

THESIS

MUSTAFA NAZARI

Introducing a new way of building to build temporary house by using biodegradable Sandstone as new material.

TEMPORARY RESIDENCE BY USING BIODEGRADABLE SANDSTONE

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*“A little sand always takes away
your worries”*

ABSTRACT

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Abstract of Master's thesis, Submitted 25 June 2017:

The research and the development of biodegradable Sandstone at TU Delft Architecture, Delft.

This study was aimed to test the biodegradable Sandstone and develop a method to improve the quality of life of the refugee camp by using biodegradable Sandstone.

The subject of this study was selected by Mustafa Nazari, he discovered biodegradable Sandstone during the study. In the first part, data was collected about the problem statement and solution by doing literature study. Then doing experiments to discover the properties of this material. In the designing phase will be determined if it is possible to create a temporary housing by using biodegradable Sandstone.

The results of this study make clear it is possible to create a temporary house by using specially designed bricks which are made of Biodegradable Sandstone.

PREFACE

The research for this thesis has been carried out at Delft University of Technology in my master's degree in Master Building Technology. From November 2016 to June 2017, I worked i worked on this thesis.

The topic for this graduation assignment, the research steps and the overall project phases were set up by myself. Together with my supervisors, Dr. ir. Fred Veer and Dr. Ir. Marcel Billow, I completed this graduation assignment through their guidance. They have always answered my questions and sent me in the right direction, allowing me to continue with my research. I would like to thank my teachers for the confidence they had in me that I could carry out this research, despite time, they always left me for guidance or questions.

Finally, I hope that this thesis inspires people who will read this to embrace this new material. I believe that biodegradable Standstone is new material which can be used as an exterior and an interior material.

INDEX

INTRODUCTION	13
RESEARCH PHASE	
AIM & RESEARCH QUESTION	14
DESIGN FRAMEWORK	15
DESIGN ASSIGNMENT	16
SAND SCALPTURE	17
ADHESIVE	18
PREPARATION	21
TEST	22
RESULTS	25
EXPERIMENT PHASE	
OPTIMIZE	27
STRENGTH OPTIMIZATION	28
THICKNESS OPTIMIZATION	29
DRYING TIME TEST	30
BENDING TEST	32
EXTRA BENEFITS BY SOLVENTS	33
DESIGN PHASE	
BRICK REQUIREMENTS	35
MORTARLESS BRICK	37
DESIGN BRIEF FOR A TEMPORARY HOUSE	38
BUILDING DESIGN	41
ROOF DESIGN	42
ROOF DETAIL	43
DOOR AND WINDOW DETAIL	45
BUILDING MATERIALS	47
CONCLUSION	48
REFLECTION	50
LIST OF REFERENCES	52
STUDIED REFERENCES	53



INTRODUCTION

To understand this project, more information was needed about the environment of the refugee camp. For this reason I read articles about the environments of refugees and about the quality of life. There are big challenges. One of these is a lack of good quality of living environment. Because the number of refugees in camps are increasing, (Baglolle et al., 2007). There are many articles published that say refugees have a difficult time because of bad conditions. However, there is no solution for this problem. There are some small projects which is written about how it would be planned or improve quality of housing, (Johnson, 2007). These temporarily houses are actually tents. The main purpose of tents is to give shelter to people for a couple of weeks. Good quality tents could be used for a couple of months. These tents are not supposed to be used for years, (Davidson et al., 2010). Other concerns are a lack of privacy, hygiene and health issues. Bad housing causes health issues: physically and mentally (Baglolle et al., 2007).

Problem statement: there is no good solution that provides refugees and displaced people temporary housing that provides shelter, privacy and high quality housing that improves hygiene and health issues.

AIM & RESEARCH QUESTION

The aim of the research is to investigate what the possibilities of biodegradable Sandstone are. This material has a lot of potential, which might contribute a solution to the housing problem of refugee camps. Besides, this material gives opportunities to investigate various aspects such as; fire resistance, acoustics, climate (exterior and interior), water resistance and constructive qualities.

The following aspects are investigated:

- Finding the most suitable binder that fits the purpose.
- Designing a system or a process to realize housing (facade, roof, climate, etc.).
- Experiments to explore the technical aspects of this material (strength, durability, etc.).

Based on the problem statement and goal for this study. The following research question was formed.

What are the possibilities of Biodegradable Sandstone?

- Is it possible to use a natural binder?
- Which technical aspects come with this material?
- How to design a system or a process to create a temporary residence?

DESIGN FRAMEWORK

To ensure that the research process is successful, a research strategy or a research method is very important. Therefore a design framework was created. The aim of the framework is to provide a common structure so that designers do not have to redo it from scratch. This framework is divided into four segments: Research, experiment, design and finalizing (Figure 1).

Research

To find out what kind of types of adhesive are available, the research had to begin with literature study. The study was done by gathering and reading information relevant to the research question. The goal of this research is to establish what kind of binder will be relevant for this research.

Experiment

After doing a literature study, the experiment part took place. The samples are tested in casting, water resistance and construction to determine which is most suitable.

Design

This phase of research is translating the data in the experimenting phase to a product. This is an important part of this study because it will determine if the solution is feasible. By asking the main research question. "Will that design answer the research question?"

Finalizing

The last part is finalizing the whole research by doing scale model. Also by presenting whether this material has potential and what the possibilities are.

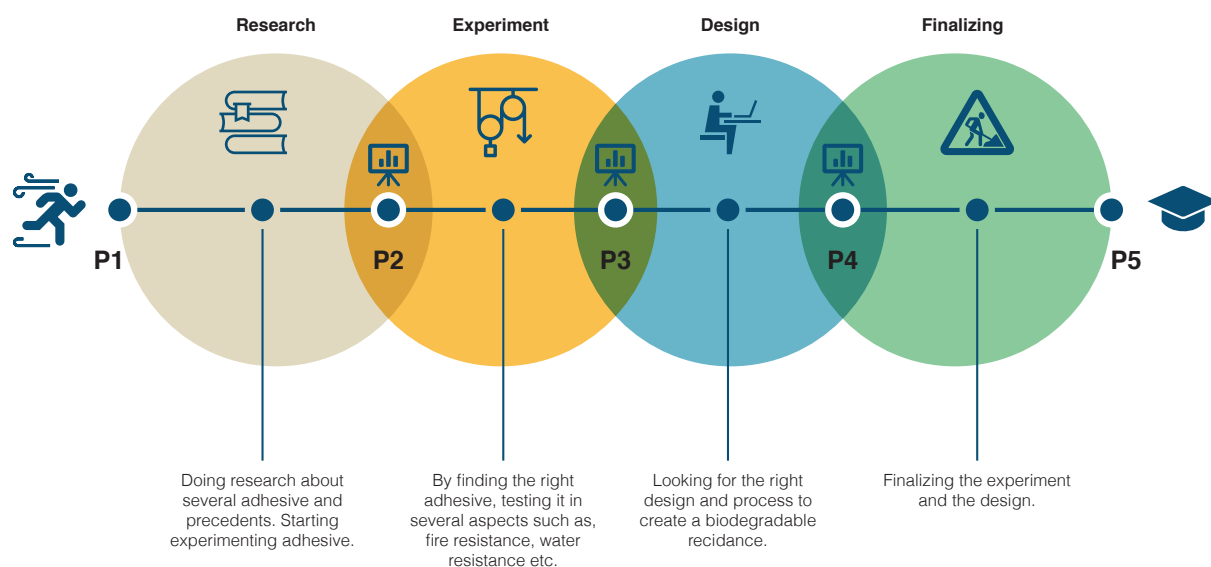


Figure 1: Design Framework

DESIGN ASSIGNMENT

The goal of this design assignment is to develop a building block made from biodegradable Sandstone which can be used to build temporary residences.

Following requirements are important for the research to establish the goal.



Biodegradable



Strength



Water resistance



Production

SAND SCALPTURE

To get better grip on this research, other objects that are built from sand are investigated. Sand sculptures were interesting objects to look into. Although these objects are often built on beaches, the secret lies in the use of river sand instead of beach sand (Figure 2). The difference is, as illustrated (Figure 3), that river sand is more angular compared to beach sand. Beach sand is rounder and smoother because it was exposed to more wind.

Due to the angularity, river sand attaches better or better said, the friction is much higher. Another key element, these builders put all the sand in a big mold and compress it with a vibrating plate compactor. By doing this the density of the sand becomes higher. As a result, the sands interlock and there is no need for an binder. That is why sand sculptures hold for a couple of months. A sand sculpture is strong enough to hold itself, but is still very fragile. If there is any pressure on the top or surface, the sculpture is damaged. This kind of method is not suitable enough for making reliable building blocks.

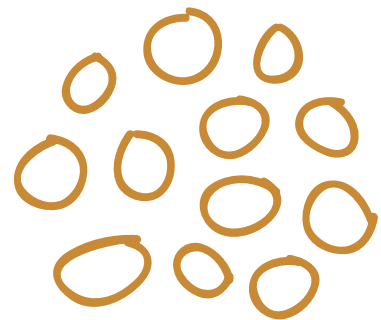


Figure 2: Beach sand

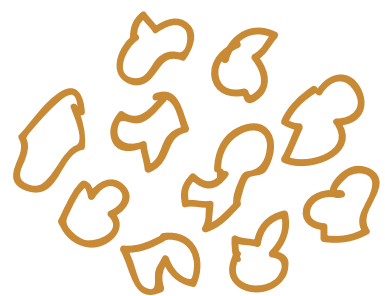


Figure 3: River sand

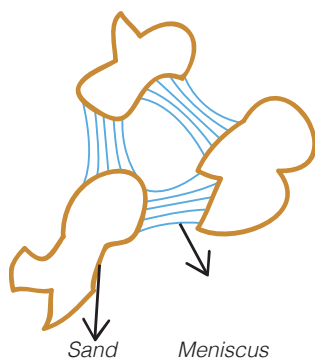


Figure 4: Micro level sand connection

A sand expert (Dr. A. (Amin) Askarinejad) at the faculty of Applied Earth Sciences at the TU Delft was consulted for more information about sand. The outcome of the interview was that sand needs an adhesive to remain longer as a solid mass and can withstand pressure. In the case of sand sculpture water is not an option to use as adhesive as water evaporates after a while and by using too much water the sand does not adhere to each other. So, it is important to understand what water does with the sand by zooming deeper in to a micro level. The illustration shows what happens on a micro level (Figure 4). Between two grain of sand there is a connection or a joint. This joint is called a meniscus. The meniscus ensures that the sand adheres to each other.

For the research, it is important to find an adhesive that does not evaporate, is water resistant enough to withstand rain and strong enough that the binder is not vulnerable to several extreme weather circumstances.

ADHESIVE

Knowing how sand sculpture works, it can be concluded that finding the right adhesive is the key to the research to achieve the goal. To find the right information about adhesives, boundaries are set to find the right information or articles about adhesive or temporary buildings. The requirements for adhesives are: degradable, harmless for the environment, adhere to sand and good availability.

The outcome of the literature study were six recipes to experiment with it: gelatin, maize, starch, agar, salt and sugar.

Gelatin

This product is a valuable protein product for food and pharmaceutical industries. This is extracted from skins and bones of mammals. The property of gelatin is that it dissolves well in warm water. On cooling, this water forms a jelly. At room temperature, the structure of the gelatin molecules is maintained by intermolecular forces. Hot water will break these connections when it is added. When the mixture cools down, then the chains connect again to each other. An interesting use of gelatin is in synchronized swimming; to keep the hair from the swimmers' backs while swimming. The cold water of the pool makes sure that the gelatin dissolves only slightly and keeps the hair tied back.

Maize

Cornstarch or maize is extracted from the corn. Maize is a popular food ingredient that is used to thicken soups or sauces. Usually the starch is mixed with water at a low temperature, to make it thicker heat is added. As the starch is heated, the molecular of the starch chains unravel. Because of this process the starch mixture gets thicker. Cornstarch is also widely used to produce bioplastic.

Potato starch

As the name implies, this starch is extracted from potato. This potato starch consists mainly of starch. Compared to corn starch it contains hardly any protein or fat. This indicates that potato starch has unique properties such as neutral taste. These typical properties are used both in nutrition and as technical applications. Starch can be used in the food industry to make noodles, wine gums, chips, custard and to bind soups and sauces. For technical applications, it is used like wallpaper glue and general purpose glue.

Agar Agar

Agar agar is a whitish, tasteless and odourless gelatin that is extracted from seaweed or red algae. The word agar comes from the Malay word for jelly. Agar-polysaccharides are the primary support structures for the cell wall of a seaweed or algae. When it is dissolved in hot water and then cooled down, you will get vegetable gelatin. The binding force of agar agar is twice as large as gelatin. Agar agar gel is also less sensitive to changes in acidity.

Sugar and Salt

For these two these no introduction is needed. These products were selected because they can be found in every kitchen. They are widely available and cheaper compared to the other products.



PREPARATION

With the information about temporary housing and all kinds of information about adhesives (Oever & Molenveld, 2012), experiments were started. The goal of this experiment is to find the right proportion between sand and adhesive. Not only the proportion but also what kind of process is needed to achieve the best final result.

Proportion

The aim of the first experiment was to find the right ratio between sand and the binder. Using coffee cups was the method to create small samples to find the best ratio. After this first phase larger blocks were created to test samples with a universal testing machine (compression test).

Mold

Water is one of the ingredient that is used to make samples. To make sure that the samples dry, the water should evaporate. If the mold is only open at the top (Figure 5) only the top part will dry. That is why it is important to design a mold that not sticks to the sand and the mold can be removed without changing the shape of the samples.

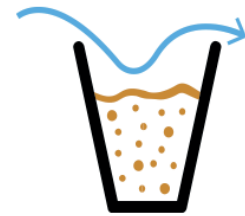


Figure 5: Dries only the top

To make sure that the samples don't get damaged by removing the mold, it is crucial not to slide it or press it from the mold. The reason for this, the samples are still wet and formable.

The solution for this challenge is to open the mold instead of sliding it (Figure 7). This mold technique ensures that the sample will stay in the same place and is able to dry from all sides.

Sample

To get an idea or insight what this material is capable off, a test in the press machine is a good start to get information about every single adhesive. For the test samples were made with the following size, 110h x 100l x 100w mm. With this size it can be get accurate results because the machine is not big enough.

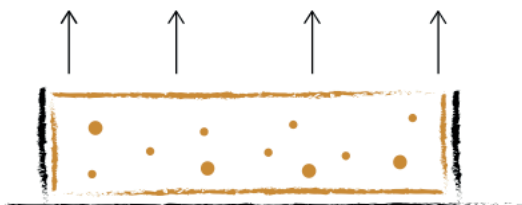


Figure 6: Sliding the sample



Figure 7: Opening the mold

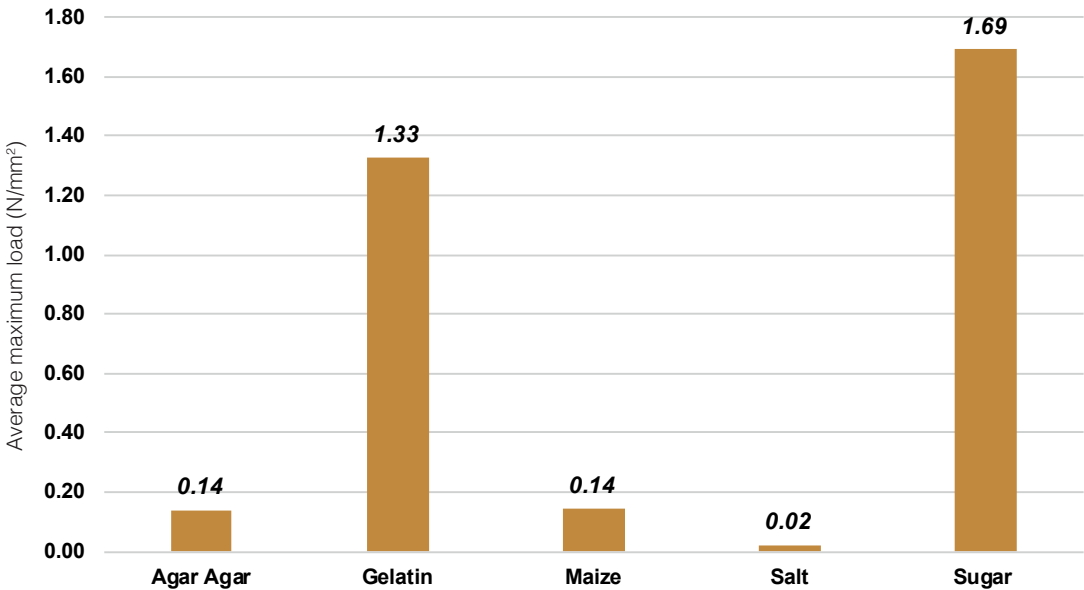
TEST

Potato starch is not a good adhesive. The two main reasons are:

- 1 The potato starch mixture needs a lot of starch to create a viscous substance. At some point, there was more starch in the sample than sand itself.
- 2 The biggest problem with potato starch is the dry time. It needs a lot of time for all the water to evaporate. Even after it dries the sample was very powdery. For these reasons, potato starch was eliminated from the experiment.

The results of the samples are known. For each adhesive, three samples were tested for reliability. During transportation one of the three samples of salt disintegrated. This already indicates that salt is not a good adhesive and does not meet the requirements.

The average was calculated and a bar graph was made to compare the average results of the adhesives (Graph 1). To get an image about the strength of the samples, there is made an illustration to get the idea how strong these samples are (Figure 8).



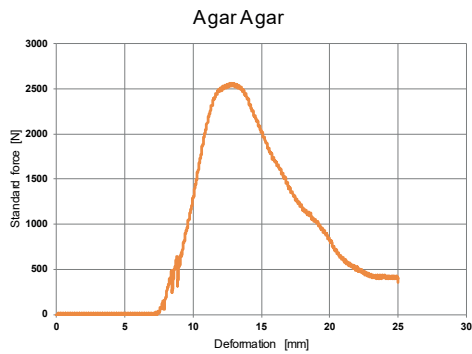
Graph 1: Average maximum load (n/mm²) with different adhesives



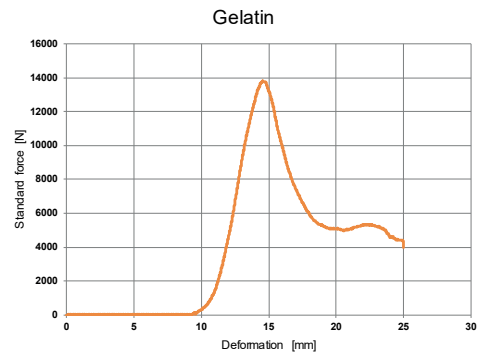
Figure 8: Comparison illustration how strong these adhesives are

As indicated earlier, there are six recipes that are tested: gelatin, agar agar, cornstarch, starch, salt, and sugar. For each recipe, three samples were made. Subsequently, these samples are subjected to the press machine to test structural integrity. This will help determine to see which of these recipes has the most potential.

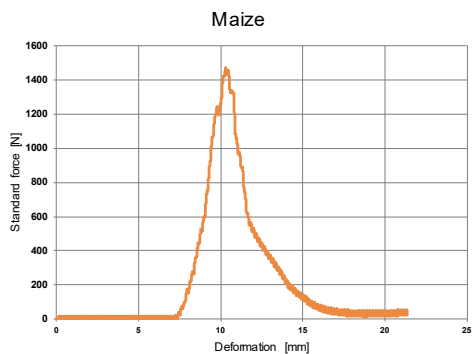
The tests resulted in Graph 2, Graph 3, Graph 4, Graph 5 and Graph 6 shows under which load the samples failed. The tests were also recorded to compare the deformation process.



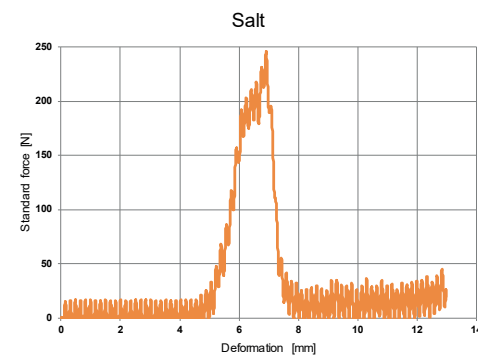
Graph 2: Flow line of pressure of agar agar



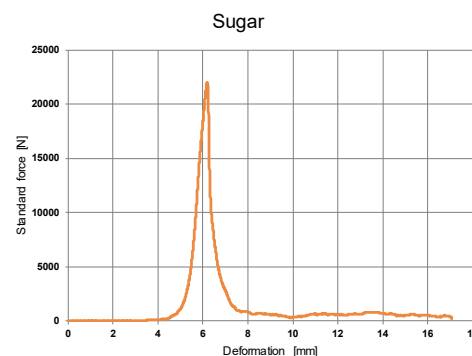
Graph 3: Flow line of pressure of gelatin



Graph 4: Flow line of pressure of Maize



Graph 5: Flow line of pressure of salt



Graph 6: Flow line of pressure of sugar



RESULTS

Looking at the results it can be concluded that sugar is the strongest and salt the weakest. Figure 9 shows a check list to see which of these adhesive meets the requirements that is made at the beginning of this research. As the table shows that gelatin meets all requirements. However, there are more aspects to look after. How did the sample react during the test?

During the test the samples with maize, sugar and salt fell apart. These samples did not end up in pieces but more like in the original state, sand. The graphs also show the line drops immediately when a sample reaches the maximum load (Graph 2). With agar agar and gelatin this is not the case. Because both adhesives have elastic properties. That means also that agar agar and gelatin adhere better than the rest of adhesives. After the test the samples did not fall apart like the samples with salt, sugar and maize.

Looking at these aspects, it can be concluded that gelatin has the best potential for this project. Gelatin is strong enough to bear a small car of 1200 kg. Moreover, if the gelatin reaches the maximum load, it won't fall apart. When compared on water resistance, gelatin wins from all other tested adhesives. When the samples with salt and sugar came into contact with water, the samples fell apart immediately.

	Agar Agar	Gelatin	Maize	Salt	Starch	Sugar
 Biodegradable	✓	✓	✓	✓	✓	✓
 Strength	✗	✓	✗	✗	✗	✓
 Water resistance	✗	✓	✓	✗	✗	✗
 Production	✓	✓	✗	✗	✗	✗

Figure 9: Check list Adhesive



OPTIMIZE

The next phase was to find and optimize the ratio between gelatin and sand. New samples were made using the same recipe. Gradually the amount of gelatine used was increased until the ratio between sand and gelatin was 2 to 1. With these samples the water resistance was tested. When does the sample dissolves?

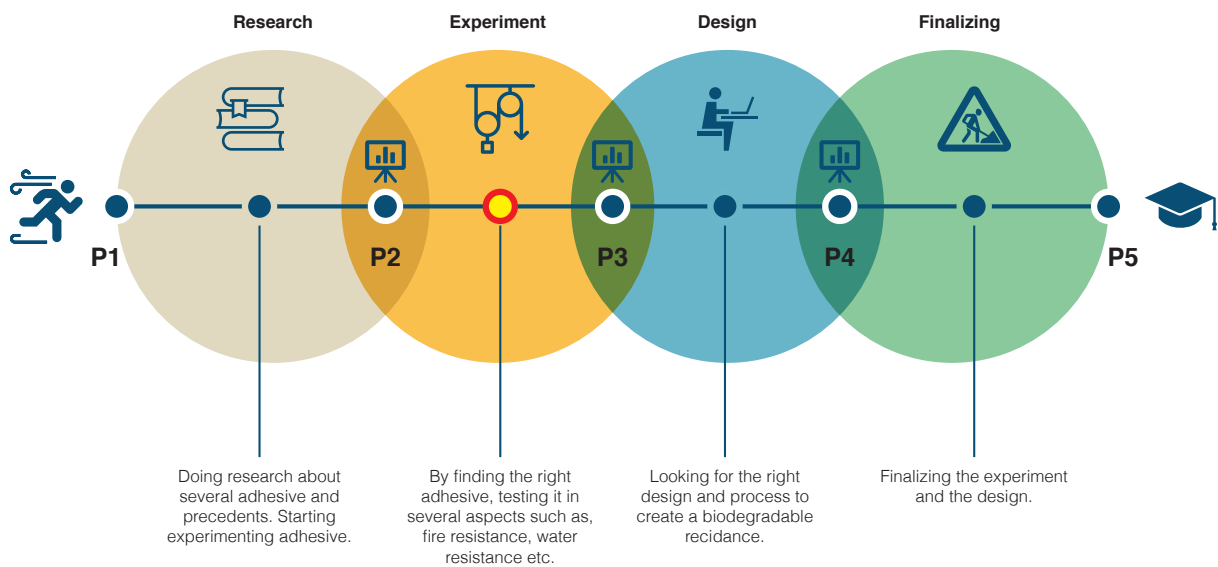


Figure 10: Design Framework experiment phase

STRENGTH OPTIMIZATION

For the reliability is it important to do the press and bending test with an identical ratio of adhesive and sand. The samples were also identical in size to use for the press test: 100l x100h x100w mm.

For the optimization of the ratio only the amount of adhesive in the specimen was changed to find the right ratio between sand and adhesive. The first samples consisted of sand and 10 grams of adhesive. With every next sample the amount of adhesive was increased by 5 grams. Per step three samples were made to get more reliable results. The results are shown in Table 1 .

The strongest specimen is not necessary the best to use as a building material in the design process. Therefore, is it important to get an overview which specimen is needed for which purpose. In some cases it is not necessary to choose for the best ratio. It would be a waste of material to use more than needed. The results show that sample 6 (35g gelatin) is good enough to use in the experiments.

There is one margin to taking in to account that during the test the specimens were not completely dry. However, it doesn't mean that this experiment was failed. In fact, it gave an insight that these samples don't have to wait to start with building until the samples dry.

	Gelatin 10 g	Gelatin 15 g	Gelatin 20 g	Gelatin 25 g	Gelatin 30 g	Gelatin 35 g	Gelatin 40 g	Gelatin 45 g	Gelatin 50 g	Gelatin 55 g	Gelatin 60 g	Gelatin 65 g
Test 1	4653.001	5528.755	1524.701	5458.658	7598.095	9359.382	7540.138	6726.248	9105.410	8951.596	8917.013	8274.634
Test 2	5453.979	6100.880	8042.258	5981.666	7755.486	8089.136	8002.433	7093.921	9529.041	8316.258	8575.201	7560.228
Test 3	3566.919	6982.986	6974.768	6064.574	6878.034	6772.929	8363.856	7193.299	9048.800	8603.744	6825.981	6843.895
Average maximum load (N)	4558	6204	7509	5835	7411	8074	7969	7004	9228	8624	8106	7560
Average maximum load (N/mm ²)	0.46	0.62	0.75	0.58	0.74	0.81	0.80	0.70	0.92	0.86	0.81	0.76

Table 1: Table of gelatin ratio results

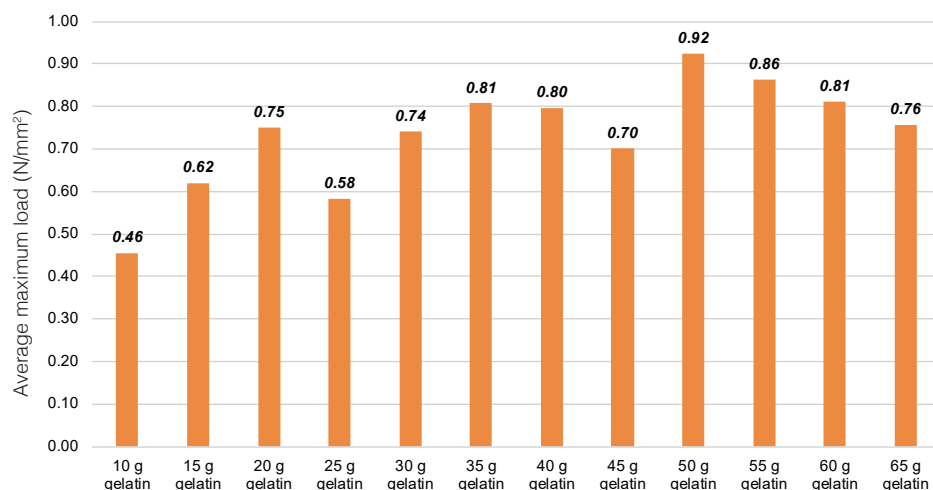


Figure 11: Average maximum load of gelatin ratio results (N/mm²)

THICKNESS OPTIMIZATION

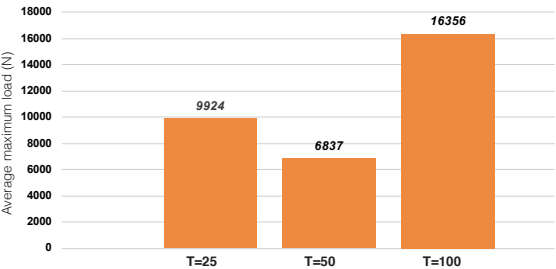
Next the thickness was tested. Was there a relation between thickness $T=$ (mm) and strength $F_{MAX}=(N)$? As shown in Table 2, there is actually no direct relation between thickness of the samples and the amount of pressure. It is true that the thicker the samples the stronger it will be (Graph 7). But it is not always necessary to choose the strongest sample. If you calculated to N/mm^2 you see that the Graph 8 shows that the thicker the material the weaker it is. This is because of the size of the surface of the samples.

Not to forget about the trade-off between drying time and thickness. To gain more insight, the drying time and thickness variables were compared, as shown in Graph 8. For this experiment three different sizes of samples were made: 25mm, 50mm and 100mm.

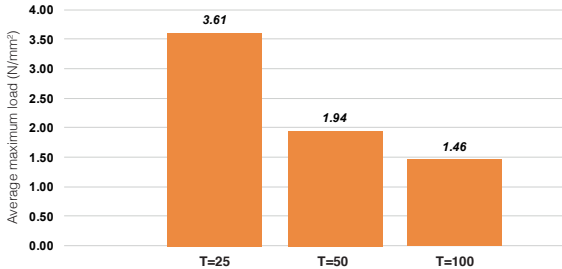
	T= 25	T= 50	T= 100
Test 1	8337	9746	17096
Test 2	9894	13089	17132
Test 3	8311	11280	13319
Test 4	8625	7634	9163
Test 5	9924	6837	16356
Average maximum load (N)	9018	9717	14613
Average maximum load (N/mm²)	4	2	1

T=Thickness (mm), L=100 mm and H=100 mm

Table 2: Results of the thickness optimization



Graph 7: Results of the thickness optimization in (N)



Graph 8: Results of the thickness optimization in (N/mm²)

DRYING TIME TEST

Drying time of this material is important to get an overview how long it takes before the material is completely cured. This phase of the research is about the relation between drying time and thickness of the sample. In the previous phase, there was an overview about the strength against thickness. With these results, there will be more information to understand how this materials act against several thickness and time.

Procedure of the experiment

The first day when the samples are made, the weight of the samples are noted. Every single day the weight of the samples were noted. This process was handled the same as the rest of the samples with this thickness, 25mm, 50mm and 100mm. There is no need to do further research with samples that is thicker than 100 mm because it is a waste of material and it will be heavier than it is needed.

Conclusion

As the graphs show the thicker the material the longer it takes to dry. The Graph 9 show that after three days the sample dries for 80%. In Graph 10 shows that the drying time is twice as long as in Graph 9. Compare Graph 10 with Graph 11, it takes three times longer to dry. there is a connection between drying time and thickness. It can be concluded for this experiment. That thickness 25 mm is most suitable compare with drying time and strength.

Date	13-02-17	14-02-17	15-02-17	16-02-17	17-02-17	20-02-17	21-02-17	22-02-17	23-02-17	24-02-17	27-02-17	28-02-17	01-03-17
Days	1	2	3	4	5	8	9	10	11	12	15	16	17
Steen 1	437.6	410.4	399.0	390.8	385.0	379.3	379.3	379.3	379.3	379.3	379.1	379.1	379.1
Steen 2	441.1	412.7	400.3	391.4	385.1	378.3	378.3	378.3	378.3	378.3	378.1	378.1	378.1
Steen 3	452.5	424.1	411.8	402.7	396.6	389.3	389.3	389.3	389.3	389.3	389.2	389.2	389.2
Steen 4	419.4	391.9	379.9	371.5	366.1	362.0	362.0	362.0	362.0	362.0	362.0	362.0	362.0
Steen 5	416.2	388.5	376.4	368.8	363.3	359.9	359.9	359.9	359.9	359.9	359.9	359.9	359.9
Weight (g)	433	406	393	385	379	374	374	374	374	374	374	374	374
Decrease weight (%)	0%	6%	9%	11%	12%	14%	14%	14%	14%	14%	14%	14%	14%

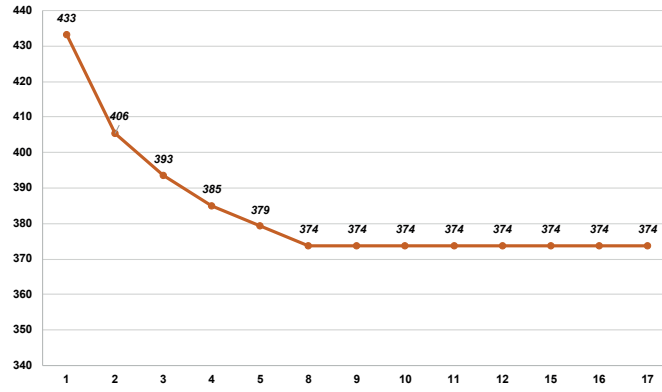
Table 3: Data on drying time of sample with thickness 25 mm

Date	13-02-17	14-02-17	15-02-17	16-02-17	17-02-17	20-02-17	21-02-17	22-02-17	23-02-17	24-02-17	27-02-17	28-02-17	01-03-17
Days	1	2	3	4	5	8	9	10	11	12	15	16	17
Steen 1	832.9	795.4	778.2	765.2	754.9	735.2	729.3	724.7	719.0	715.2	705.3	701.1	696.9
Steen 2	849.2	812.0	794.6	780.5	770.2	749.5	743.4	738.8	733.0	729.1	719.4	714.2	709.4
Steen 3	851.1	814.4	797.0	782.3	771.8	752.0	746.1	741.5	736.8	731.9	718.6	712.3	708.1
Steen 4	810.0	775.3	759.7	748.6	738.1	716.4	710.6	706.2	701.6	697.1	688.8	684.1	680.3
Steen 5	841.7	802.7	784.9	769.8	759.6	737.3	730.9	725.6	720.1	714.5	703.4	698.1	694.7
Weight (g)	837	800	783	769	759	738	732	727	722	718	707	706	704
Decrease weight (%)	0%	4%	6%	8%	9%	12%	13%	13%	14%	14%	16%	16%	16%

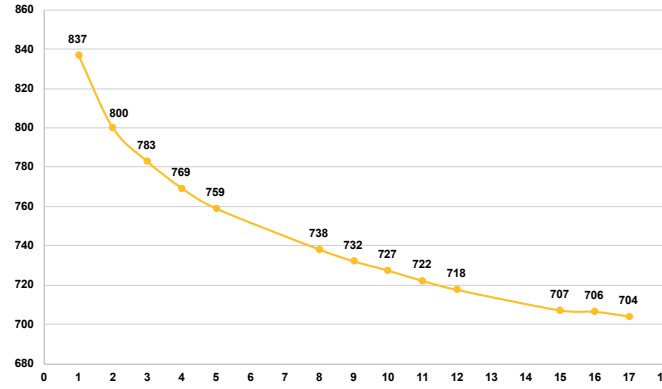
Table 4: Data on drying time of sample with thickness 50 mm

Date	13-02-17	14-02-17	15-02-17	16-02-17	17-02-17	20-02-17	21-02-17	22-02-17	23-02-17	24-02-17	27-02-17	28-02-17	01-03-17
Days	1	2	3	4	5	8	9	10	11	12	15	16	17
Steen 1	1717.2	1675.5	1698.4	1631.9	1616.5	1582.8	1572.0	1563.4	1554.0	1544.1	1521.5	1514.0	1506.5
Steen 2	1763.3	1722.8	1651.7	1680.6	1667.0	1637.1	1628.1	1621.5	1614.6	1607.1	1590.3	1582.8	1575.3
Steen 3	1849.4	1773.3	1747.6	1727.8	1712.9	1683.6	1675.8	1669.5	1662.9	1655.7	1639.3	1631.8	1624.3
Steen 4	1787.0	1742.7	1717.3	1696.7	1681.9	1652.6	1644.2	1637.8	1631.1	1623.4	1606.2	1598.7	1591.2
Steen 5	1916.7	1805.8	1779.6	1759.2	1744.4	1714.1	1705.6	1698.9	1692.1	1684.4	1668.8	1659.3	1651.8
Weight (g)	1807	1744	1719	1699	1685	1654	1645	1638	1631	1623	1605	1601	1590
Decrease weight (%)	0%	3%	5%	6%	7%	8%	9%	9%	10%	10%	11%	11%	12%

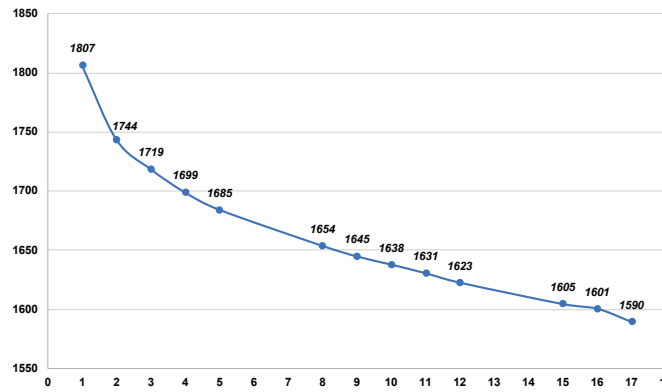
Table 5: Data on drying time of sample with thickness 100 mm



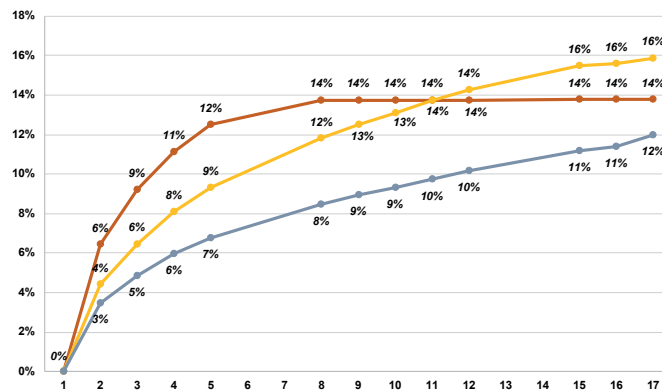
Graph 9: Weight data of sample with thickness 25 mm



Graph 10: Weight data of sample with thickness 50 mm



Graph 11: Weight data of sample with thickness 100 mm



Graph 12: Decreasing weight of samples in %

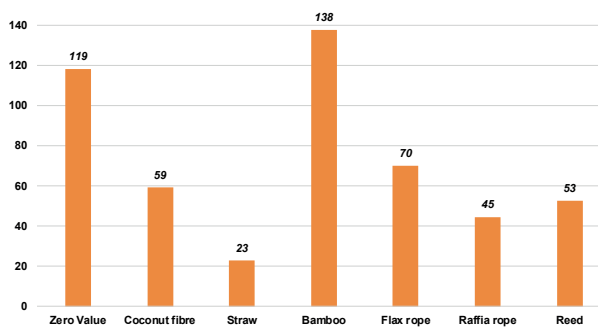
BENDING TEST

After getting an overview about strength test, it is also interesting to understand how this material “biodegradable Standstone” react in bending strength. For this research several samples were made in the size: 80 x 40 x 25 mm.

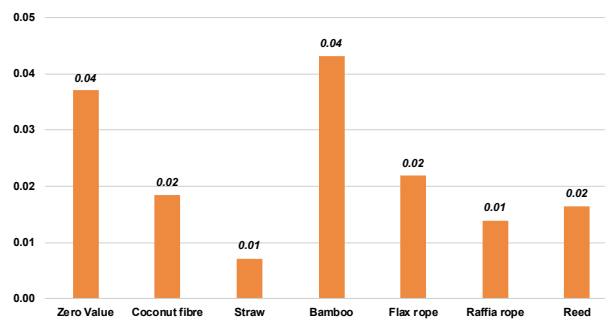
As an addition several materials are chosen to add in the sample to increase the bending strength:

Coconut fiber, Straw, Bamboo, Flax rope, Raffia rope and Reed.

For comparison it is important to also test a sample without additions. The Graph 13 shows interesting results. The Graph 14 shows results in N/mm². Surprisingly the samples with addition, except for bamboo, decreases the bending strength. The sample without addition perform much better. The sample with bamboo isn't much better than the normal sample without any addition. The reason behind the decreased strength is that the addition creates a layer instead of a homogeneous mass as it show in Figure 12 and Figure 13.



Graph 13: Bending test results maximum load (kg)



Graph 14: Bending test results maximum load (N/mm²)

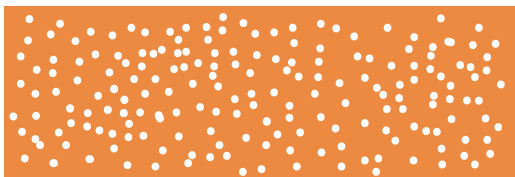


Figure 12: Illustration of a sample without addition

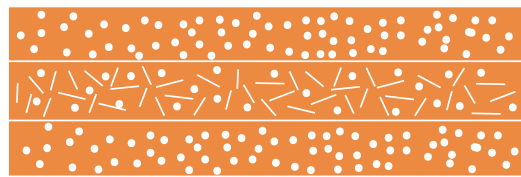
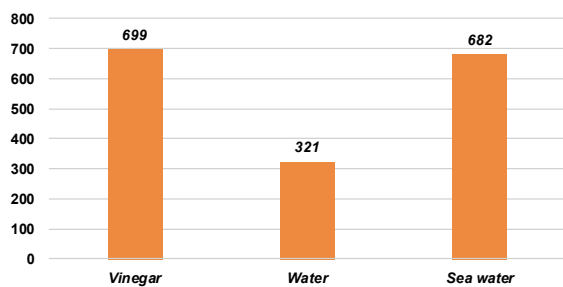


Figure 13: Illustration of a sample with addition

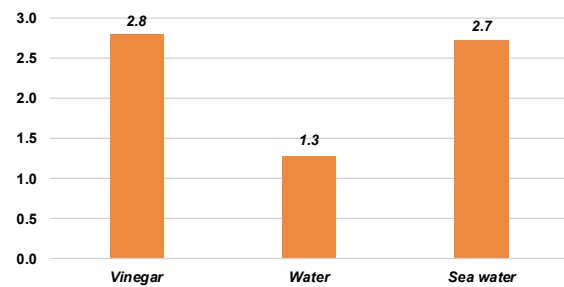
EXTRA BENEFITS BY SOLVENTS

For the process of making this product it is needed to have an additive to dissolve the gelatin and mixing it with sand. At the beginning of the research vinegar was the only additive to dissolve the gelatin. The reason of using vinegar was because it dissolves the gelatin best. But considering the cost and transportation of vinegar it is not an ideal choice for local production of the sand mixture. Therefore the next question arises: what does a sample do with normal water and what effect does salt water (from the sea) has on the mixture with gelatin.

Three samples were made to test this. Each sample has its own additive: water, vinegar or salt water. Water is chosen because this is easier to get in future building locations and much cheaper than vinegar. To consider that water is in some country scarce and it could be expensive too. This argument is an important point to take into account. Seawater is available in almost every country and may only need some form of transportation to bring it to the building site.



Graph 15: Strength results of sample with different solvents (kg)



Graph 16: Strength results of sample with different solvents (N/mm²)

The Graph 15 and Graph 16 shows some interesting results. Expected was that none of the additives had an effect on the press strength. However, the graph shows that sample with plain water was 54% of the strength compare to vinegar and seawater. The samples with vinegar and seawater are almost the same. The reason behind the decrease in strength of water sample has to do with bacterial reaction in the sample. The expectation is that vinegar and salt water disinfect the sample. Which prevents bacterial growth. It was noticeable that after the test the samples were very smelly, this indicates a bacterial reaction.

From this experiment, the conclusion was drawn that sea water is the best option as additive to solve the gelatin. In this case artificial salt water was used, but there is difference between sea water and salt water. Like the percentage of salt in the water. Sea water contains also contains other particles and minerals. For this reason, extra research is needed to find out if there is any difference in strength between artificial sea water and real sea water.



BRICK REQUIREMENTS

The design of the brick is an important phase of this research in order to create temporary housing. The brick will be the main subject how to build a temporary house.

After all the research on mechanical and material properties of the biodegradable Standstone, four main requirements were formulated:

1 Hollow

The brick should be hollow due to the drying time. The thicker the material, the longer it takes to cure and dry. Speed is a crucial aspect in this subject. There is no need to create a solid brick. It will be a waste of material.

2 Wall thickness: 30mm

Since the brick is hollow, the wall thickness had to be set. 30mm thick is strong enough to hold a wall and the right dimensions to dry well.

3 Interlocking shape

To be able to build fast, it is necessary to design a brick which can be used without any addition during the building process. That is why it is important to design a brick that does not need a mortar to stack.

4 Single brick design

To increase production speed and increase simplicity during the building process it is preferable that there is only one brick design for the entire house.

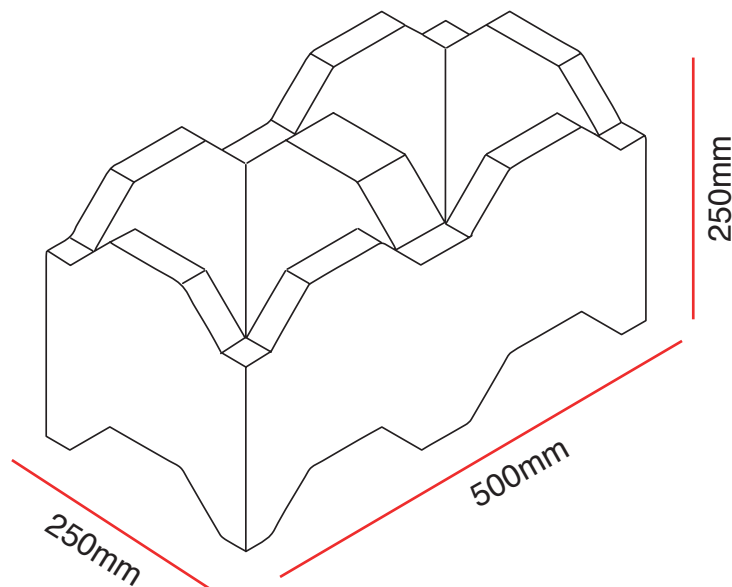


Figure 14: Brick that is designed to built houses with it.



MORTARLESS BRICK

The brick is design in a way that can be stacked like a lego blocks. Figure 15, shows the dimensions of the brick. The dimensions of the brick are 500l x250h x250w mm.

The inlets of the brick have the same size in each side. These inlets fit exactly to each other. Due to these inlets, the bricks fit perfectly without using any mortar and is self-aligning. The system is can be used also as half brick system wall. In addition, the stone is also designed that it can also be used in the corners without any adjustment. See Figure 16 and Figure 17 for illustrations.

In addition, the inlets ensure that the stones remains in place without being shifted in the horizontal plane, Figure 17.

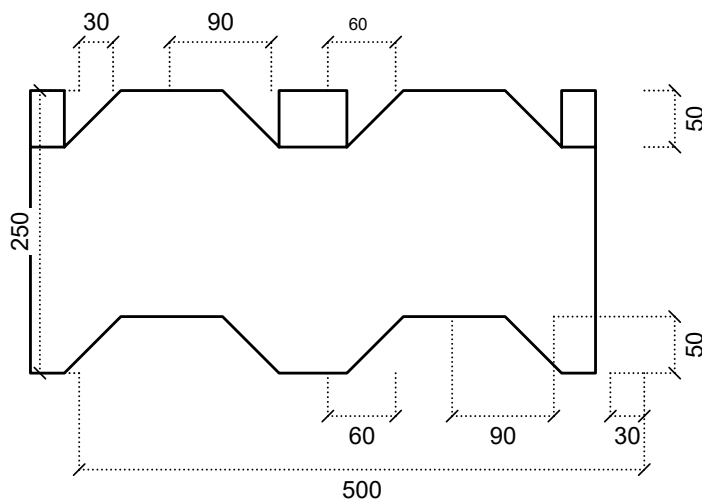


Figure 15: Dimension of the bricks sides view

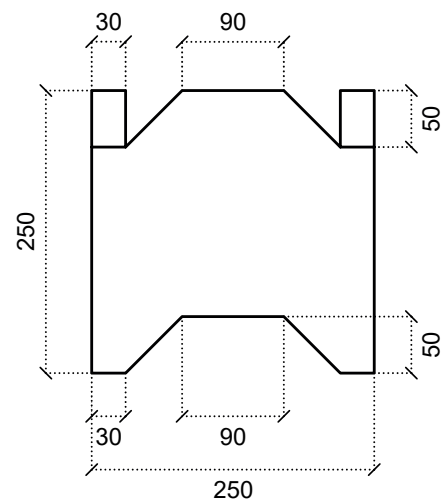


Figure 16: Dimension of the bricks front and bak view

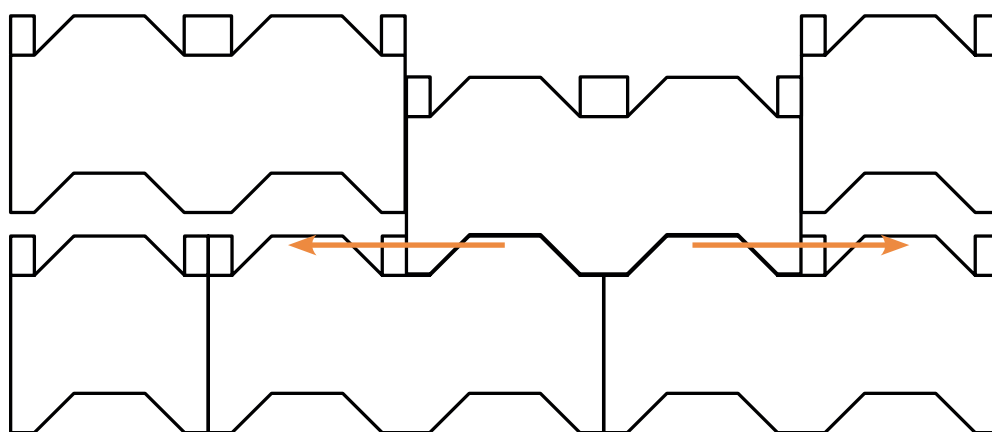


Figure 17: Illustration of the function inlets.

DESIGN BRIEF FOR A TEMPORARY HOUSE

Specific demands for the refugee temporary residence do not exist. There is some information that contains some requirements about living condition of the refugees but no information on the design specification. That is why it is important to create a design brief that contains which requirements are needed to build a temporary house.

On the database off UNHCR there was a document which had information about which requirements are needed for a healthy refugee camp (Appendix 1). The article contained the following information about accommodation/shelter.

- Use local material
- Minimum shelter space 3,5m² per person (average for family of six people)
- Refugees should be able to stand upright in the shelter
- Shelter should stand two to three years

Also, good to know what refugees said in the past about the living environment of the refugee's camps. The main complaints were: a lack of water resistance, too much noise, lack of insulation and the lack of privacy.

In the refugee camp, we are dealing with different cultures and religions. Every culture or religion has their own way of living in their homes. It has to be taken in account that building design should fit all different needs. That is why the option to separate the internal space was add.

The following list is the design brief which will be the guideline for designing a temporary residence for refugees:

- 21m² surface
- Water resistant
- Insulated
- Windproof
- Privacy
- Daylight
- Internal space can be separated

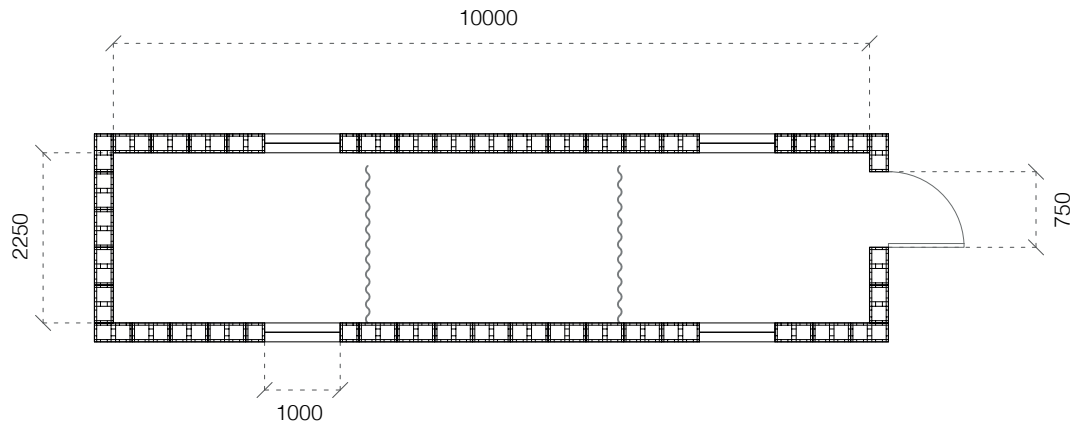


Figure 18: Floor plan separated in three parts with curtain

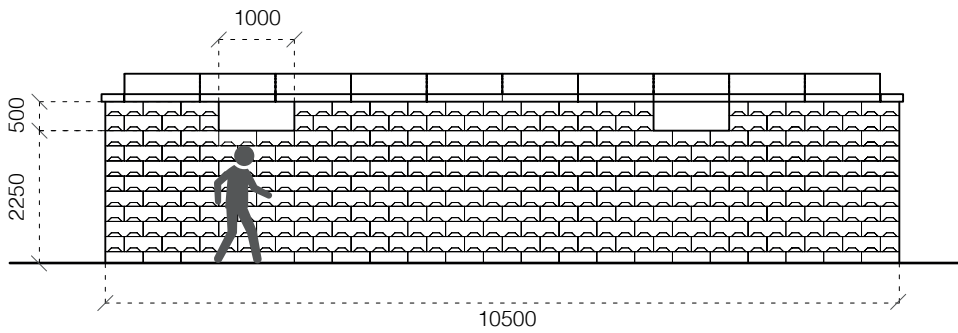


Figure 19: West facade

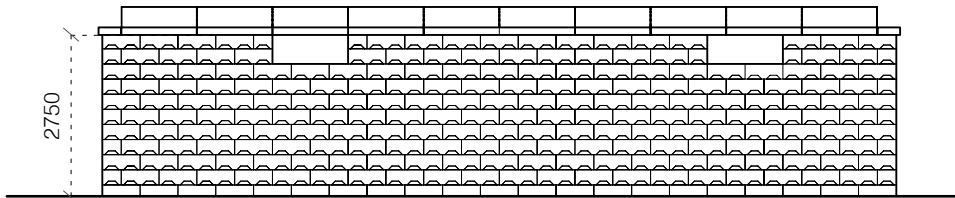


Figure 20: East facade

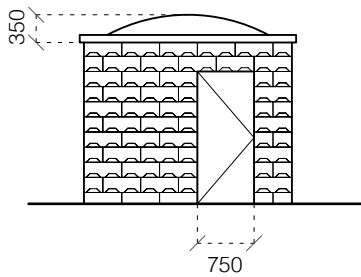


Figure 21: South facade

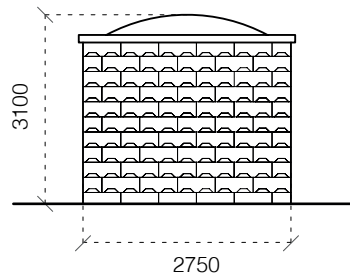


Figure 22: North facade



BUILDING DESIGN

As mentioned in the previous chapter, the surface should be 21m². There are several options to approach demand surface. But in this case the dimension of a shipping container is most suitable dimension: 2591w x2438h x12192l mm. This is in case when there is a tool or a part of the building that is needed to be shipped in a shipping container.

As a result the floor plan dimension is 2300wx10100l mm, Figure 18. This floor plan can be separated in three parts by using curtains. This is entirely up to the occupant to make use of it as mentioned in the previous chapter.

The design of the facade is very simple, Figure 20. There are no exceptions apart from the window and doors. The brick design is also visible on the facade. You see a certain pattern becoming a part of the design of the facade.

Every culture has their norms and values. One of the requirements of the design brief is privacy. To provide sunlight in the house, there should be windows. A space without windows would feel like a shed.

The windows are placed high up in the wall. When they are placed lower, like many normal houses, people could see inside. This is the point that most people don't like to be watched and they use curtains to block the window, Figure 19. When the user blocks the windows with curtain, then the function of the window will not be effective. It will be useless. That is why the windows are placed high to provide privacy.

Each side of the facade has two windows with the following dimensions, 1000l x500h mm, Figure 19. These windows are not as the regular windows which you can find in a normal house. These windows are very simple and covered with Plexiglass.

ROOF DESIGN

The roof is one of the important part of a designing process. The requirement for the roof are as follow:

- Modular
- Lightweight
- Prefabricated
- Boltless system

The roof parts are already prefabricated in order to save time and energy. Also, the roof has to be modular and lightweight in order to be transported and handled with only a few people. The parts should be connected without fasteners since there are no tools at the building site. This system is called a boltless system. Less tools, material and weight means less transport. Besides, there is a chance tools get lost in the process.

With these constrains a roof element was designed:

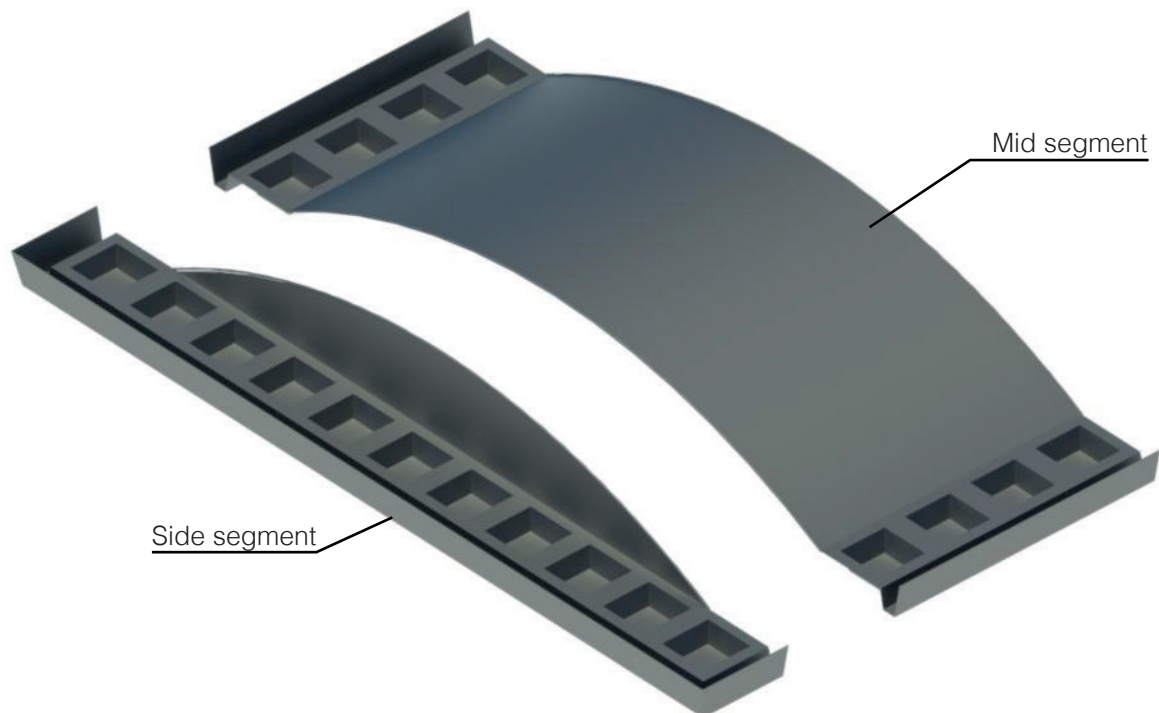


Figure 23: 3D Impression roof design

ROOF DETAIL

This chapter will give a better view of how the roof element has been designed.

The roof design has been given an arc shape so simple production methods could be used. The production that will be used for this roof design is called vacuum forming. This is a production technique that uses a plastic sheet that is preheating to a forming temperature. Right after preheating the plastic sheet, the sheet is stretched onto a single mold. The air underneath the plastic material is removed by a vacuum pump and the sheet of plastic is formed after the mold see (Figure 24).

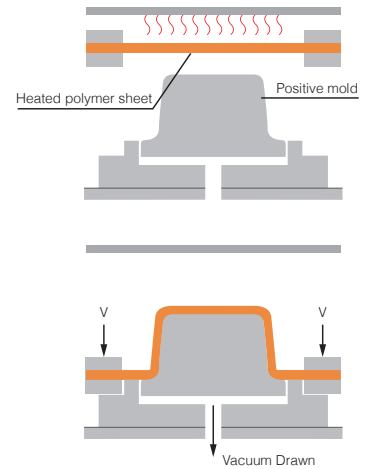


Figure 24: Thermoforming principle

As shown in Figure 23, the roof design consists of two different shapes: a middle segment and an end segment. End segments are designed to close the sides of the roof. Multiple middle segments are used to cover the entire roof. All segments are connected with an interlocking shape.

The segments are placed on the wall without using any fasteners. The sides of the roof design have slanted bins. These get into the hollow bricks so that they remain in the same spot. In addition, these bins also serve as a ballast reservoir. After the roofs are placed, sand is added to the bins. This will ensure the roof gets a weight and is not blown away by the wind.

Figure 27 shows the details of the roof how they are connected to the house.

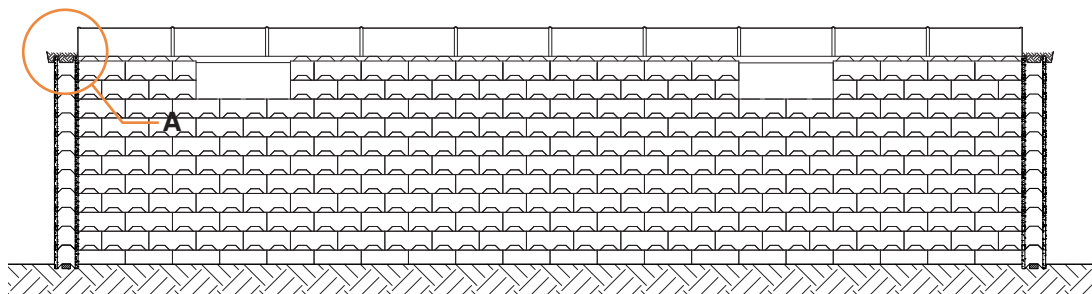


Figure 25: Section plane A-A'

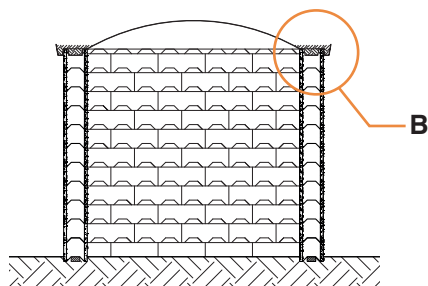


Figure 26: Section plane B-B'

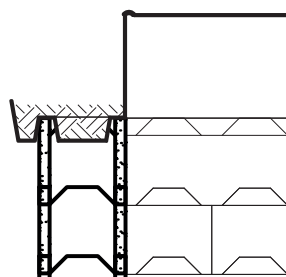


Figure 27: Roof detail A

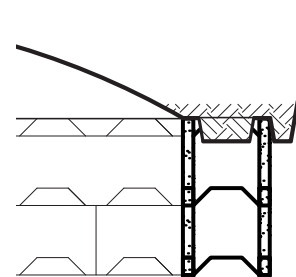


Figure 28: Roof detail B

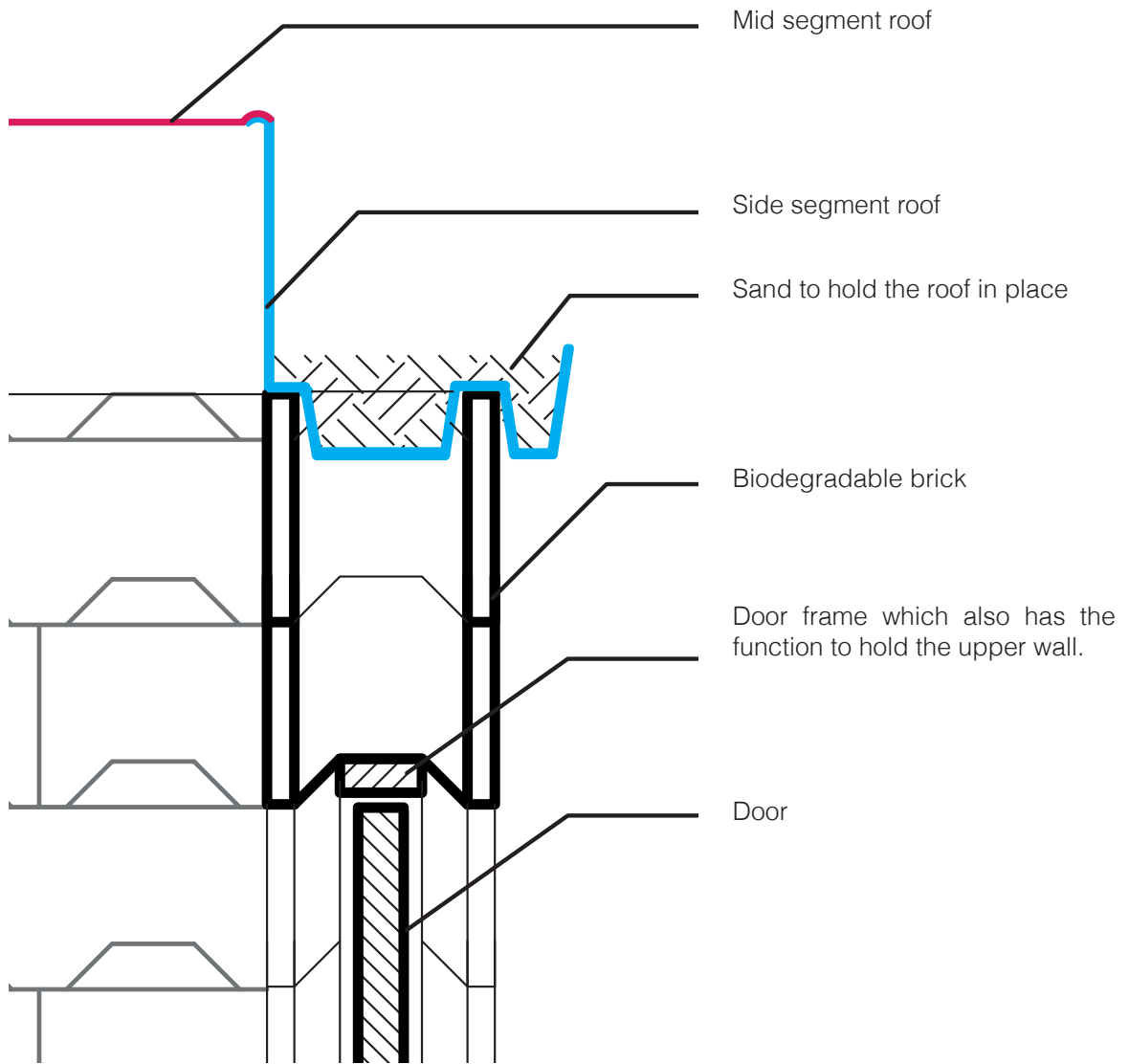


Figure 29: Door detail with roof connection

DOOR AND WINDOW DETAIL

The window and the door have simple detailing. Except that windows uses a single Plexiglass without any window frame. And the door is a simple door as any indoor door. These details are illustrated in Figure 29.

Above the window there will be a wooden beam which is holding the roof. This concept is exactly the same as the door detailing. There will be also a wooden beam that will hold the rest of the wall. This is necessary because the wall is built with interlocking bricks.

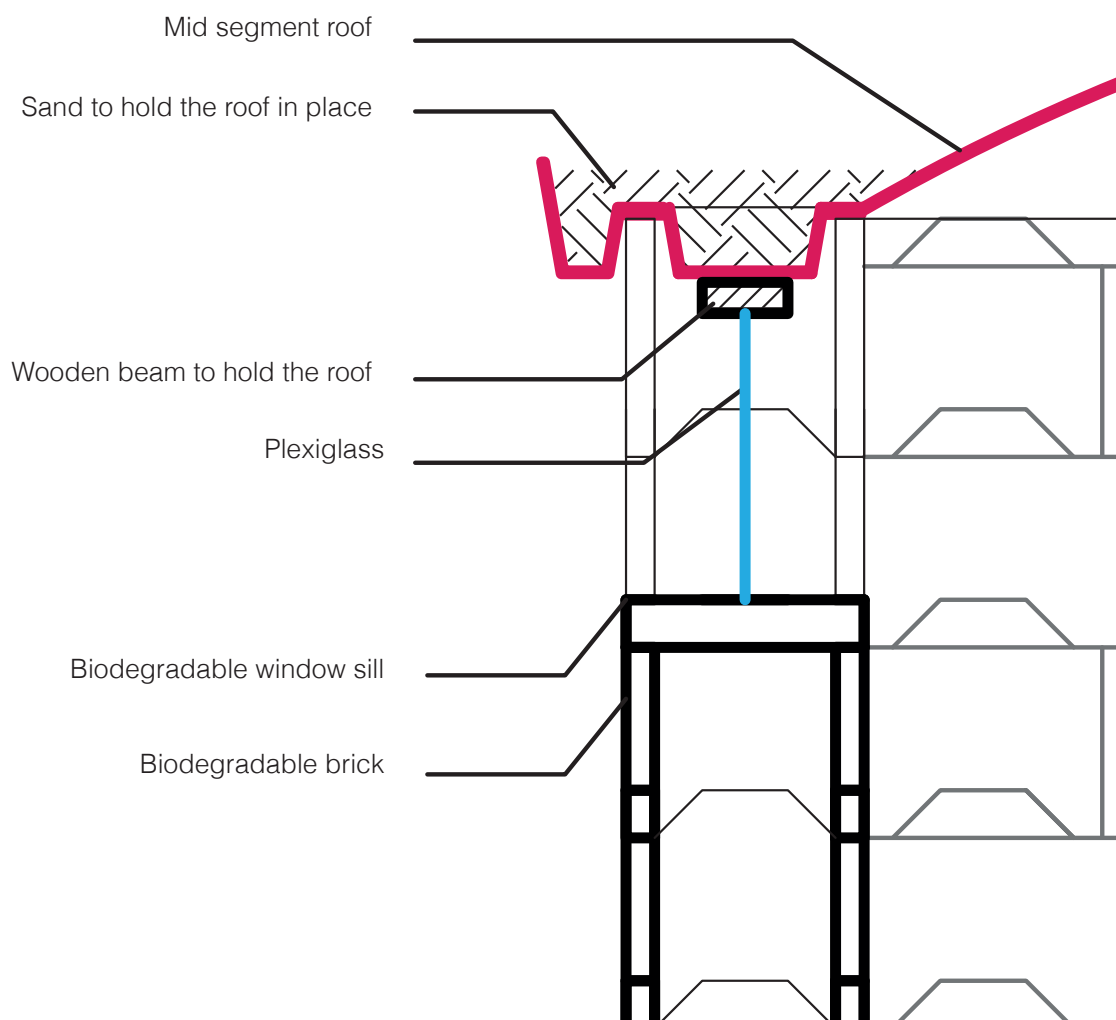


Figure 30: Window detail with roof connection



BUILDING MATERIALS

In this chapter is about what is needed to make the whole house. A list is provided with all materials that is needed to create one temporary residence:

- 9146 kg of sand
- 269 kg of gelatin
- 1292 Liter of seawater
- 10 middle roof segments
- 2 end roof segments
- 4 Plexiglass glass (1000 x 500 mm)
- 2 curtains (3000 x 2200 mm)
- one door (750 x 2000 mm)

Besides the supplies what is needed. There are also some important tools that is needed to be transported to accomplish the temporary house:

- Concrete mixer
- Shovel
- Big water boiler
- Molds to create bricks
- Masonry trowel
- Some buckets

It is important to have a management time table to create this house. To get an overview it is important to have data about molding times.

For creating biodegradable Standstone, it does not need much time to mix the ingredients. This cost mostly 30 minutes, including the preparation. However, after casting the sand in the mold, the sand should stay in the mold at least four hours. After getting the bricks out of the mold it is going to take at least three days to dry for 80%. After this it is possible to hold the brick and start building the house.

CONCLUSION

As mentioned at the beginning of this thesis the aim of this research is to investigate what the possibilities are of biodegradable sand. The problem statement of this study is to find a solution to the housing problem of refugee camp. These people have difficult times in refugee camps due lack of quality. The conditions are that the tents do not provide safety and privacy. This causes health issues, physically and mentally issues, (Baglolo et al., 2007). Not to mention that tents decrease in quality over multiple years, (Davidson et al., 2010).

Biodegradable sand has a lot of potential which might contribute a solution to the housing problem in refugee camps. Based on this problem statement and the potential of this material the following research question was formed:

What are the possibilities of Biodegradable Sandstone?

1. It is possible to use a biodegradable adhesive.

It is possible to use a bio adhesive, there is made a list which contains different bio and vegetable binders. These are the bio adhesive which is tested, Maize, Sugar, Gelatin, Potato starch, Salt and Agar Agar. This gave the opportunity to investigate if there are any differences. To conclude there were big differences between bio adhesive. Figure 31, summarizes these bio binders in a table. Which can be concluded that gelatin scored the best for the requirements that is made. Unfortunately, it is not possible to use a vegetable binder. Because this did not fit the requirements.

	Agar Agar	Gelatin	Maize	Salt	Starch	Sugar
 Biodegradable	✓	✓	✓	✓	✓	✓
 Strength	✗	✓	✗	✗	✗	✓
 Water resistance	✗	✓	✓	✗	✗	✗
 Production	✓	✓	✗	✗	✗	✗

Figure 31: Check list Adhesive

2. Technical characteristics of biodegradable Standstone

A list is made which bio adhesives are the strongest. And surprisingly sugar was the strongest. Slightly less scored was gelatin. But sugar is not water resistant. Gelatin was used because it fits all requirements. The best ratio between gelatin and sand is 1/34 g. Depending of the thickness of the material, the longer it takes to dry. In this case 30 mm thickness is the best choice because it dries for 80% in 3 days. Besides, this thickness is strong enough to hold a single stone wall. Some experiments are done with different solvents. In this case seawater is the best solvent to mix with gelatin and sand. Compared to fresh water, sea water is much easier to get and cheaper. Not to mention, due the salt inside the water it disinfects the mixture. This prevents bacterial growth.

Lastly, biodegradable Standstone is very bad at withstanding bending forces and excellent in compressive forces.

3. An interlocking brick design and a building for temporary residences

To create a temporary building is an interlock design brick the most suitable solution. With this system, it is possible to build a house without using any extra tools or materials. The brick is designed in a way that they interlock with each other. This system calls "The Mortarless Interlocking Block System". Stacking these bricks is mostly compressive forcing which is fine for this material. To increase production speed and increase simplicity during the building process it is preferable that there is only one brick design for the entire house. That is why is chosen for one brick design.

Also, the roof will be with the same principal system. Boltless system will be applied for the roof. The roof will be not same material as the brick due the bad bending force quality of biodegradable Standstone. The roof will be made from polymer which thermoforming production is applied.

Conclusion

Biodegradable Standstone has a lot of possibilities. Provided it is only meant to use for temporary projects. To clarify, this research was not supposed to replace concrete or bricks. It was meant as an option to choose in a certain goal or purpose. This is also a possibility to use a material which lasts a couple of years without harming the nature. One can build a house of biodegradable Standstone and after using it, you can leave it without having guilt for damaging the environment. This is the opportunity to use less materials, like wood, and throw away. Let's use materials which not harm this world.

REFLECTION

There are several aspects to approach your goal. The chosen aspect for the graduation is relation between research and design. This is based on the chosen subject, biodegradable Standstone. This material is new and there is hardly any information about it. To be able to design a product you have to understand what are the properties of this material. The method 'research and design', is most suitable method to approach the goal.

Research and design

This part of phase has to two different aspects: research and design. In the phase research is a part of gathering information about the subject/product. This information will be used in the designing phase. And reflects back to research. It is an interaction between research and design. Designing is translating the research in product and the product reflects to the research.

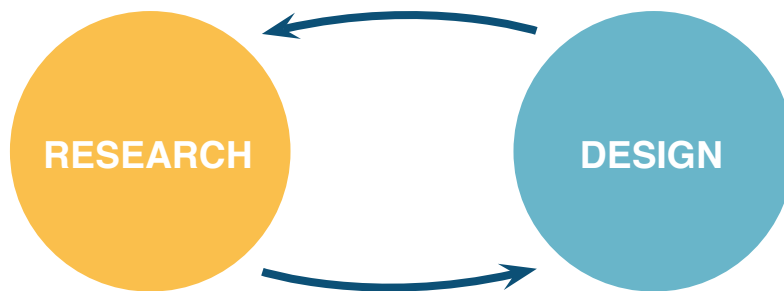


Figure 32: Research method: research and design

This process designing "research and design" has been used during the graduation. Also, it was important that this method should be visible in the planning. To ensure that the plan becomes clear, the graduation time was divided in four phases: research, experiment, design and finalizing (see Figure 33).

The first two phases are research phases, they mainly consisted of gathering information about the product. The third phase was the design phase and the last phase was finalizing the graduation. This graduation plan was successfully performed. It was clear what should be done and what following steps were. At some moments complications occur. But very educational. For example, the proportions that were found during the process, must be prescribed. Another sample, the material was very sticky. This material sticks very easy to the surface of the mold. It was very difficult to detach it from the mold.

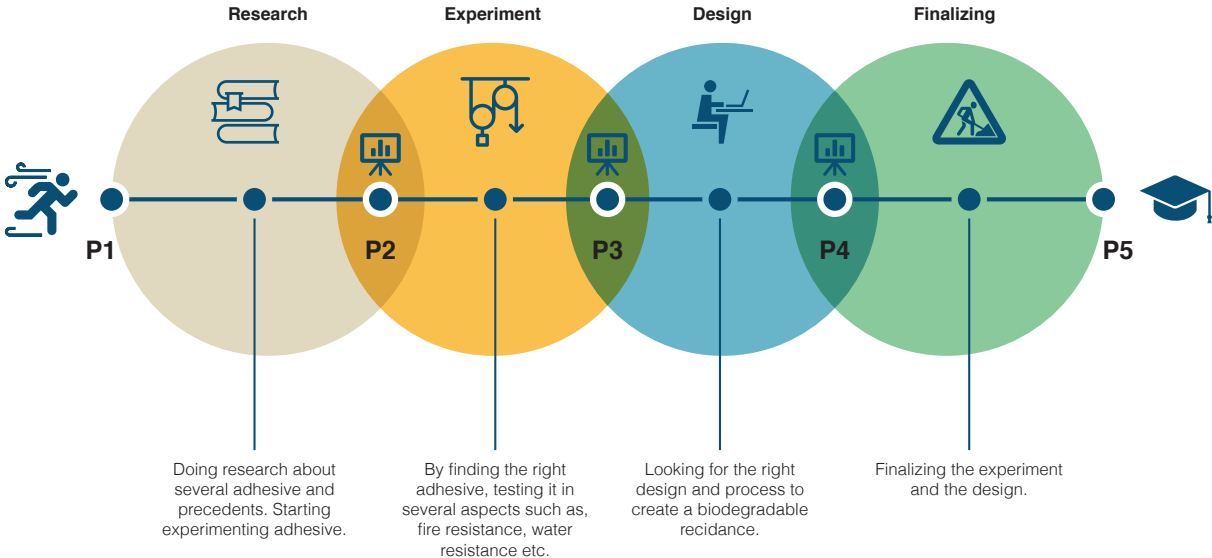


Figure 33: Design Framework

Looking at further research, the brick that is designed is slightly too big. Because during the production the brick failed a couple of times because it was too heavy. That is why the size should be reconsidered. Also, the design of the roof could be optimized. There must be easier ways to approach a better and easier design to produce which is cheaper at the same time.

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APPENDIX 1



LIFE IN A REFUGEE CAMP

Time	45 – 60 minutes
Level	intermediate
Skills	reading, speaking, writing
Knowledge goal	raising awareness of life in a refugee camp
Materials	Ss' worksheet: p. S1 - p. S3 - texts A - F (one for each group) p. S4 - a photo of a refugee camp, "Language of Comparing and Contrasting" (one for each student)

1 Lead-in

- Ask Ss: *Have you ever been to a summer camp?* Tell Ss to form pairs and discuss their experience, and to think about typical characteristics of a camp (e.g. living in tents, a lot of people in one place). If there are people who haven't, pair them with those who have. When finished, discuss it in the class.
- Present the picture of a refugee camp (p. S4) or print it out from www.globalissues.eu. Ask Ss what type of camp it is and who lives in such a camp. If Ss don't come up with the word, tell them that it is a refugee camp. Ask them:

What is a refugee?

What are the differences between a summer camp and a refugee camp?

A refugee is a person who has left their country because they didn't feel safe. This may be because they belong to different racial or ethnic groups or have different political views to the current establishment.

2 Reading activity

- Tell Ss that they are going to learn some facts about living in a refugee camp. Ask them to form groups. Ideally there should be the same number of students in a group as the number of groups (e.g. three groups and three Ss in each). In small classes you can ask people to work individually or in pairs, and then do the final speaking activity and the poster as a single group. If you want Ss to work in groups and you do not have many, each group can get two reading texts or you can choose only the texts from A – F you want them to do.
- Each group gets a text (A – F) about a certain aspect of life in a refugee camp (p. S1-3). Ask them to read the information and prepare a summary of the main points. Tell them that after they have finished, they will go and talk about the facts they have learnt to people from other groups. The summary should be prepared from the refugees' point of view, i.e. Ss should use the form "we" when possible to make it more personal.
- When Ss are finished, ask them to form different groups. Each group should contain people who know different facts. Ask Ss to present their summaries.

- If you want to finish the activity here, give Ss a few minutes to discuss what they have learnt and to compare lives of refugees to their lives. Otherwise continue as suggested in the follow-up.

3 Follow-up

- Ss remain seated in their groups. Tell them that they are going to create a poster where they will compare and contrast lives of refugees with their own lives. Give them time to discuss the differences.
- Give Ss the handout Language of Comparing and Contrasting (p. S4). Go through it.
- Ask Ss to create a poster where they will compare their lives to that in a refugee camp. They can compare one aspect or more. Ask them to use the language they have, draw pictures and be as creative as they want to be.
- When finished, put the posters on the wall and ask the class to walk around and read their classmates' posters. When finished, invite Ss to ask questions about the posters of the other groups.

4 Homework

- A. Ss watch a video about Carly, a refugee girl. You can find it on www.youtube.com: Carly, a refugee's story (UNHCR, 1999). Discuss it the next lesson.
- B. *How do refugees live in your country?* Find information on the Internet about the living conditions of these people. Present your findings during the next lesson.

Sources of info/photos/videos:

<http://www.unhcr.org>

<http://doctorswithoutborders.org/news/refugees>

<http://www.refugeecamp.org>



A. GENERAL INFORMATION

Every refugee camp is different because every situation is different.

Population

The number of people living in a camp depends on the crisis itself. When the number of refugees is in the hundreds of thousands, a few smaller camps with a population of no more than 20,000 are established rather than one big camp. In smaller camps it is easier to manage problems such as fire, security or the spreading of diseases.

Location

Camps are usually situated on the edges of towns or cities, away from borders and war zones.

Length of Stay

Camps should be only temporary solutions, giving refugees a place to live until they can safely return to their country. They are not meant to become permanent homes or settlements. However, refugees often have to live in the camps for much longer than expected.

In Albania, refugees from Kosovo lived in camps for only three months, while refugees from Somalia have been living in camps in Kenya since 1991.

Camp advantages

- Provide protection
- Easier to find out how many people live there, and what they need
- Some basic services are easier to organize (e.g. food distribution, vaccinations)

Camp disadvantages

- Too many people increase the risk of spreading diseases
- People are dependent on aid coming to them from the world
- Isolation and not much to do
- Degradation of the surrounding environment
- Security problems within the camp



B. ACCOMMODATION and SHELTER

Materials

Shelters for refugees are usually made of local materials such as wood, metal sheets, tree branches or plastics. When possible, refugees build their own "houses". Shelters usually have stoves for heating and cooking. In warm climates cooking facilities are often outside.

Space

The minimum shelter space recommended is 3.5 square metres per person in warm climates where cooking is done outside, and 4.5 to 5.5 square metres in cold climates where indoor kitchen and bathing facilities are needed. The minimum distance between shelters should be two metres.

Tents

In emergency situations or if local materials are not available, tents are often used. Refugees should be able to stand in all areas of the tent without hitting their heads on the ceiling. Tents last two to three years.

The Organisation of Shelters

The best method is to organize the camp into smaller units where each unit has its own community facilities such as toilets (latrines), water-points and washing areas.

C. DRINK

Quantity

It depends on the climate and on the habits of the population. In order to survive, people need to drink 4 to 5 litres a day. But water is also needed for cooking, washing the dishes or clothes, and personal hygiene, so ten litres per person per day is seen as the minimum.

Water Point

There should be at least one place to get water for every 200 to 250 refugees. Shelters should be no more than 100 metres from a water point.

Water Sources

Sometimes there are nearby water sources such as rivers, lakes, wells or springs. If the water source is clean (e.g. from wells or springs), it can be used without treatment. Water that comes from rivers and lakes can be contaminated and must be treated before people can use it. When water is not available nearby, it has to be transported to the camp.

Water Quality

Water can be contaminated with microorganisms that cause disease. This is why the quality of the water is as important as the quantity. In a refugee camp, where so many people live close to one another, epidemics can start easily and spread very quickly. Cholera, a disease caused by drinking contaminated water, can kill people within hours if they do not get medical help.

How water is treated

1. Sedimentation: The water is stored for a few hours so that the biggest particles can settle to the bottom.
2. Filtration: It is then necessary to get rid of the small, invisible particles by filtering the water through sand filters.
3. Chlorination: The last step is chlorination. This is done by adding a chlorine solution to the water which kills all the microorganisms.



D. FOOD

When people have to leave their homes quickly, they usually do not have time to take food with them. This is why refugees must be able to get things to eat when they arrive in a camp.

Food needs

Depending on the region and their eating habits, families are usually given basic ingredients such as corn, grains, beans, oil, sugar, and salt. For cooking, they may find wood around the camp to build fires, and they use cooking utensils that they have brought with them or received from aid agencies. The minimum recommended daily ration is 2,100 calories per person.

Example of a recommended ration

Commodity	Recommended Ration (grams per person per day)
Cereal (e.g. rice or wheat)	400
Pulse (e.g. beans or lentils)	60
Oil/Fat (vegetable/butter oil)	25
Sugar	15
Salt	5

Storing food

Food is usually stored in one large tent. This tent should be situated near administrative offices for reasons of security, and also near the entrance of the camp so that supply lorries do not have to drive through the camp.

Food Distribution Point

Food distribution can be done at one place or divided into several ones. Refugees are given food which lasts for a week or even a month so that they do not have to wait for it every day. The camp is divided so food is distributed to different people on different days to avoid long queues and chaos.

E. HEALTH

Hospital

Some refugee camps have good and well-equipped hospitals where doctors are able to deliver babies or even operate. If refugees can go to a hospital in the host country, the camp will not build its own. A hospital usually serves a population of 200,000 (or one hospital per ten refugee camps).

Health Post

In a camp there are usually smaller health posts established, each for 3,000 to 5,000 refugees. Nurses provide treatment for things such as sore throats, fevers and cuts. Serious cases are sent to the main health centre.

Toilets (Latrines)

Ideally there should be one latrine per family. If public latrines are used, there should be at least one for every twenty people. When there is no organized way to go to the bathroom at the beginning, people usually go to the "toilet" anywhere around the refugee camp. But the human waste can cause the spread of many infectious diseases, so it is necessary to organize a waste disposal system immediately. Latrines should be at least 6 metres away from homes, but not further than 60 m. For privacy, mud, bricks and other materials are used to build a roof and walls around the latrine.

Diseases

There are two categories of disease that usually appear in a refugee camp. The most common non-epidemic diseases are malnutrition (when people do not have enough food), breathing problems and malaria. But there are also deadly diseases that can turn into epidemics such as cholera. Cholera is a disease that people can get by drinking contaminated water or eating contaminated food. Without quick treatment, about 50 percent of people who get cholera will die of dehydration.



F. EDUCATION

Education should be provided in a camp because it's very important for children to have a sense of normalcy. The international community should support refugee education in those countries where the host government is unable to do so by helping local schools and/or by establishing a system of refugee schools. There should be one school per sector of the camp (about 5,000 people).

Advantages of Education

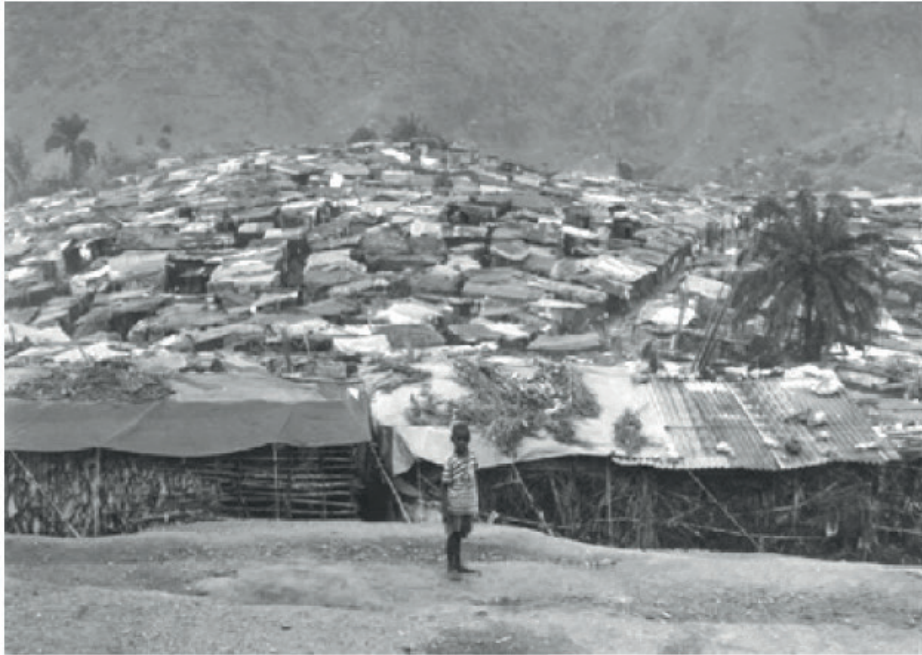
- Education protects children who are refugees.
- Education helps to meet the needs of children and is a way of promoting their future development.
- Schools and pre-schools have an important role because young children can play here.
- The early weeks and months in a refugee camp are characterised by a sense of shock, which can be followed by a sense of depression and resignation. Going to school helps to restore a sense of purpose in children's lives. Refugees themselves almost always identify education as one of the main priorities.
- Education gives children the opportunity to discuss their experiences of violence, danger or having no home. By doing this they develop an understanding of these events.

Refugee Curriculum

A recent review of UNHCR's Refugee Education Activities noted that the curriculum in refugee schools should also include topics specific to the refugees' situation such as:

peace education, conflict resolution, human rights, the environment, health issues (including sex education and drug abuse), an introduction to the host country culture.

Pic. 1



LANGUAGE OF COMPARING AND CONTRASTING

Comparing

- A and B lead similar lives.
- A is similar to B as regards/regarding food which is needed every day.
- A is (exactly, practically, more or less) the same as B.
- Both A and B need water to survive.
- A is as difficult as B.

Contrasting

- A is (much, rather, somewhat) smaller/bigger/more difficult than B.
- A is not as healthy as B.
- A is not (exactly, entirely) the same as B.
- A is (completely, quite) different from B in terms of the water supply they need.
- A and B are (completely, totally) different.
- A differs from B in the way of life.
- A needs ..., whereas/while B needs
- In contrast to A, B usually eats more meat every day.

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