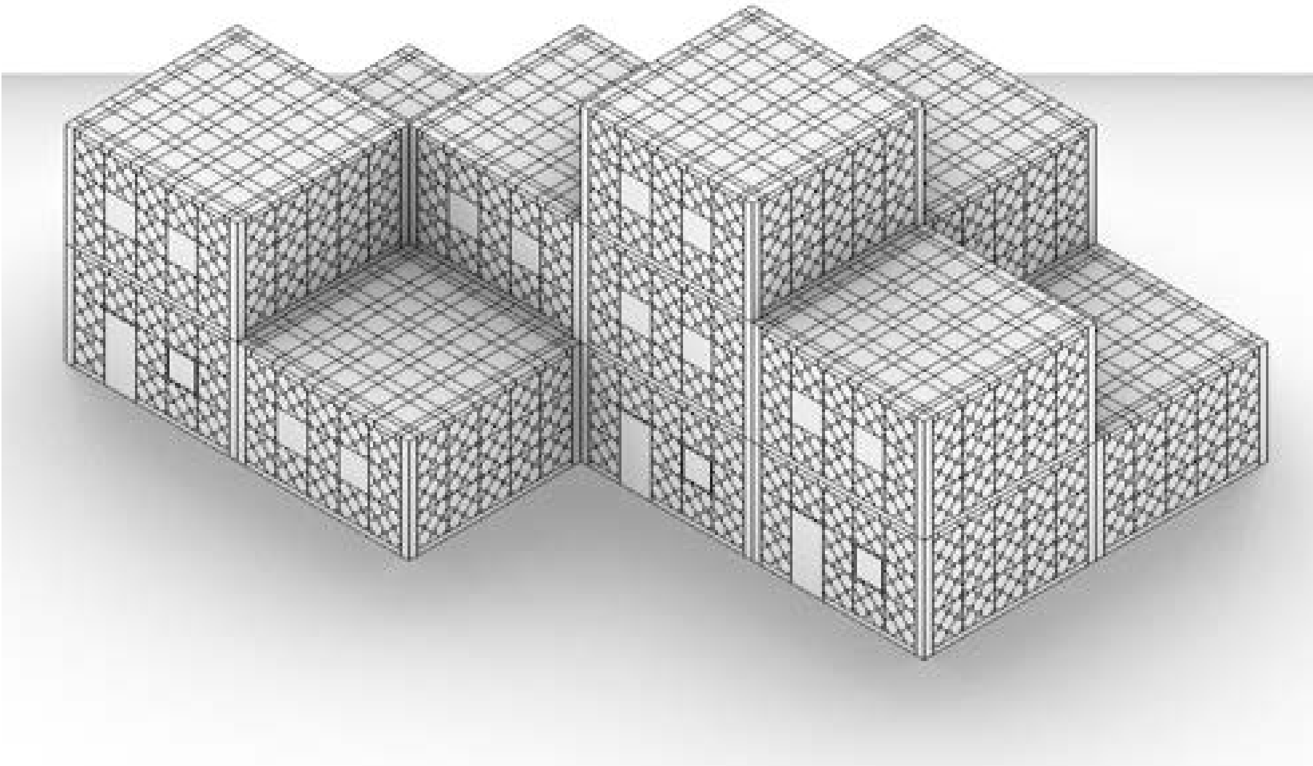


Fig.71 - Existing Structure of Unit

09 THE PROPOSAL
(a)

Potential Solution: Creating sustainable housing for the planatation workers using Bagasse as the key material.

Potential Resources: Bagasse as a by/waste product of the Sugar Cane mills. Natural Bonding can be locally sourced similar to our model. Availability of on-site construction.

The Design:
These singular pods have been design considering the space needed for one room. They can be placed anywhere on the plantation and also be dis assembled and relocated. The shape of the structure allows the building to grow on all 3 axis similar to the favelas.

These units will be easy for plantation workers to assemble and it requires no cement. The thick bagasse block will act as great insulator and aldo keep the unit fire proof. By removing certain blocks it allows the workers to create openings in the structure allowing the creation of doors and windows. The structure will be tensioned by the frame of the unit.

Fig.72 - Wall Structure Using Blocks

Fig.73 - Bagasse Blocks For Wall

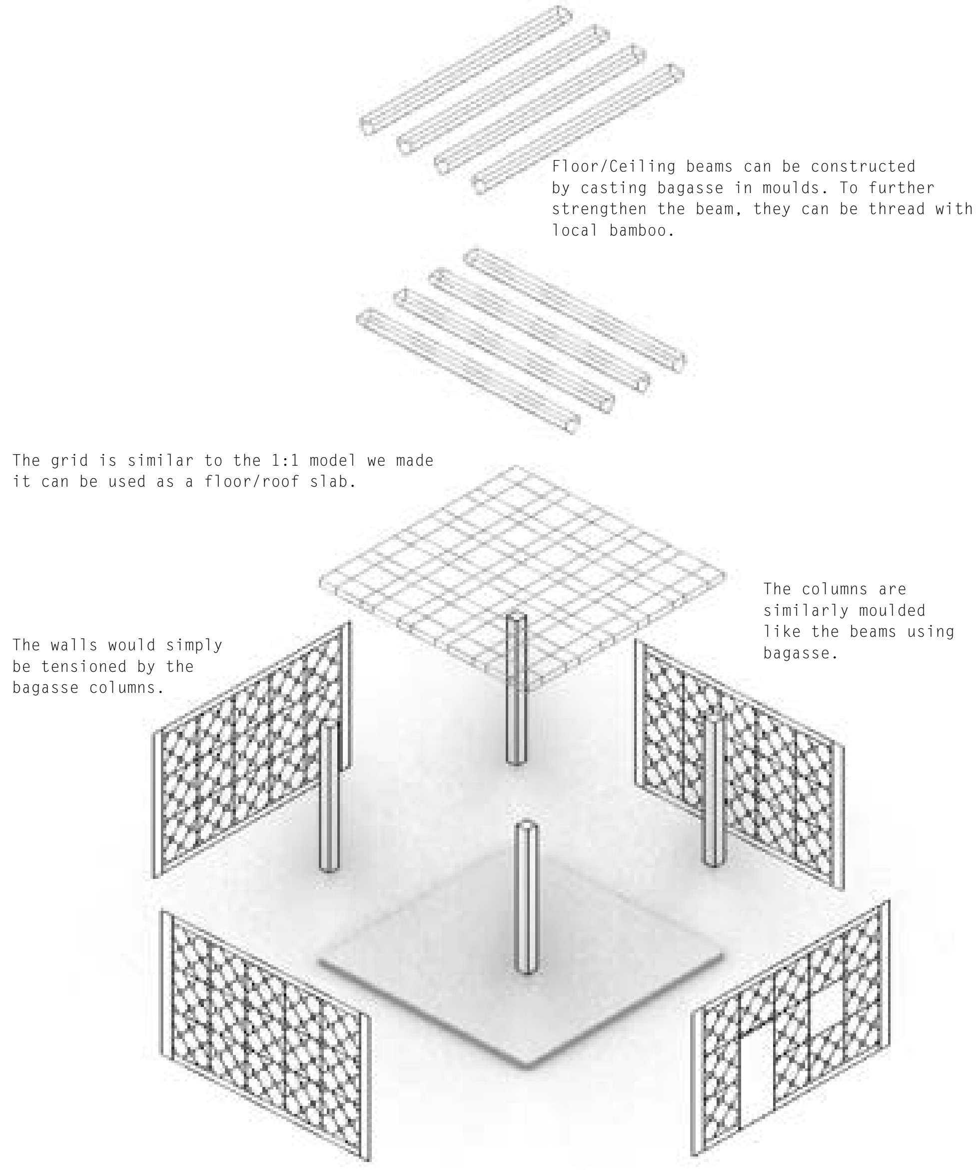


Fig.74 - Isometric Expolsion of Single Unit

09 AUSTRALIA
(b)

Location: Australia is a sovereign country consisting of the main Australian Island, Tazmania, and several small Islands surrounding the mainland. It covers an area of 7,617,930km2, and is crossed through the centre by the Tropic of Capricorn.

Climate & Precipitation: In 2020 Fraser Island suffered a huge wildfire that destroyed land, and caused Hervey Bay and nearby Fraser Coast to be covered in smoke for days. Wildfires in Australia are becoming increasingly common with the rising temperatures and droughts. Since 1910 the temperature in Australia has been steadily rising by 1.5 degrees every year. A climate estimation for 2090, as a worst case scenario, shows that the temperature will have increased by nearly 5 degrees, and the rainfall reduced by 23%.

Industry Location & Production: Australia is the 5th largest producer of Sugarcane, with all of the growing taking place in Queensland.
Hervey Bay is located on the Fraser Coast in Queensland, Australia and is surrounded by the Maryborough Cane Fields. In 2020 the Maryborough Sugarplant was shut down and given just two years to use up the current supply agreements. Growers have been forced to transport their crop to Childers, a 61km journey. Now there are plans to purchase the mill and utilise the sugarcane to produce renewable diesel.

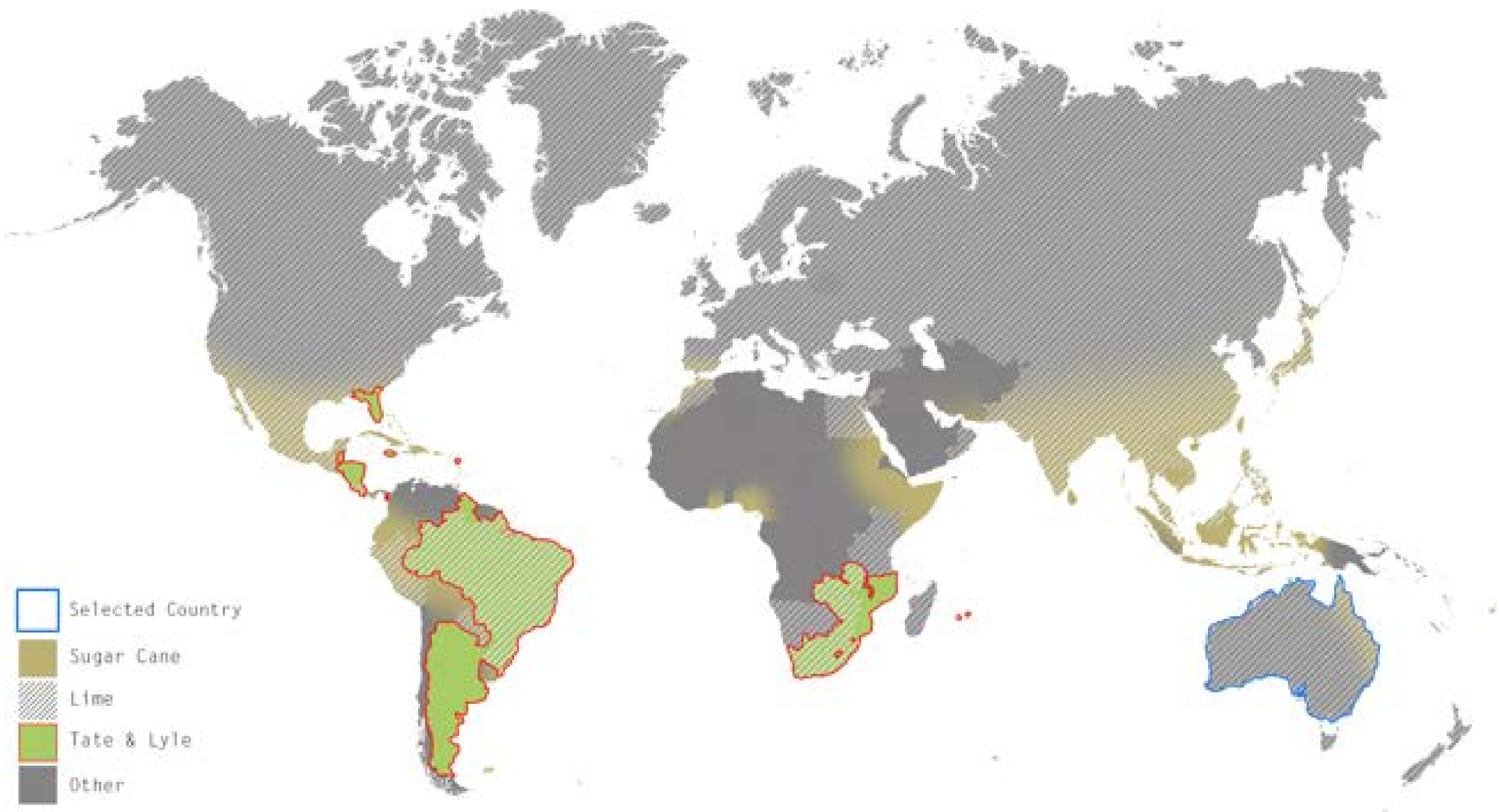


Fig.75 - Australia in World Map

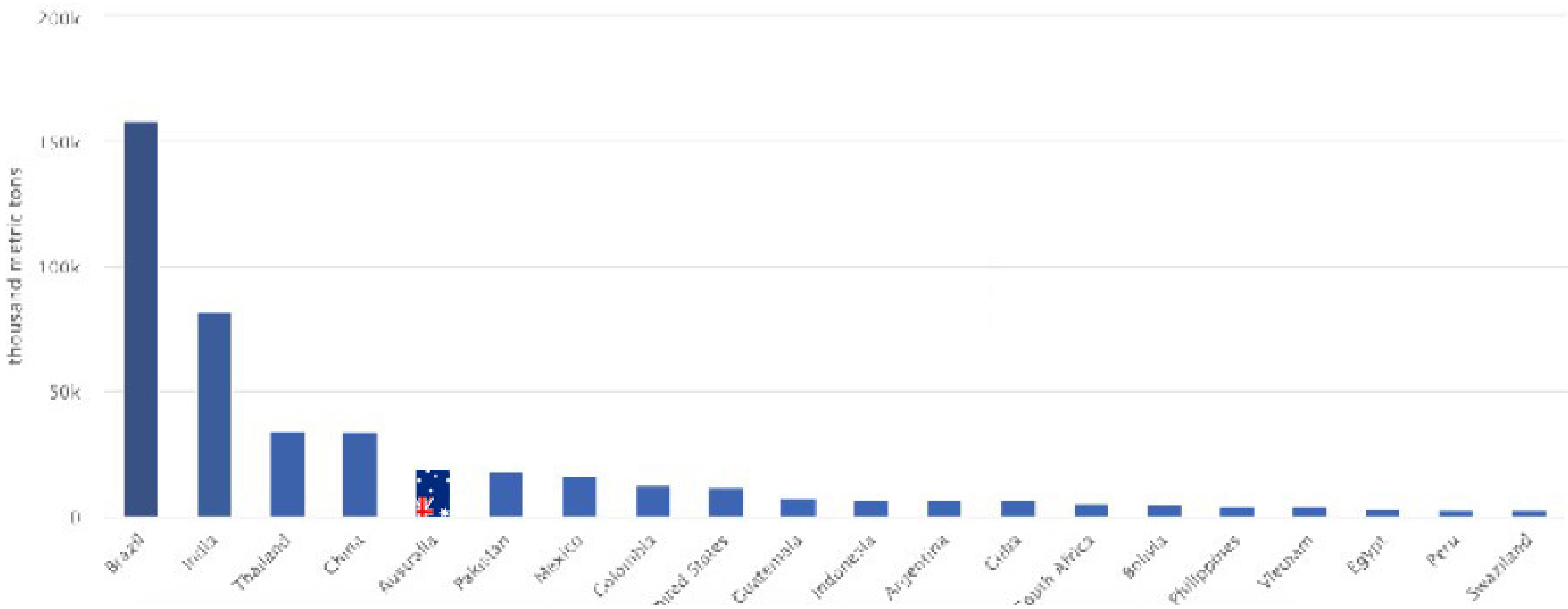


Fig.76 - Bagasse production in the world

Fig.77 - Bagasse production in Australia

Fig.78 - Sugar Cane Farmers The Gillespie Family, 1958

Fig.79 - Sugar Cane Farmers The Gillespie Family, 1958

09 THE PROPOSAL
(b)

Fig.80 - Sugarslab Cladding with Gypsum Board versus Lime Mortar

Fig.81 - Axonometric Exploded Construction Section

There is currently an unknown regarding the weakness in corners/edges, especially for use in cladding. The rigorous testing we have performed have shown the intense strength in the material, but have also shown us that these areas are the weakest. The most important aspect of this design will be making sure that the fire resistance of the product is consistent, and that the benefits are not undermined by these edges. We are still unsure exactly how the joins will work and that is something that needs further development. There is the possibility of coating the cladding with a Gypsum Board and Lime Mortar cladding, or painting the Sugarslab with Lime Mortar directly. The reasons for doing so are for aesthetics, for increasing weather tolerance, and reducing the risk of insects/snakes making their homes amongst the complex geometry of the Sugarslab Cladding.

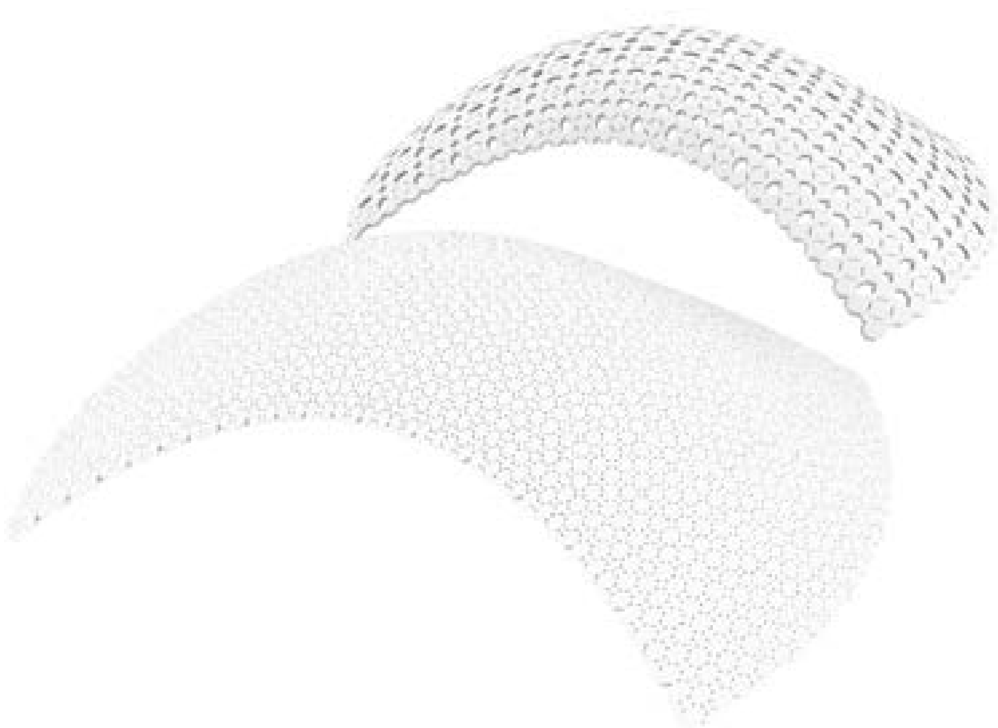


Fig.82 - How Size Affects Pattern

Fig.83 - Block of Flats - Before Cladding

Fig.84 - Block of Flats - After Cladding

Fig.85 - Typical House - Before Cladding

Fig.86 - Typical House - After Cladding

My proposal is to create Sugarslab blocks in two forms; a thin (100mm) cladding with gypsum board and lime finish, and a larger block for new builds. The blocks will be moulded into specific geometric shapes in order to create an interlocking system that can be utilised and recreated in many formations.

The product will be rigorously fire tested, as well as testing compression, water resistance, and thermal mass. This will allow us to assess how efficient the material will be at protecting properties from extreme weather events like fire and floods. The expected outcome is that the properties that currently exist will be upgraded with a new building envelope, which will; help control internal temperatures and consequently reduce energy consumption in air conditioning and heating, extend the life of buildings by future-proofing them against climate change, and allow families to remain in their own homes and therefore reducing the current housing crisis. We also expect an expansion of use across new builds and infrastructure being built in an effort to increase local tourism and provide better social investment for residents.

09 INDIA

(c)

Location:
Kolhapur city is situated on the banks of Panchganga river and is surrounded by Sahyadri mountain ranges in southern part of the Maharashtra state of India.

Climate & Precipitation:

- A lot of rain(rainy season) falls in the months: June, July, August, September and October.
- Kolhapur has dry periods in January, February, March, April, November and December.
- On average, June is the wettest month with 32.8 inch (833 mm) of precipitation.

Industry location and Production:
Kolhapur region is leading the state in terms of sugar recovery rate. The mills have produced 215.72 lakh quintal sugar by crushing 186.67 lakh tonnes of sugarcane with a recovery rate of 11.56 per cent.

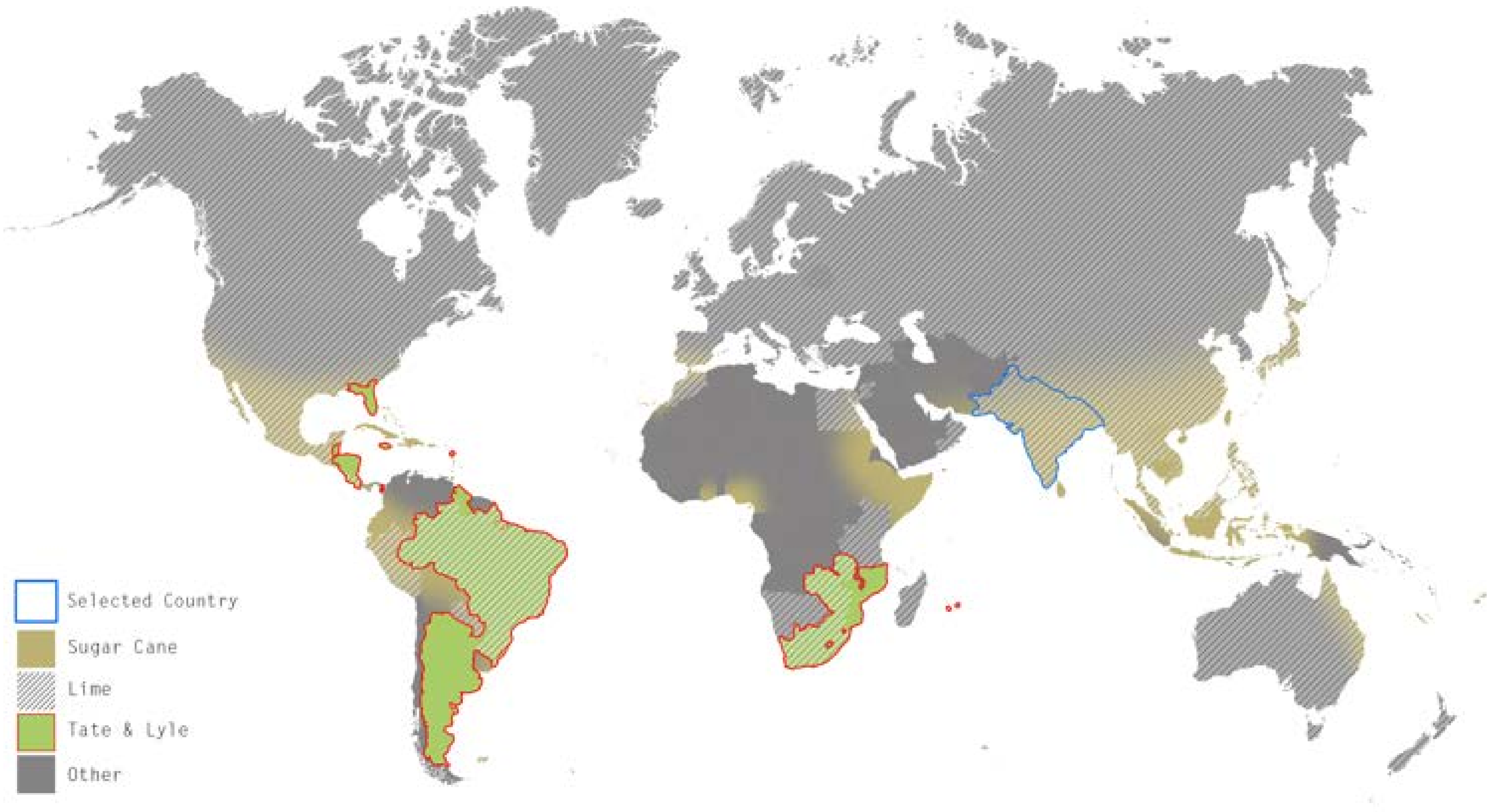


Fig.87 - India in World Map

Fig.88 -Indian Sugarcane Harvest

Fig.89 - Sugarcane Harvest

Fig.90 - Sugarcane Workers

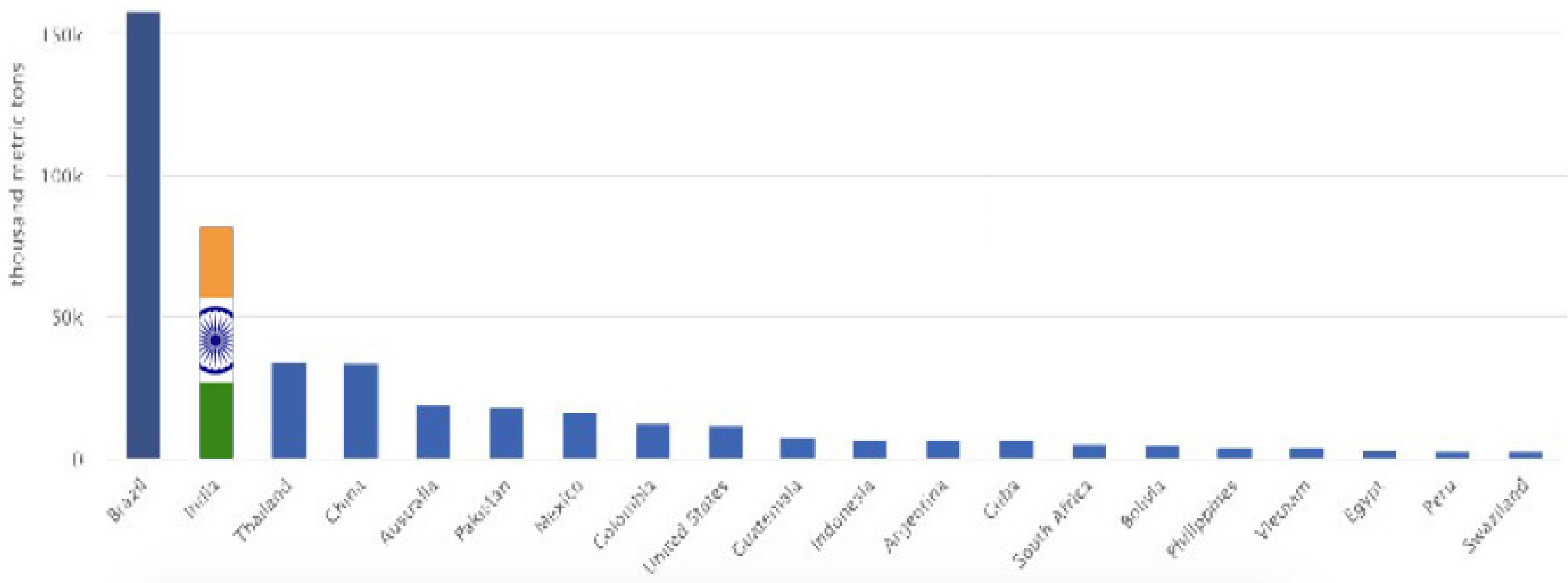


Fig.91 - India in World Map

09 THE PROPOSAL
(c)

Potential Problems:

- People here are very disturbed due to the regular floods they cause during rainy season.
- As they need to reconstruct their shelter
- 100% Damage and loss the suffer with their sugarcane farms, which results in huge economical and financial crisis.

Potential Resources:

- Bagasse as a waste product of the sugar cane farms.
- Abundance of earth and kaolin clay.
- The central region of the district has brown fertile soil while the eastern region of the district has black soil.
- Due to the presence of phosphorus in the soil the overall land of Kolhapur district is suitable for plantation of Sugarcane.

Fig.94 - Damage of Sugarcane Crops Due to Flood

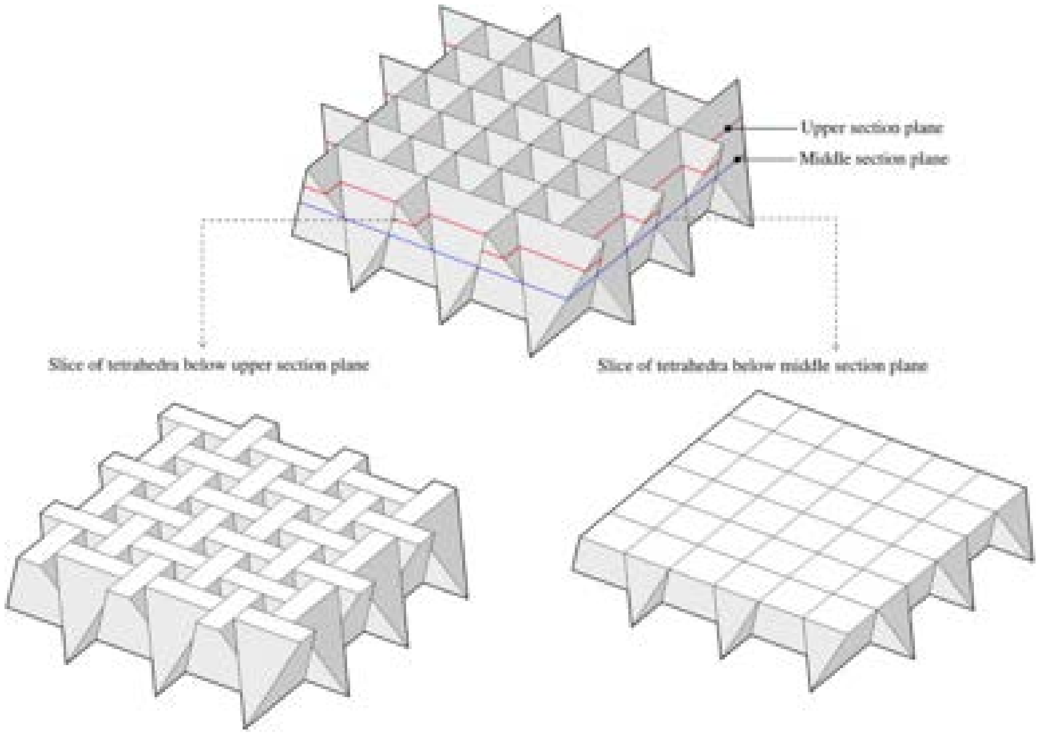


Fig.95 - Interlocking Pattern Used

Fig.92 - Damage of Farms Due to Flood

Fig.93 - Shelters Destroyed Due to Flood

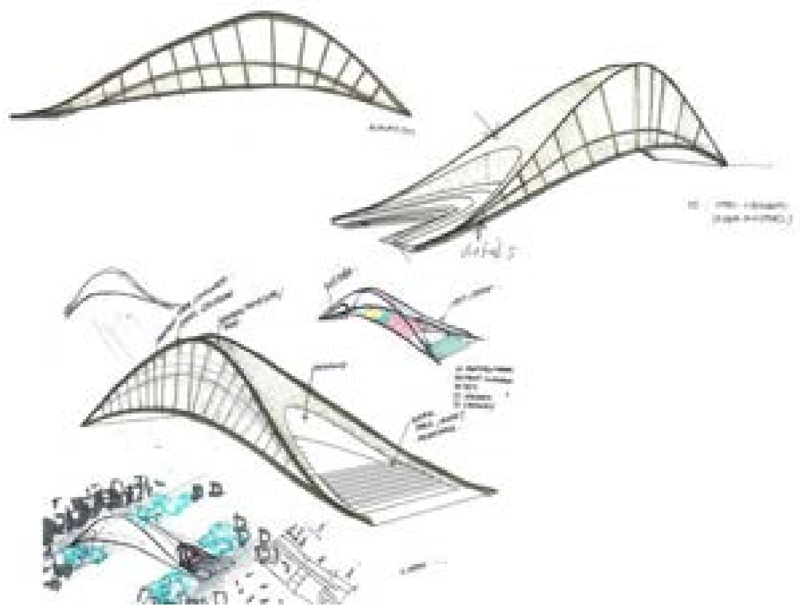


Fig.96 - Conceptual Vision 1

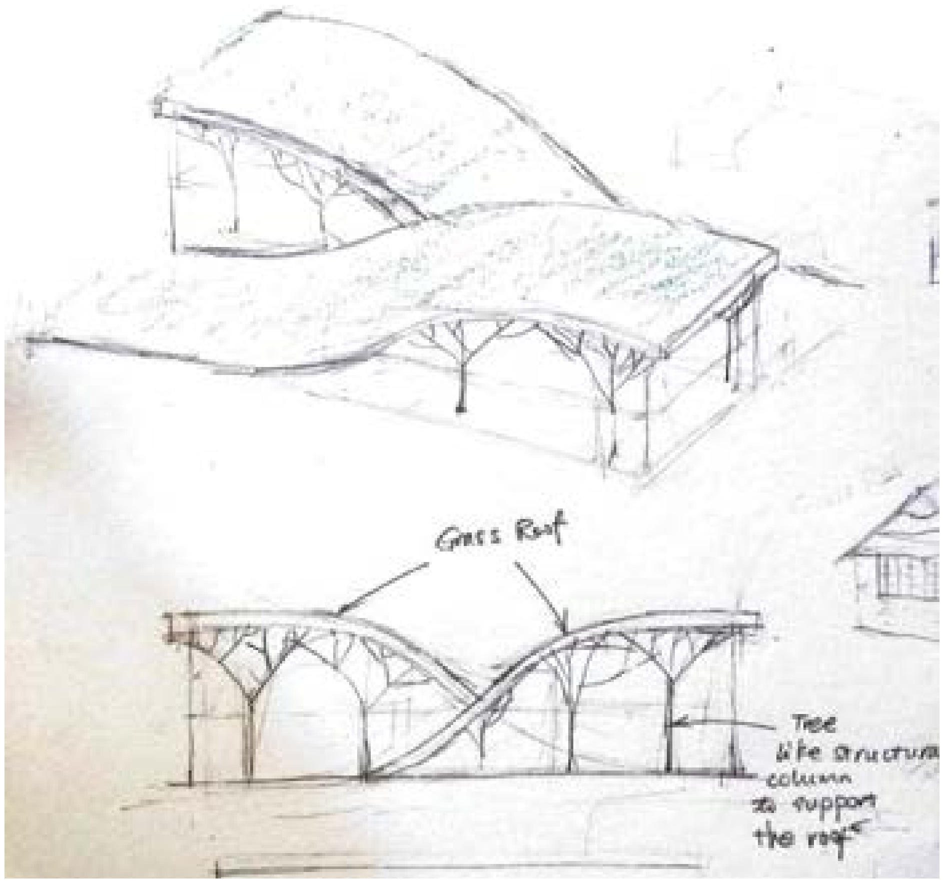


Fig.97 - Conceptual Vision 2

Fig.98 - Modular Organization

Initial Idea:

A minimal but effective shading unit that can be built in-site or even prefabricated. Rather than separate structures designed for specific needs, a single multi-purpose structure for gathering, resting and shading. The form is rigid and shell-like, while also being functional. The aim was to design an eye-catching structure to remind the Sugar Cane workers that they need to look after themselves and do not need to reconstruct them every year due to the damage caused by heavy floods.

Materials Used:

The three shells that create the main structure would be designed using the Wattle and Daub method, in which either bamboo or sugar-cane poles would be used as the frame and the skeleton, while a bagasse-lime mixture is cast on top of the mesh for structural rigidity to create the shells. For structural integrity, ropes would be used to pull the structure back and pin it to the ground to enhance the stability of the whole. See Fig.06 for the layers and the construction of the structure and Fig.07 for the Wattle & Daub method.

09 THAILAND
(d)

Location: Thailand is a country located in South-East Asia. Thailand is one of the top Agricultural producers in the world and has the second largest economy in South-Asia. The country is bordered to the north by Myanmar and Laos, to the east by Laos and Cambodia, to the south by the Gulf of Thailand and Malaysia, and to the west by the Andaman Sea and the extremity of Myanmar.

Climate & Precipitation : Thailand‘s climate is influenced by monsoon winds that have a seasonal character (the southwest and northeast monsoon). Most of the country is classified as tropical savanna climate.
In tropical savanna climates, the dry season can become severe, and often drought conditions prevail during the course of the year. Tropical savanna climates often feature tree-studded grasslands due to its dryness.

Industry Location & Production : In Thailand, Manufacturing,Agriculture and Tourism are major contributors to the country’s economy.
Sugar cane farming is the 4th largest contributor to the agricultural sector of Thailand (behind Rice,Rubber and Cassava).
The Thai government has been encouraging the rapid expansion of sugar cane plantations and giving the sugar industry a significant percentage of the state‘s farming subsidies as part of its efforts to advance the bioeconomy.
Currently, 100 million tonnes of sugar cane are grown annually in Thailand by over 300 000 small- to medium-sized sugar cane farmers, constituting 5.5% of the global sugar supply.
It is cultivated in 47 provinces and covers about 8% of the total agricultural land.

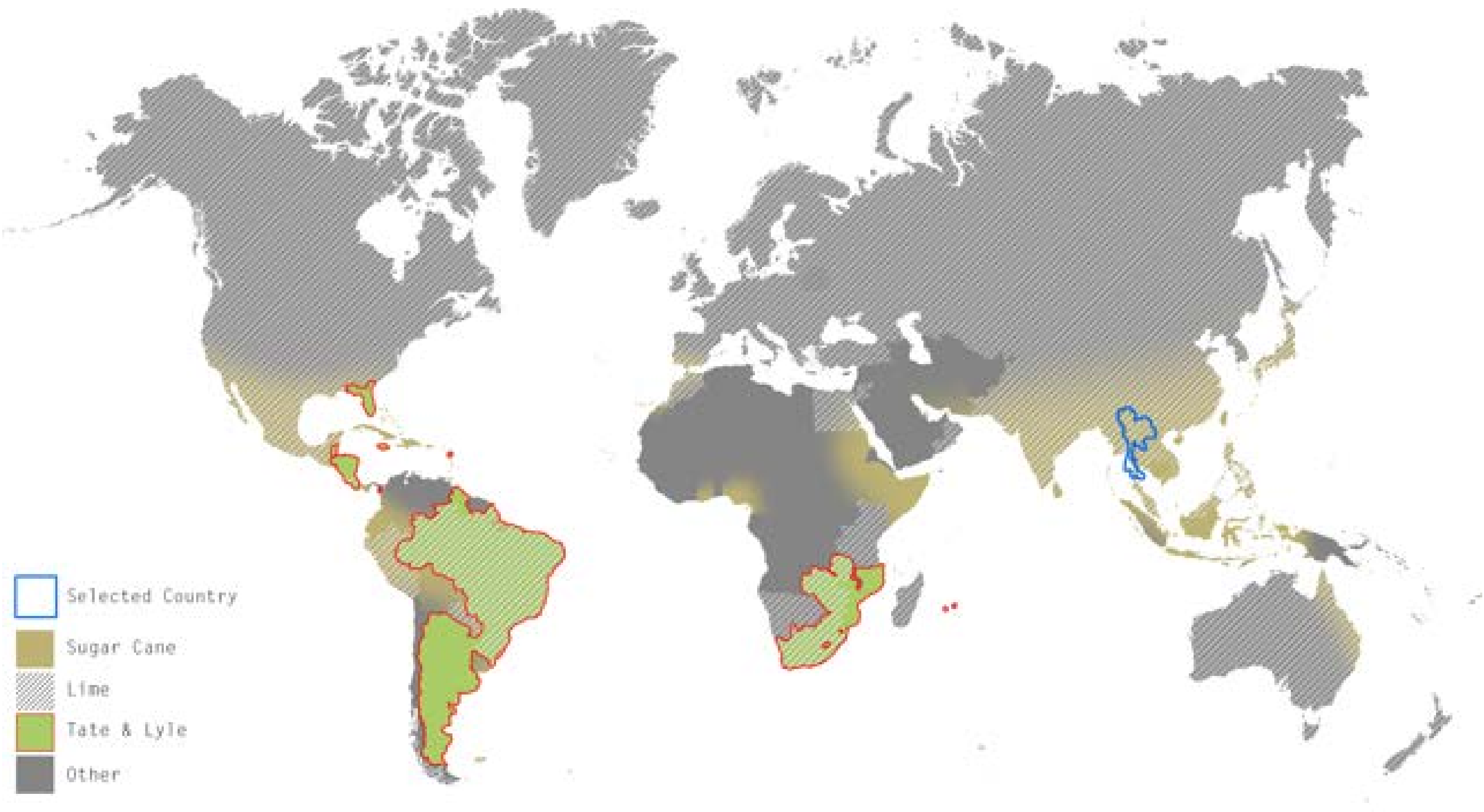


Fig.99 - Thailand in World Map

Conditions of Workers : In Thailand,sugar cane fields are operated as a small-medium scale business by individuals.Depending on the size of the farm,harvesting is done manually or with the use of machine-cutters.
The absence of sugar cane harvesting equipment is a significant issue for farmers. Since small-scale farming is the norm, most sugar cane producers burn their crops right before harvest to facilitate harvesting and get rid of weeds and animals that might be hidden in the fields.

Common problem in Cane Field : Sugarcane burning has a detrimental effect to human health. Fires made from burning agriculture are one of the largest sources of black carbon which threatens both human and environmental health.Additionally, since crop burning occurs in the cooler, high-pressure months of November to April, there is insufficient wind to dissipate the smoke. Black carbon's ability to speed up glacier melting means that it may be a cause of drought. The 2019-20 season saw Thailand's cane production reach a 10-year low as a result of what may have been the worst drought in the nation's history. Farmers' ability to make a living was endangered. The main problems faced by farmers in Thailand is drought and air pollution.

Fig.100 - Bagasse Production in Thailand

Fig.101 - Bagasse Production in Thailand

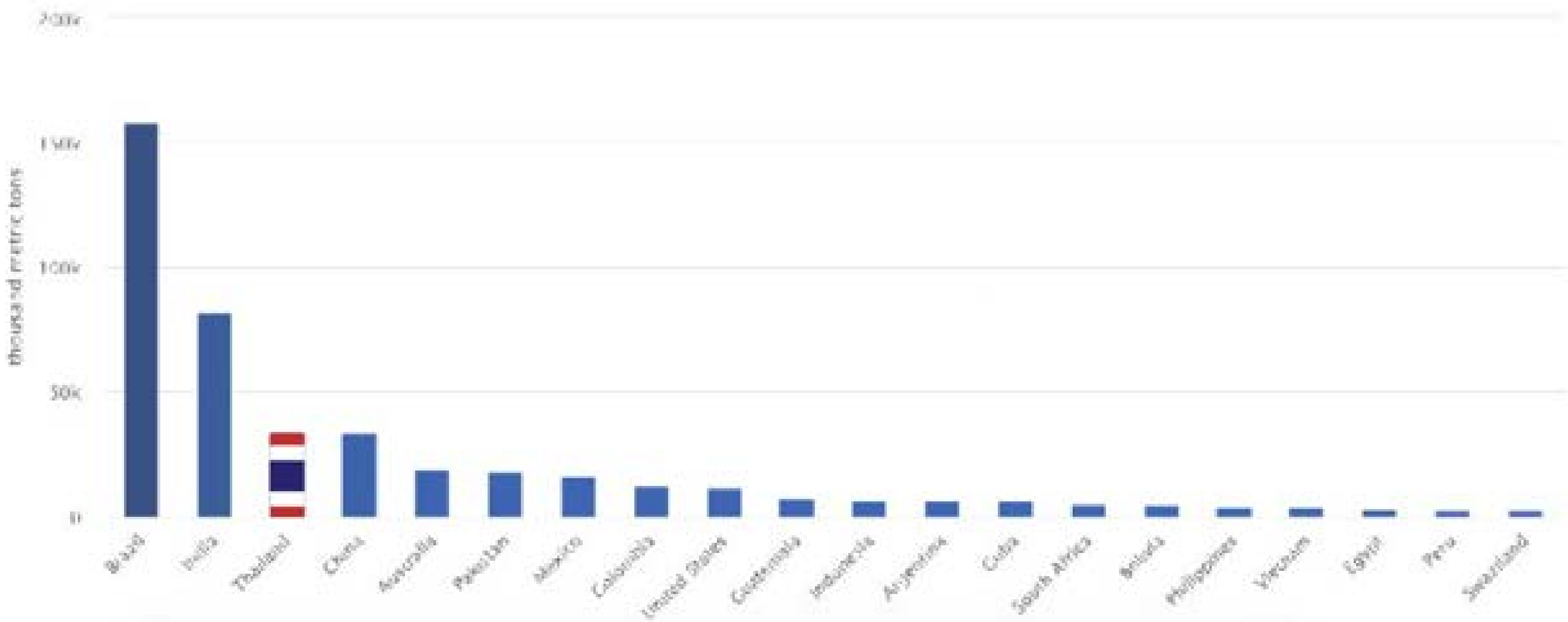
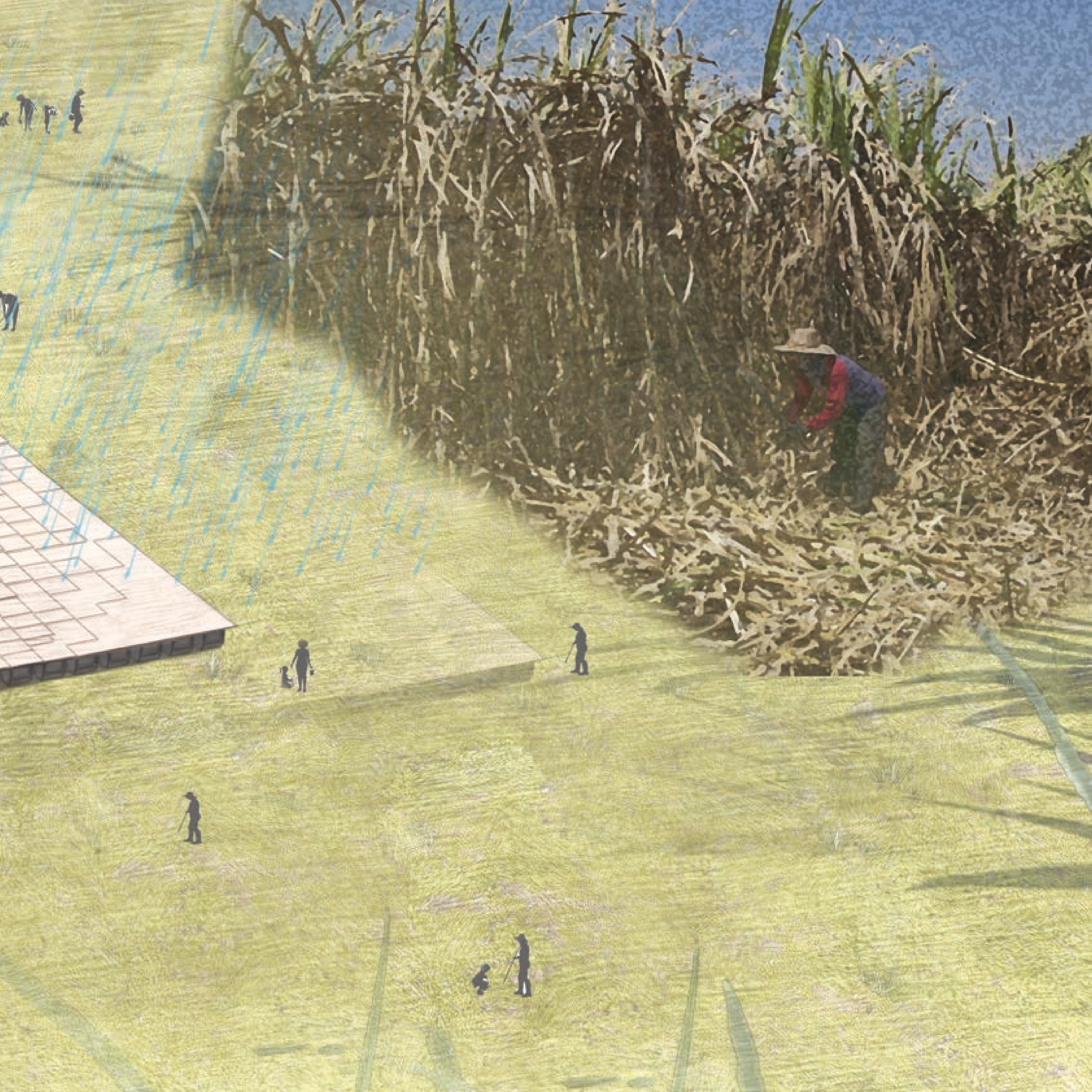


Fig.102 - Bagasse Production in The World



09 (d) THE PROPOSAL

Water Collection to address drought: A form that acts as an installation piece,a shed and also allows water to be collected on site for use in the drought season. The component that creates the form is made from bagasse and plastic.Water will naturally flow down the form to reservoir tanks which can be accessed during the dry seasons for plantation use. The shed also acts as a resting spot for the workers. The bagasse and plastic block can be made in many shapes and size and can be arrange in various manner to suit it's context; long as the form aids the water collection.

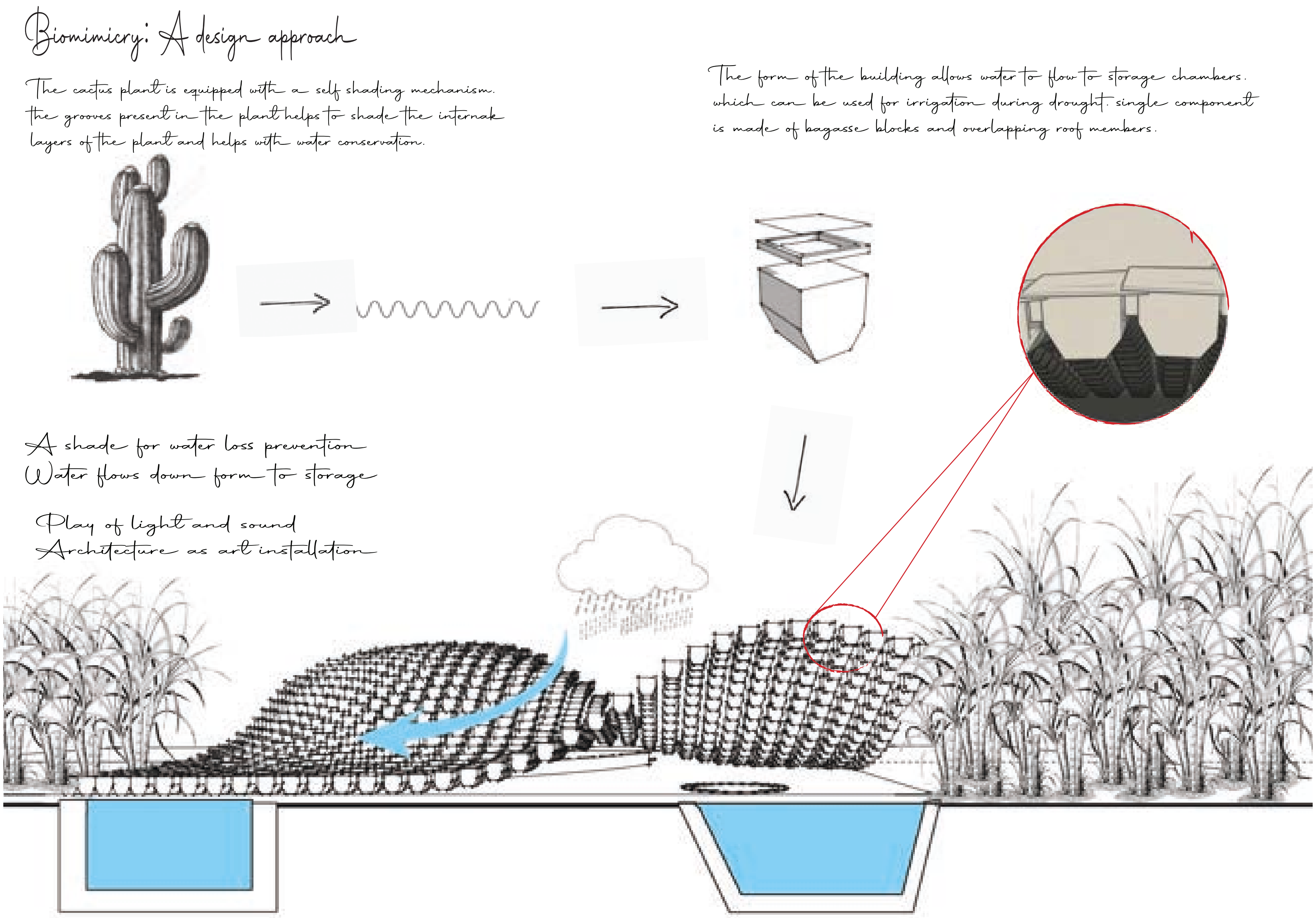
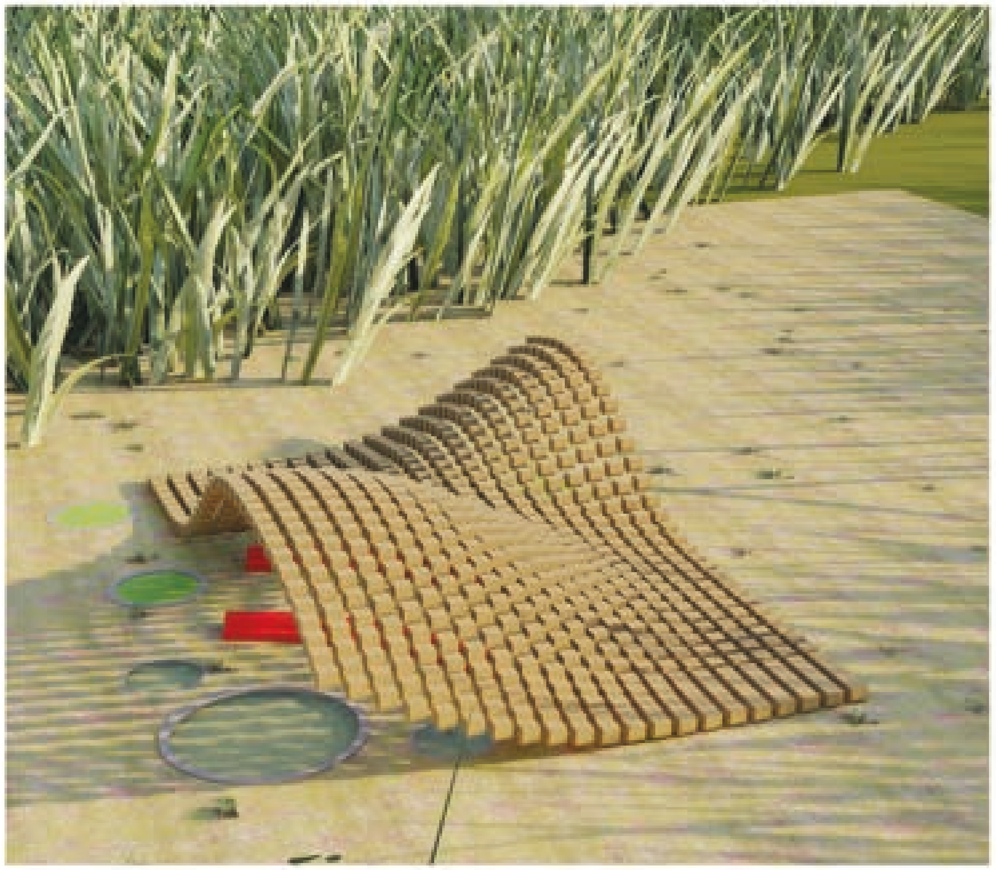
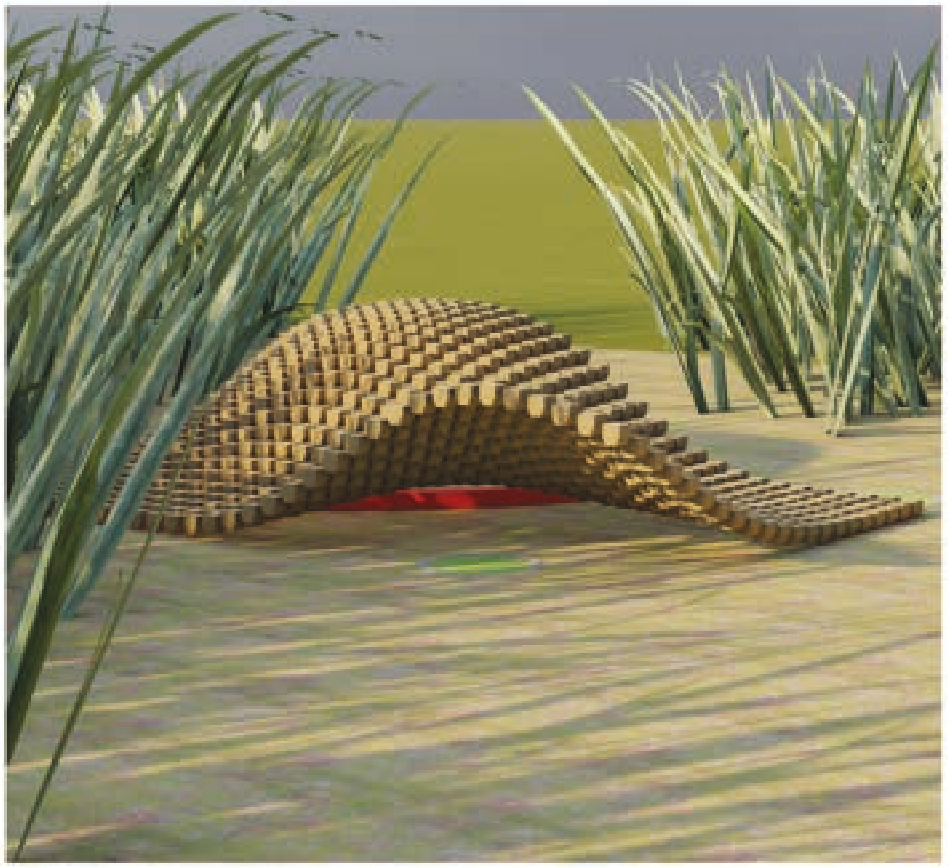
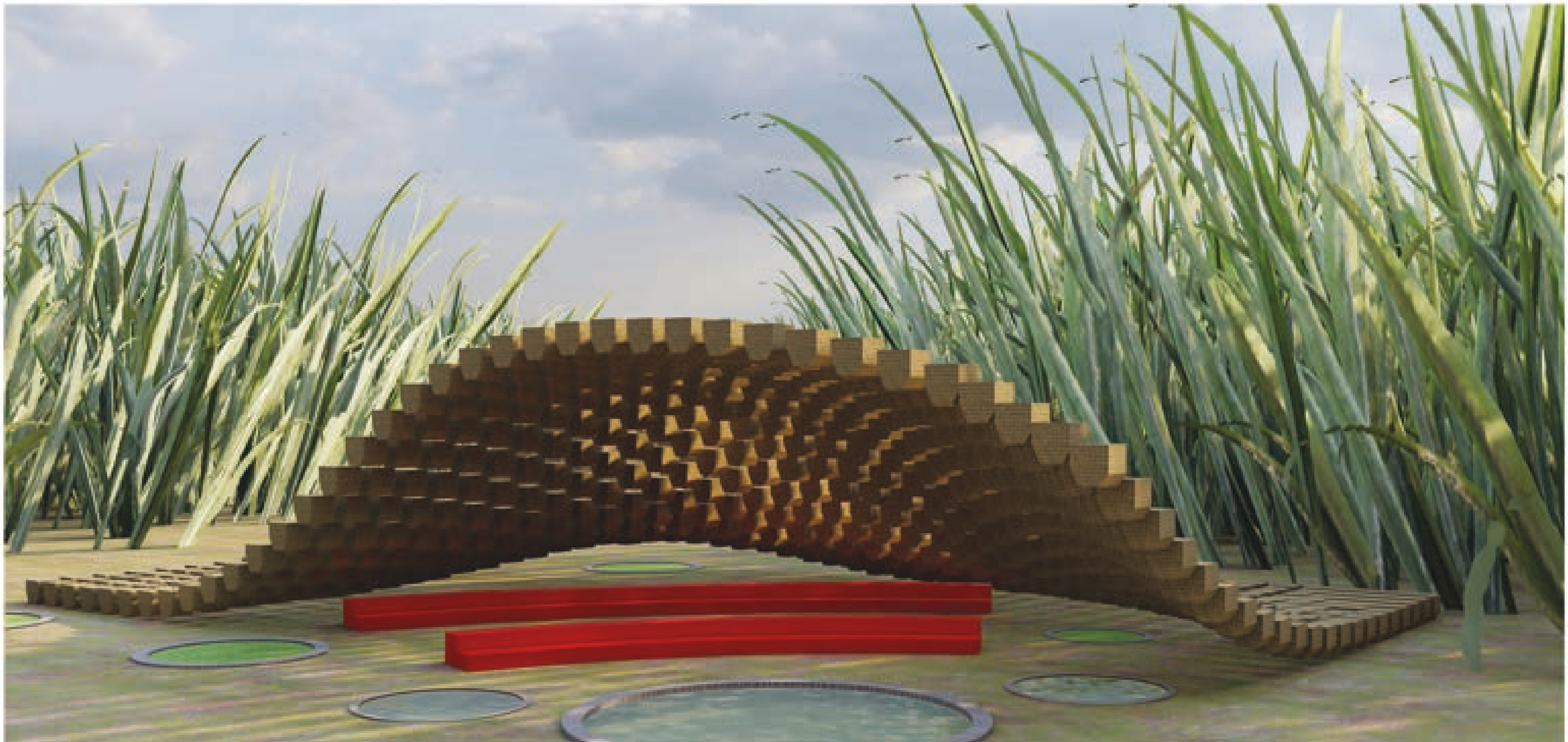


Fig.103 - Design Development Diagram

09 THE PROPOSAL
(d)


Fig.104 - Magnification X50


Fig.105 - Magnification X50


Fig.106 - Magnification X100

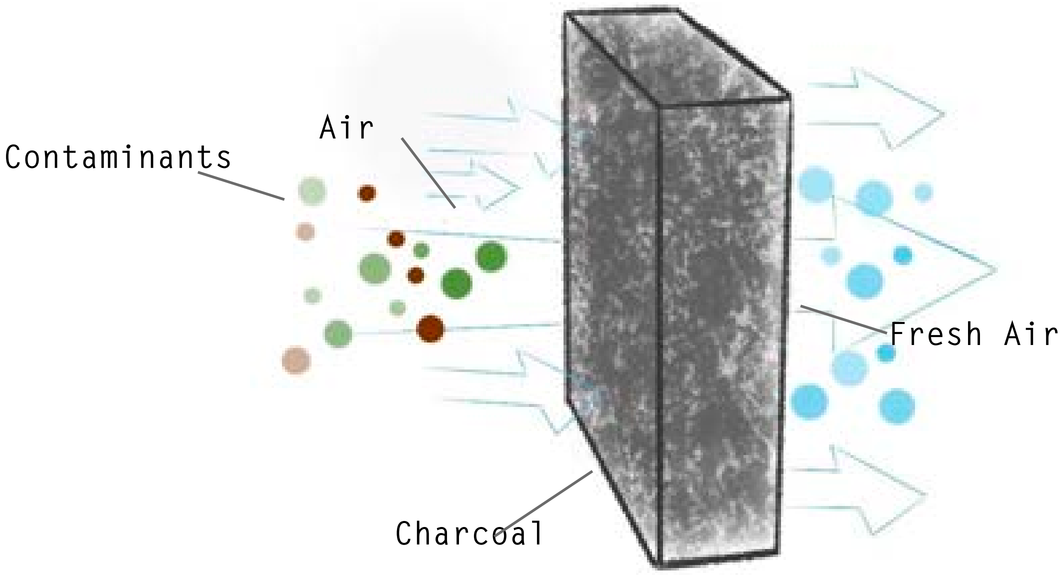


Fig.107 -Charcoal Block showing air purification process

<u>Potential Use Of Bagasse \\ Air Purification:</u>
Sugarcane burning is the preferred method of harvesting this, and the despite the detrimental health effects, farmers still chose this method due to not only being more efficient but farming is also responsible for more than 1.5 million jobs nationwide. Furthermore, modern combine harvesters not only wouldn't be aiding the life and income of these farmers but also, as mentioned above, majority of sugar cane plantation belong to small scale farmers who wouldn't actually need a combine harvester to do this, resulting in burning.

In response to air pollution from burning sugar cane, our proposal to resolve this would be to create an enclosure using Sugarslab technology, where air would be purified which would automatically aid to better the life of farmers and improve working conditions. The enclosure/structure would be designed with several geometric openings which would decelerate the air entering and create a draft where it attracts more air particles as well as move them through the enclosure consistently. We found that a depolluting material 'Titanium Dioxide nano-surface' would break down contaminated air into clean air and this could be applied as paint or varnish. The problem with this is we won't know how this would react with bagasse and, how this would be imported. Alternatively, we thought that charring the exterior of the structure could also act as an air purification method.

Fig.108 - Proposed Geometry

The proposed idea can be a geometrical structure designed using digital fabirication technology. Above is an example of a surface design using this, and potentially interlocked creating a structure which could potentially turn into an exterior.The charred exterior can in fact work with more or less any structure/building built out of bagasse.

Under the microscope - The porous structure of the charcoal is used to absord and trap the air particles as the air flows through this. Here you can see a piece of the charred Sugarslab under the microscope. (Fig 112, 113, 114)


Exit

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