RESEARCH PAPER

BIOBASED MATERIALS
SHOPHOUSE BANDUNG

GRADUATION | ARCHITECTURE ENGINEERING

TUDelft

BIO SHOP HOUSE

LOUISA DE RONDE

4087356


BIO SHOP
HOUSE

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Researcher | Louisa de Ronde | 4087356

Laan der zeven linden 33, 2645GR
Delfgauw, The Netherlands

Architecture Teacher - Monique Smit
Research Teacher - Marcel Billow

Graduation Studio Architectural Engineering

TU Delft

CONTENTS

ABSTRACT

"WHICH BIOBASED MATERIALS CAN REPLACE THE CURRENT BUILDING MATERIALS AND IMPROVE THE BUILDING PROCESS AND METHODS?"

The fashion village consists of industrial kampungs surrounding the factories that are located in the city Bandung of Indonesia. Under the influence of the fashion industries, the peri-urban part of Bandung has transformed into unplanned and polluted factory towns. The current houses are mostly built out of concrete, steel and stone which causes more CO2 emission and discharge of water. The use of these materials leads to several climate- and living environment issues.

This research paper summarizes the technical research to answer the aforementioned question. This research that focuses on the solutions to introduce biobased building materials aims to provide for affordable building materials and at the same time make the building methods and process sustainable. This will have a positive influence on the fashion village to create a better living environment and climate.

The research is based on several methods; literature study, local interviews, internet research and case studies. These resources give the knowledge and information required to form suitable solutions that answer the technical research question. The main results are appropriate, biobased building materials that can be locally produced by the villagers. The properties of these materials are then compared with each other to form conclusions and the answer to the research question.

Keywords: Biobased materials, Indonesia, Bandung, Kampung, Building process, Fashion village, Sustainable, Building materials

“UNTIL THE INDUSTRIALIZATION OF TEXTILE PRODUCTION THERE WAS A VERY STRONG THE CONNECTION BETWEEN THE LOCAL ECOLOGY AND ECONOMY” [1]

INTRODUCTION

INTRODUCTION

In the past twenty years, Bandung turned into an industrial life and work environment of the textile and garment industries. Before this industrialization and tremendous economic and spatial growth, Bandung consisted of different self-sustaining villages with terraced wetlands. After this significant change, the peri-urban in the south of Bandung near the rivers has transformed into unplanned and polluted factory towns. Working and living are completely intertwined, although not always in a right way.

At the moment, there is not enough space for all the factory workers to live in the neighborhood and most houses do not have the possibility to start a personal business or shop to create an independent economic. Besides the lack of living space, the traditional building technique is almost expelled by the transformation. The factory villages are full of houses, built out of concrete, stone and steel which causes more problems with CO2 emissions and the discharge of water.

For a long time, the rivers and slopes of Bandung have been in use as terraced wetlands combined with forest gardens provided many resources. After the arrival of the fashion industry, favoring the factories, almost all of the green space, wetlands and plantations disappeared. The green structures were imperative for a stable climate. The city has faced a lot of natural disasters like floods, high temperatures, and dry spells after the disappearing of the green space.[2]

Because of the enormous change in the industrialization, a lot of different problems arose that are related to the arrival of the factories. This transformation has much influence on the culture, the landscape, the way of living, economics and building methods.

The primary goal of this graduation project is to change the building method and process into a sustainable cycle, with biobased building materials that can be locally produced. This new building cycle is relevant to a better environment, climate and way of living.

To research the possibilities for biobased building materials, the following technical research question is formulated: *"WHICH BIOBASED MATERIALS CAN REPLACE THE CURRENT BUILDING MATERIALS AND IMPROVE THE BUILDING PROCESS AND METHODS?"*

The second primary objective is creating a new shophouse typology in combination with an integrated garden and renting rooms. This new typology is relevant for the local villagers to manufacture their independent economic by producing and selling their products. The integrated garden will provide green space that has been lost over the past years due to the industrialization.

To apply the research solutions from the first question and reach the objective the following overall design question is formulated: *"HOW TO TRANSFORM A POLLUTED FACTORY VILLAGE INTO A SUSTAINABLE COMMUNITY BY IMPLEMENTING A NEW TYPOLOGY FOR SHOPHOUSES?"*

The next chapter explains which methods are used to answer the technical research question and how the research is built out of different subjects. After the methods, the results of the research are described which leads to the conclusion of this paper and the answer to the technical research question.

METHODS

METHODS

This research is based on several methods; literature study, interviews, case studies and internet research. These resources give the knowledge and information required to form suitable solutions that answer the technical research question.

The research is split up into different parts. First, the local building was investigated based on literature, observation of pictures and previous studies of Bandung. This chapter is followed by results of five local interviews with the inhabitants of the kampung in Bandung. The interviews are mainly focused on the building materials and the preferences of the local villagers.

After this part, general information about biobased materials is researched based on literature followed by a case study of Baduy in Indonesia to examine the traditional building method and materials that give information for certain critics that are applied to the chosen materials for the database. The database is organized in different categories selected by the components of a house. The categories are structure, non-structure wall, facade cladding, floor cladding, interior finish and roof cladding. After the database, there is an overview of all the selected materials with certain criteria that will give the information and knowledge to form the conclusion. On the next page, an illustration is presented that summarizes the methods and structure of the research.

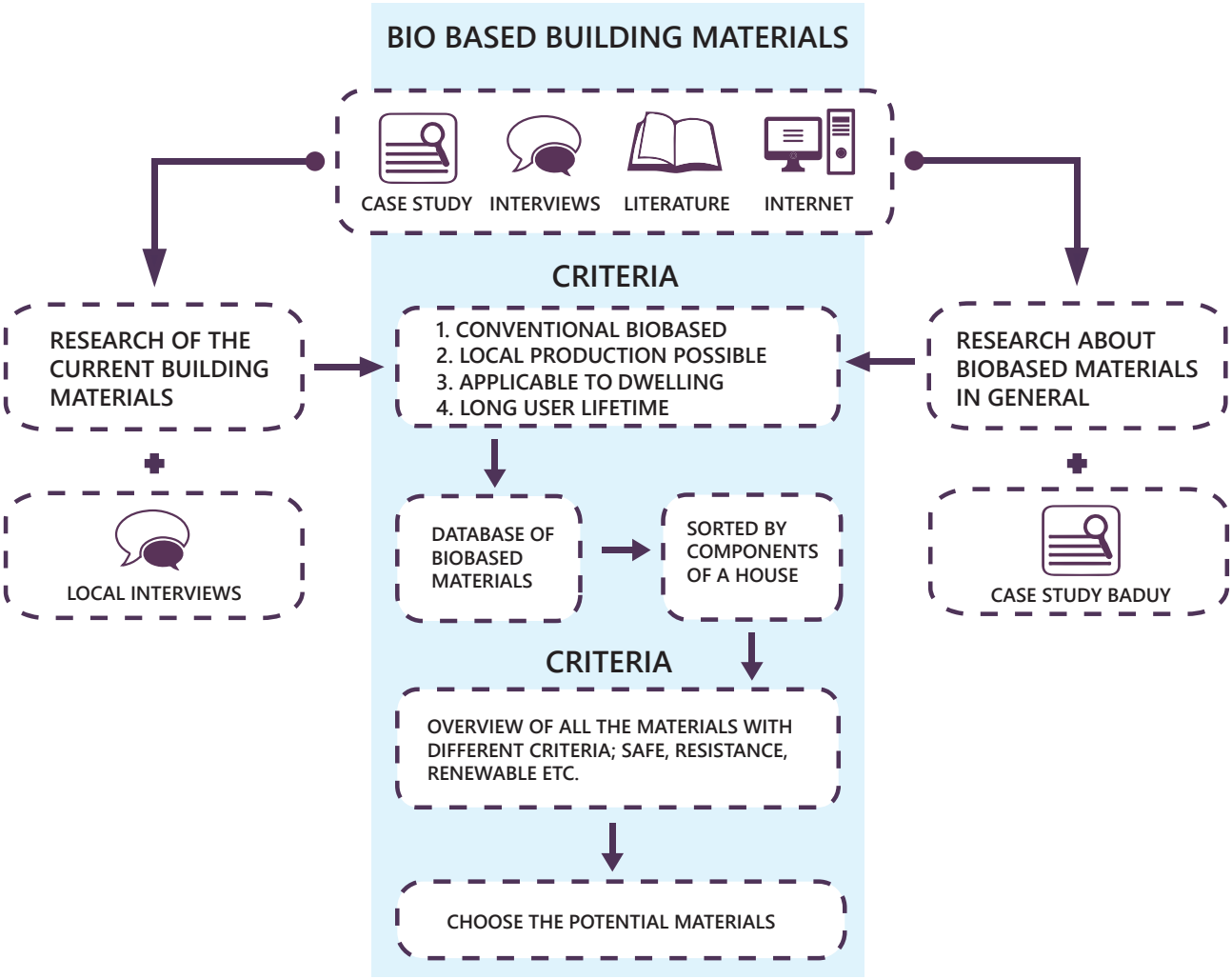


Image 1 Research methods and structure (own ill.)

RESULTS

LOCAL BUILDING MATERIALS

LOCAL INTERVIEWS

BIOBASED MATERIALS IN GENERAL

CASE STUDY BADUY

DATABASE BIOBASED MATERIALS

OVERVIEW DATABASE

LOCAL BUILDING MATERIALS

The villagers in the kampung of Bandung generally use building materials that fit their budget and the current supply. Most villagers buy their building materials in local shops in the kampung. Bricks, cement and corrugated steel are the most common materials. In the poorest area of Bandung, they use lower quality materials such as untreated bamboo, corrugated steel sheets and asbestos sheets. Most people and constructors are not aware of the danger and adverse effects to their health and environment by using materials such as asbestos, concrete and steel.

The houses are built up out of one or two layers. The ground floor, made of concrete, is usually higher that the natural ground to avoid the floods. If the house has a second floor, it is made generally of a light construction. The roof is usually built out of a wooden construction cladded with tiles and the self-supporting walls on the ground floor are made out of concrete or bricks. For the interior, are often used ceramic tiles for the floor and walls. On the next page, there is an overview of the most common building materials with the costs per unit.

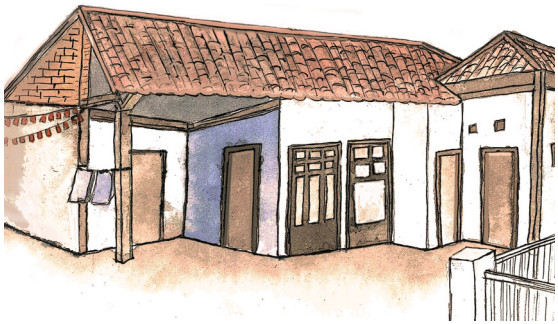


Image 2 General house in the kampung (own ill.)

Image 3 Small house in the kampung (own ill.)

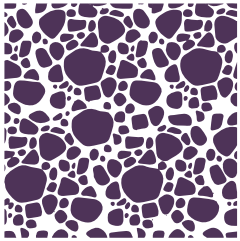
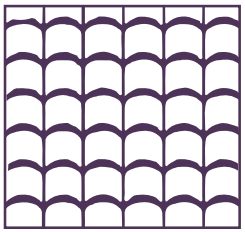
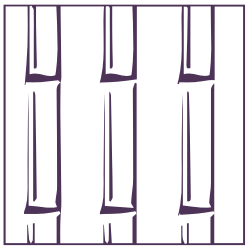
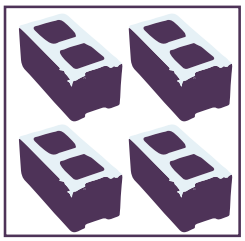
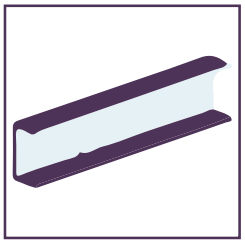
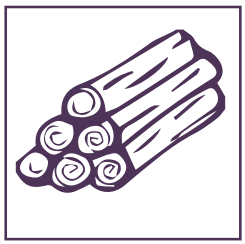
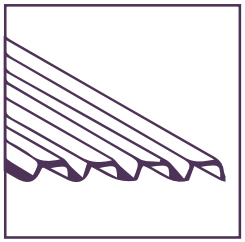
MATERIAL		UNIT	PRICE Rp/€	MATERIAL		UNIT	PRICE Rp/€
	CONRETE	1 kg 50 kg	1400 0.10 70.000 4.90		WOODEN BLOCK	5x10x 400 cm	65.000 4.55
	ROOFTILES	per tile	4000 0.28		BAMBOO	6 m Untreated Treated	5000-12000 0.35-0.84 60.000 4.20
	HOLLOW CEMENT BLOCKS	per m3	730.000 51.10		STEEL C-PROFILE	1 kg 50 kg	1400 0.10 70.000 4.90
	WOOD	per m3 Jati Borneo Recycled	15.000.000 1.050 5.000.000 350 2.000.000 140		CORRUGATED ZINC SHEETS	one sheet	40.000 2.80

Image 4 Catalogue of the most used building materials [3] (own ill.)

LOCAL INTERVIEWS

A small group of students visited five different houses this year in the kampung of Bandung to interview the inhabitants about their circumstances and living environment. Together, we created, before their trip to Bandung we created small cards with images of several common and uncommon building materials to research the preference of the villagers about the currently used materials, traditional and new materials. At image five there is an overview of the preferred building materials of each house.

As the results are presented it can be mentioned that roof tiles, ceramic tiles, bamboo plywood, concrete and plastered are not preferred. While teak wood, peat bricks, bricks, straw and woven reed are the most popular materials. These materials, except for clay bricks, are generally sustainable and natural. In comparison with the currently used building materials, that are not preferred, they mostly choose the natural and sustainable materials.

Materials	H 1	H 2	H 3	H 4	H 5
Coconut shells			X		X
Bamboo			X		
Bamboo plywood					
Bamboo woven					X
Peat bricks	X	X			X
Clay bricks	X	X		X	X
Concrete	X				
Roof tiles					
Teak wood	X	X	X	X	
OSB wood			X	X	
Straw		X	X	X	
Ceramic tile					
Woven reed		X		X	X
Plesteran	X				

Image 5 Interview results building materials (own ill.)

BIOBASED MATERIALS IN GENERAL

Scientists predict that as we continue with the use of fossil resources, as soon as 2030 we would not have enough resources to provide enough energy for the still increasing population around the world. The effect of using fossil resources lead to enormous CO2 emission, toxic gases and pollutants. These effects cause an adverse influence on the climate conditions and the quality of life of all the inhabitants. Because of these changes and adverse effects, it is important to use new resources that reduce all these effects.[4]

Biobased materials have two categories: Conventional and Emerging. Conventional biobased materials are made from animals or plant materials. For example, it could exist out of crop-based materials such as flax, bamboo and coconut fibers. These biobased resources are biodegradable. Emerging biobased materials are often active subjects of research and development. These materials are extracted or produced from materials with biological origins. Emerging is not necessarily biodegradable but renewable. They can be regrown for example sugar beets can be first an extract from sugar then lead to polylactic acid.[5] For this research, the research will focus on solutions in the sector of conventional biobased materials. The reason, therefore, is emerging biobased materials not applicable for the inhabitants of Bandung because it requires an advanced scientific process and research to produce those kind of materials.

By investigating the possibilities to use biobased building materials instead of the current building materials is it possible to transfer the kampung to a sustainable fashion village. The benefit of switching to bio-based materials is enormous. Biobased materials have the potential to reduce energy use, greenhouse gases and toxic pollutants over their lifecycle and creating short and closed loops and cycles while fossil fuels have long cyclical lifecycles of millions of years.[6]

CASE STUDY BADUY

This case study in Indonesia is a good example of building with biobased building materials. Baduy is a traditional village that exists out of an ethnic group. The village is situated a few hours out of Jakarta and is known for its traditional building methods and materials. The Baduy has two different groups, the communities who reside the area and the communities that form a barrier to the outside world. The villagers, around 40 families, who live inside of Baduy have limited contact with the outside world because the outside barrier protects it. The people of Baduy are very traditional and craft most of the supplies by themselves, such as food, clothing and building materials.[7]

The houses are built on wooden stilts placed on a self-made foundation of rocks to protect the ground floor and construction against water, mods and insects. In general, the floor is made of wooden structure with a top layer of bamboo. The walls are made of a wooden frame that is finished in tiles of bamboo. The roof is made of a bamboo or wooden construction with tiers of sugar palm leaves tied with ropes. The building method is illustrated on page 22.

Usually, a house will stand for two years, after that period the community of the village reuse some of the building materials and rebuild the house. The whole community is working together to create the different parts of the house and maintain the village.[8] These traditional building methods and materials can also be applied in the Bandung area, but the user life time does not suffice. For this research, the biobased materials should have a long lifetime by implementing a new material or production process. This forms one of the criteria for the first selection of the material database.

Image 6 Pictures of houses and materials in Baduy (own pictures)

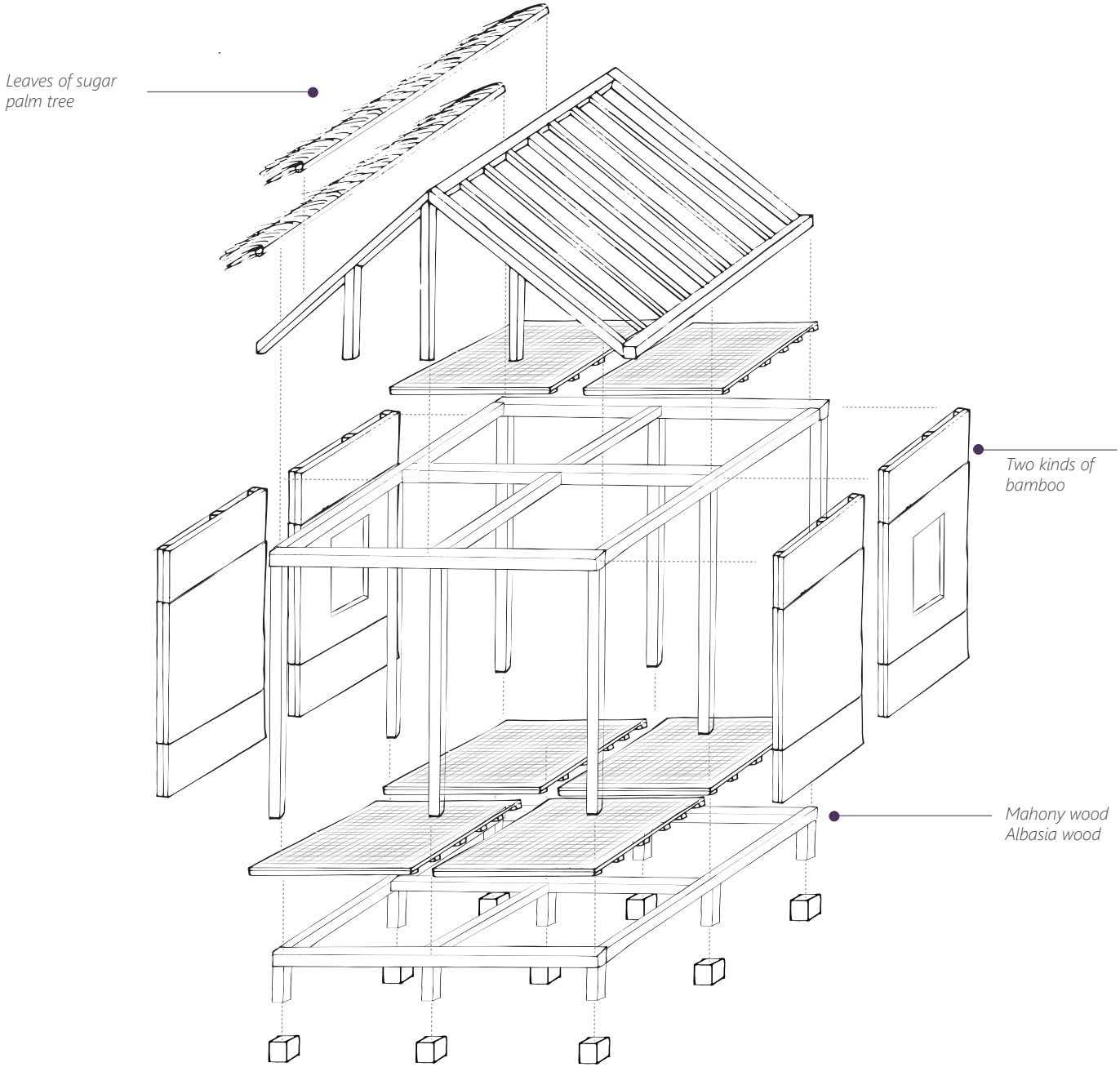
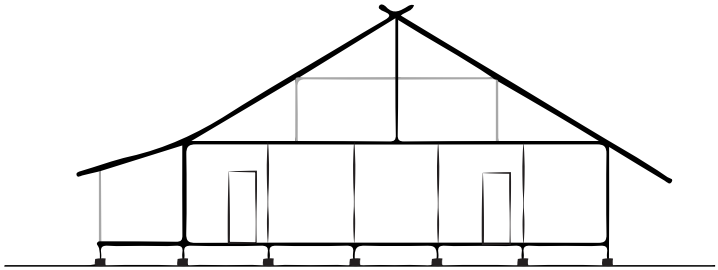
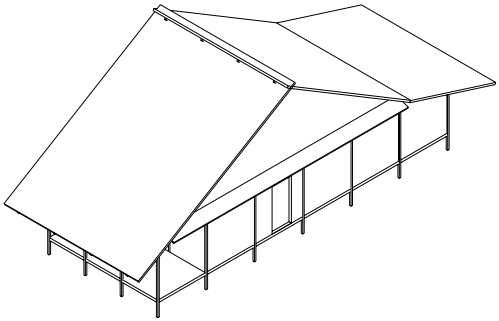
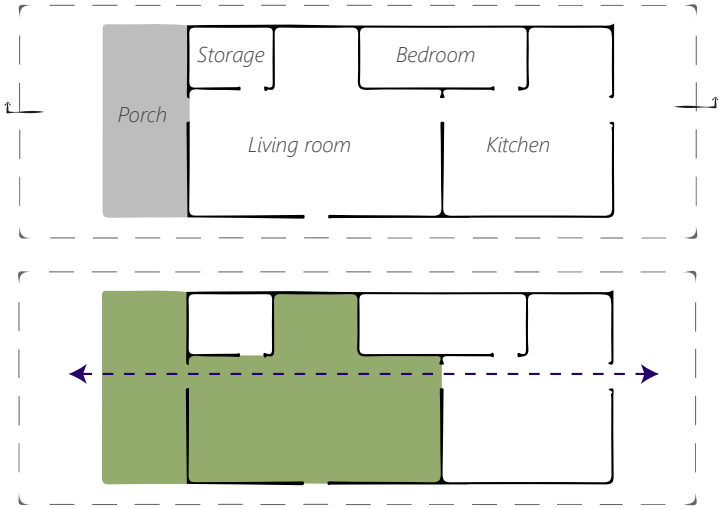


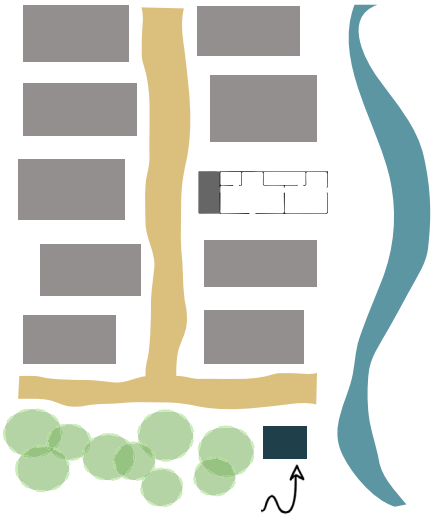
Image 7 Building method and materials of a house in Baduy (own ill.)







The living area is in the front of the house with an integrated porch because the people are mainly living outside towards the main road of the village. This principle originates from the traditional way of living and customs.



The toilet is a separated building outside, and they bathe in the nearest river.

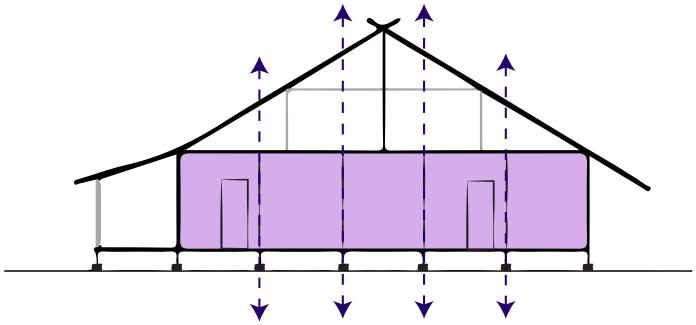
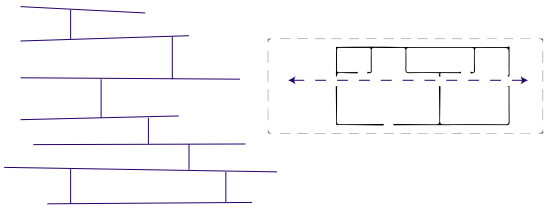


Image 8 Analysis drawings of a house in Baduy (own ill.)



The long primary formation followed out of the strip-like land.

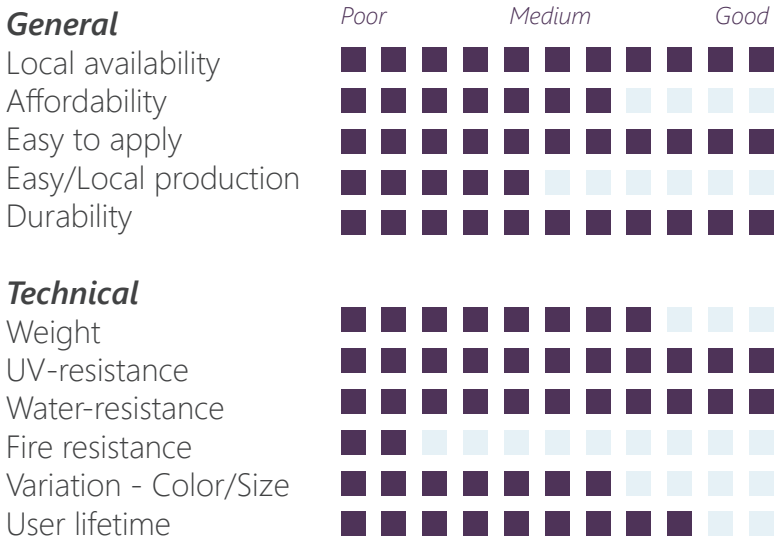
DATABASE BIOBASED MATERIALS

In this part of the research, the chosen biobased materials are described and its properties are listed. These materials are selected on certain criteria that derived from the first chapters of the results. The criteria are; conventional biobased materials, applicable to dwelling, local production possible and long user lifetime by implementing new materials or manufacturing processes. The materials are divided into the following categories; structure, non-structure wall, facade cladding, floor cladding, interior finish and roof cladding.

BAMBOO BEAM \ N-FINITY

Image 9 Bamboo beam N-Finity

MATERIAL PROPERTIES



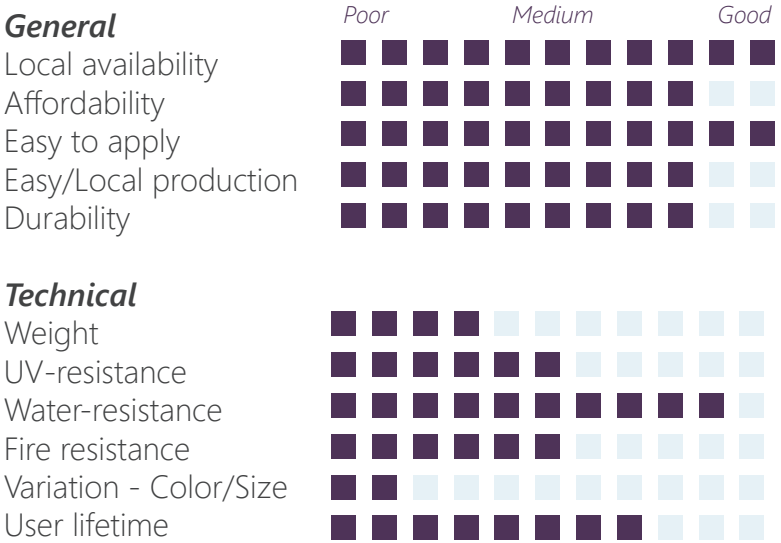
MATERIAL AND PRODUCTION

The N-finity outdoor bamboo is made by laminating impregnated strips into beams. The beams are treated with a special impregnation process that provides the product with the highest durability class according to the EU norm. The beam is produced in various dimensions and is available in 1960 - 5800 mm length.[9]

The beam can be used as construction element because it has been tested in term of mechanical properties (bending, tension, compression and shear. First the bamboo is cut into small pieces by a special saw. After that the bamboo strips are made as straight as possible and dry them in a high temperature room. After this process the strips are glued onto each other under high pressure.[10]

Image 10 Peat bricks bioblocks

MATERIAL PROPERTIES



MATERIAL AND PRODUCTION

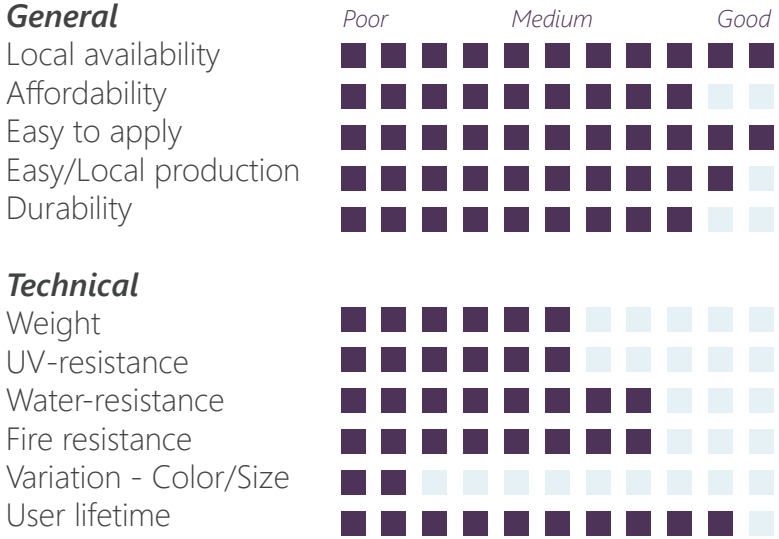
Bioblocks are made of pressed peat. The bioblocks regulate moisture very well because they absorb and retain excess moisture that they later release. The blocks are 100% sustainable, recyclable, natural and biobased. The production is also very durable and effortless; the blocks are laid to dry in the open air in racks for eight weeks. They do not need a high temperature or to be baked in an oven like clay bricks.[11]

In Indonesia, there are the largest peat swamps of the whole world. Often they are drained to use the land for farming, but that causes large fires in the hot summer. Because of the high amount of peat,

MANURE BRICKS \ ECOFAEBRICK

Image 11 Cow manure bricks Ecofaebrick

MATERIAL PROPERTIES



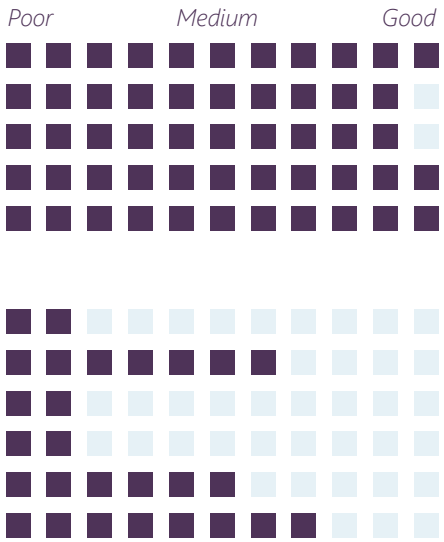
MATERIAL AND PRODUCTION

The ecofaebrick is made out of 75% cow manure and 25% of clay. This prevents the damaged environmental causes by digging up clay and reduces carbon emissions. The bricks are 20% lighter and 20% stronger than the typical clay brick.[13]

These bricks are excellent building materials and cost less in comparison with a clay brick. The production process of the ecofaebrick is the same as the clay bricks, but because of the replacement of firewood with the cow dung methane biogas during the process it has lower production costs and it is more environmental friendly.[14]

Image 12 Bamboo slab panels

MATERIAL PROPERTIES



MATERIAL AND PRODUCTION

These panels are made of bamboo slabs. The conventional production of slabs substantially reduces the waste while effectively utilizing the potential of a bamboo cane as a natural resource. The oblique cross-sections of bamboo are laid between sheets, which are made of cross-bonded bamboo strips. The diagonal slabs are glued in alternate rows in opposite directions. This creates a resilient core that is comparable with a truss structure.

The panels have a thickness of 35mm with a stability of a 6mm steel plate or a 23mm plywood board. The applications for these boards are for furniture, interior purposes and self-supporting elements. [15]

STRAW & COCONUT \ STRAWAVE

Image 13 Straw fiber panels

MATERIAL PROPERTIES

	Poor	Medium	Good
General			
Local availability	■	■	■
Affordability	■	■	□
Easy to apply	■	■	□
Easy/Local production	■	■	□
Durability	■	■	■
Technical			
Weight	■	□	□
UV-resistance	■	■	■
Water-resistance	■	□	□
Fire resistance	■	■	■
Variation - Color/Size	■	■	□
User lifetime	■	■	□

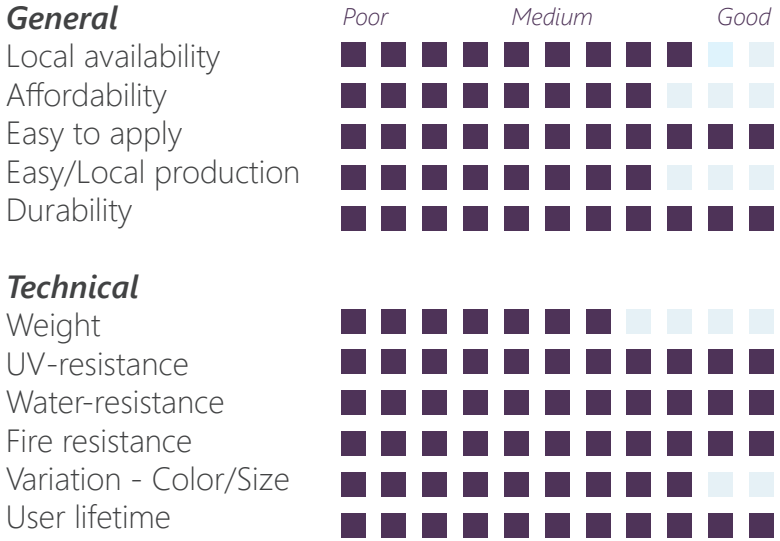
MATERIAL AND PRODUCTION

These products are made of recycled agricultural, natural fibers, straw fibers and coconut fibers. The fibers are separately mixed with bio-resins and cast in a custom-designed mold to create the final wave panels. There are different wave designs available with various color patterns.

The panels can be used as cladding in a non-structural facade and as an interior finish. The panel has a dimension of 400mm x 400mm. The production process does not require special machines or skills to create the product. [16]

Image 14 Panels of plant residues

MATERIAL PROPERTIES



MATERIAL AND PRODUCTION

Ceranex is a durable facade cladding from plant residues. The plant residues are from aubergine fibers, grass from verges, reeds, and pruning waste. The panels are made from tree ingredients; liquid, powder and fibers. These ingredients are combined and form a high-quality fiber material that uses a small amount of energy during the production. Almost every wood, plant or man-made fibers can be used to manufacture the composites.

The facade panels are 100% recyclable with no chemical additives. The panels are suitable for almost every climate because of the excellent resistance against water and fire. They are also rot proof, acid resistance and colour-fast.[17]

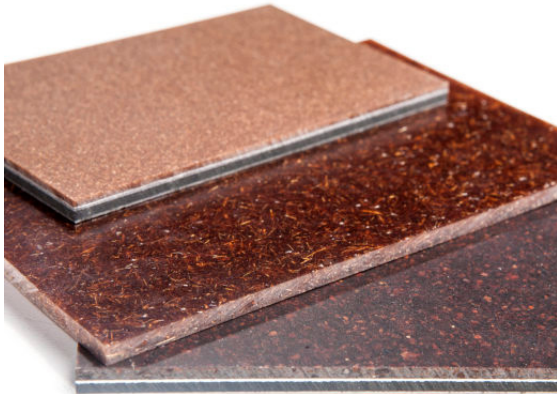
Image 15 Natural fiber panels

MATERIAL PROPERTIES

MATERIAL AND PRODUCTION

The Trashell panels are made from green agro-fibre thermoset composites, natural fibres and plant-based thermoset bio-resin. Almost all agro-fibres can be used, for example; coconut shells, cereal straw, and black coal ash as agro-active fillers to reach the different colors and texture effects. The panels have glowing additives to use the product for exterior applications.

The production process costs few energy, and the material is very durable. To reach the complete green-based biocomposites for architectural cladding applications the matrix applied is plant-oil based.[18]



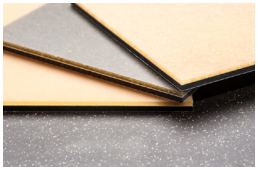
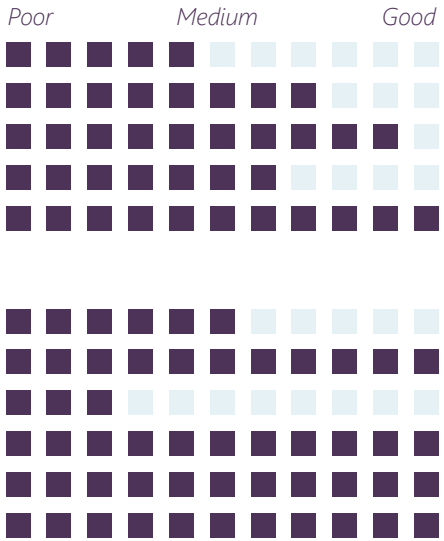


Image 16 Coffee floor planels

MATERIAL PROPERTIES



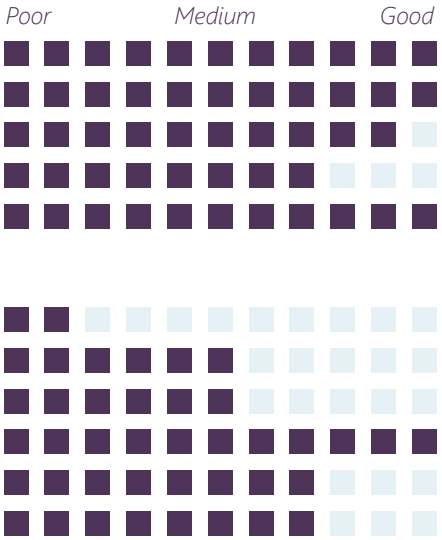
MATERIAL AND PRODUCTION

These panels are made from 80% used coffee and get a new lease of life for another 20 years. The panels are made in a combination of a bio-based resin that can be processed at room temperature. It takes around fifty espresso coffees for one square meter of panels. The panel gets a matt finish and has a closed resilient surface.

The bio-based resin is based on linseed oil and can be bonded with vegetable granules, bark chips and wood chips. But also fruits like berry seeds or leaves can be obtained to get a range of colors and patterns based on nature.[19]

Image 17 Straw floor panels

MATERIAL PROPERTIES



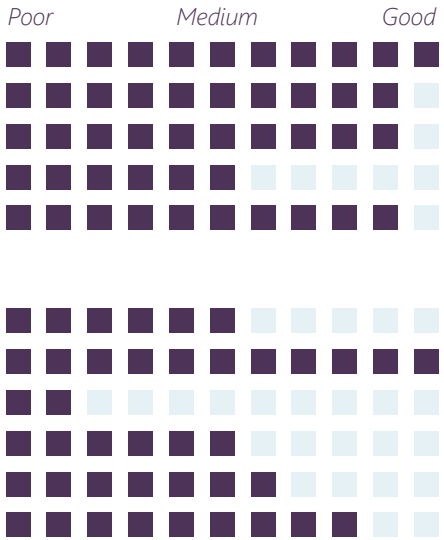
MATERIAL AND PRODUCTION

These flexible panels are recyclable and compostable for architecture applications. The panels are made of 80 - 90 % straw, a natural fiber and residual material which is worldwide available. This material is very cheap and not competing with the food production. The panels can also be made with wheat, maize, rice, oat or rye straw. If rice straw is used, the fiberboards have a silicate concentration of up to 20% of the dry fiber weight. Silicate is a natural fiber with a classification of a good fire-resistance. Besides the fibers, an eco-friendly thermoplastic elastomer is added for binding the ingredients. At the end of its user lifetime, the panel can be recycled or composted.[20]

BANANA FIBER \ BANANA PLANT

Image 18 Banana plant carpet

MATERIAL PROPERTIES



MATERIAL AND PRODUCTION

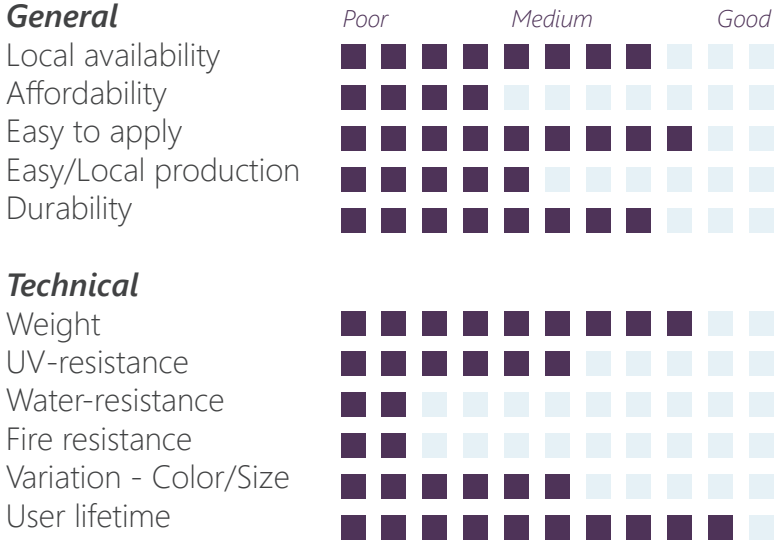
These carpet tiles are made from residues of the banana plant which is 100% biodegradable, strong and lightweight. Currently, the banana plant is used for making ropes or woven mats, but usually, the fibers are seen as waste and are just dumped.

The fibers are suitable for rugged and na tural design purposes. This banana carpet has a soft feeling and a shiny brown or gray color. The company that makes this product is Leoxx that

are researching the possibilities for sustainable solutions in architecture.[21]

Image 19 Teak root blocks Jungle

MATERIAL PROPERTIES



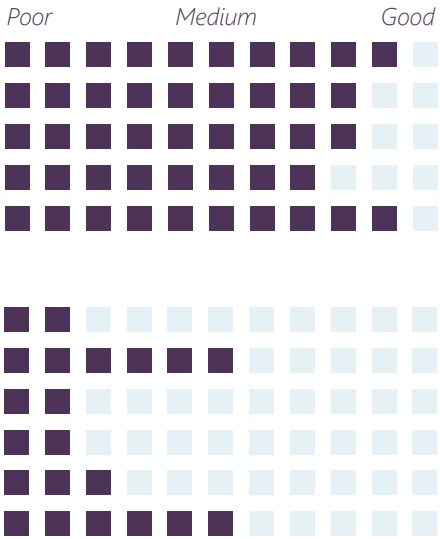
MATERIAL AND PRODUCTION

The jungle blocks are made of the roots of felled teak trees and are a by-product. The roots are cut in pieces and edited till blocks of different sizes and thickness. The blocks are combined at a panel and they are available in two different dimensions and natural colors.

The dimensions are 600x600mm and 100x100mm. The panels are mad by local professional craftsmen and can be used for indoor walls. Teak wood is a common material in Indonesia, but this product is quite expensive because of the production process. [22]

Image 20 Mahony bark panels

MATERIAL PROPERTIES



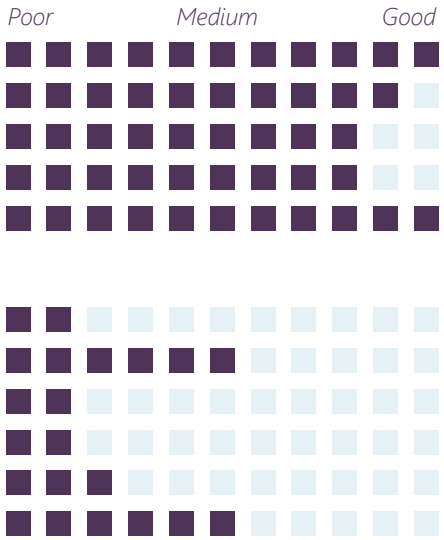
MATERIAL AND PRODUCTION

These panels are made out of mahogany bark and the they are made by hand. Mahogany trees are often used as building materials or other purposes and normally the bark of the tree is a waste product. The bark is cut into slight sticks that are glued together on a net. After this process that protects the bark by finishing it against fungus and insects.

Because of their structure, the panel is not suitable for every application but for the best quality they have to be used in a dry ventilated area. They can also be used outside, but only on surfaces that are not subject to precipitations.[23]

Image 21 Coconut shell panels

MATERIAL PROPERTIES



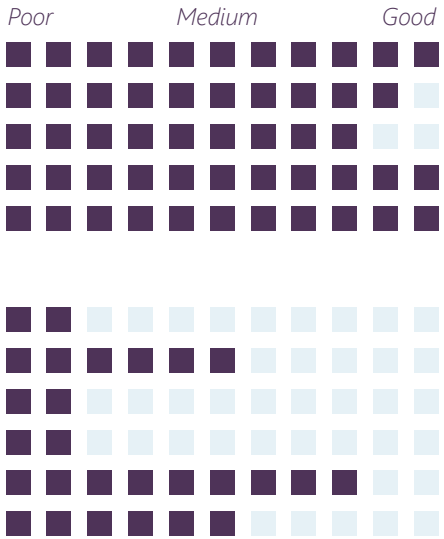
MATERIAL AND PRODUCTION

These panels are handmade, durable and easy to use and made from post-consumer coconut waste material. The pieces have a dimension of 30mm x 30mm. For the production, the hollow side of the coconut shell used and painted with a natural color. After the paint has dried, they glue the pieces together on a net without further finishing. Only water-based paints are used in the production process.

Because of their structure, the panel is not suitable for every application. They are best supplied in a dry ventilated area. They can also be used outside, but only on surfaces that are not subject to precipitations.[24]

Image 22 Coconut shell panels

MATERIAL PROPERTIES



MATERIAL AND PRODUCTION

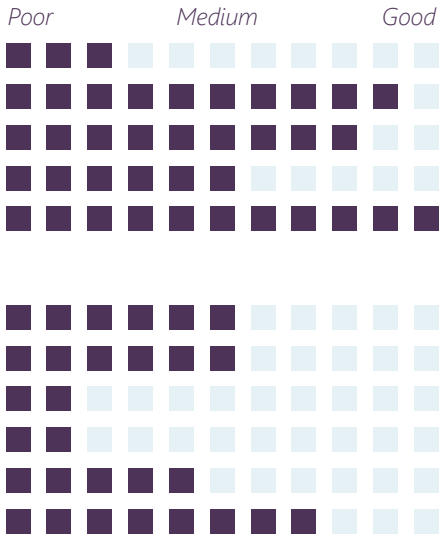
Cocomosaic panels are handmade in Indonesia. The panels are made from the post-consumer waste shells of coconutes. The coconut shells of 30x30 mm are painted with a natural color and glued together on a net without further finishing. Only water-based paints are used in the production process.

Because of their structure, the panel is not suitable for every application. They are best supplied in a dry ventilated area. [25]

FLAX \ FLAX PANELS

Image 23 Flax panels

MATERIAL PROPERTIES



MATERIAL AND PRODUCTION

These panels are mad of flax fibers and biobased glue. Flax is an environment-friendly textile fiber because it grows without hardly using chemical fertilizers or pesticides. The glue is made of renewable and natural resources what makes this product 100% biobased.

During the harvest, the flax is retted in a natural manner. This type of fiber does not need to strengthen before processing the product. After this process the fibers are cut down into small pieces and mixed with the biobased glue to form the panels. The panels are available in different sizes up to 2500mm x 150 mm.[26]

OVERVIEW DATABASE

CRITERIA	LOCAL AVALIBLE	LOCAL/EASY PRODUCTION	EASY TO APPLY	AFFORDABLE	UV RESISTANCE	WATER RESISTANCE	FIRE RESISTANCE
STRUCTURE							
Bamboo beam							
NON-STRUCURE WALL							
Peat brick							
Cow brick							
Bamboo slabs							
FACADE							
Straw & Coconut							
Plant residues							
Natural fibers							
FLOOR							
Coffee Panels							
Straw Panels							
Banana fibers							
INTERIOR							
Teak Roots							
Mahogany bark							
Coconut							
Coconut							
Flax panels							
ROOF							
n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Image 24 Table overview of the biobased materials with the final criteria (own ill.)

Poor Medium Good

CONCLUSION

CONCLUSION

The first part of the research provided the knowledge and information to create the criteria for the selected biobased materials to answer the technical research question: *"Which biobased materials can replace the current building materials and improve the building process and methods?"*

Based on the research the most common building materials are concrete, steel and bricks which cause a lot of problems with the climate and living environment. Out of the local interviews, it can be concluded that the local inhabitants rather choose, an exception of clay bricks, for natural and sustainable materials such as reed, peat bricks and straw instead of the currently used materials. Nevertheless, the inhabitants of Bandung are building with non-biobased materials. A possible reason therefor can be that the villagers mostly buy their building materials at the local shops, where the offer is limited. They also often underestimate the local natural materials because of the short lifetime. An excellent example of a sustainable village that is built with the traditional methods and materials is Baduy. This community represents in theory a biobased village because the building materials are directly out of nature such as; Mahogany wood, bamboo and palm leaves. But because of the short lifetime of a house (up to two years) this is will be not the best solution for the Kampungs in Bandung because of its inefficiency. Therefore, to replace the current building materials the follow criteria are necessary to create realistic solutions that have enough potential to be applied and use by the inhabitants of Bandung: conventional biobased materials, applicable to dwelling, local production possible and an extended user lifetime.

Based on these criteria various biobased materials are described in the results organized by different categories.

Structure and Non-Structure wall

For the structure, there is one potential material; bamboo beam. For the non-structure wall, there are three potential material; peat bricks ,cow manure bricks and bamboo slabs. Out of the research and the overview of the materials can be concluded that the peat bricks has the best properties. But most houses in Indonesia are built on a higher foundation to provide floods and protect the construction against water, mold and insects. To building above the ground usually, the structure exists out of columns and beams that will be filled in with other materials. As a result, the laminated bamboo beams can serve as the skeleton of the structure in combination with the peat bricks, which create the outside walls. By combining these two materials, it can reinforce each other. The only disadvantages of the bamboo beams are the production process that requests advanced machines and the low score at the fire resistance. But since this research is focused on small-scale dwelling and buildings the flight distance is short enough to be safe. The production process cost of the bamboo beams will be higher, but the product will be stronger and easier to apply because of its rectangular shape and higher density. The bamboo slabs are suitable for the interior wall to dived the functions. These panels are lightweight but strong.

Roof

Since the development of biobased materials is relatively new, existing literature on this topic is sparse. For the roof, there were not recently possible materials to be used that fits the first criterium.

Facade cladding
For the facade, three promising materials can be used as cladding. The material with the best properties is the facade panel made out of plant residues. This material has a broad range of possibilities of the ingredients to manufacture the composites. But the production process is not known in detail, so there still can be disadvantages.

Floor cladding & Interior finish
For the floor, there are also three materials that have enough potential to be used, where the panels of straw have the best properties. The panels are made of 80 - 90 % straw, a natural fiber and residual material which is worldwide available what makes this material suitable.

The interior finish has five possible materials where the panels made of coconut shells has the best scores, but the variation in colors and size in the design will influence the final choice of materials.

Final conclusion
Several biobased materials meet the requirements and criteria to replace the current building materials. Every material has, in the end, advantages and disadvantages. But they have enough potential to be used in the design of a shophouse. But the influence of the design, the combination of the materials and the connection between the different materials will affect the final choice.

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