

Temporary structure made from wooden pallets

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ABSTRACT

In this research paper firstly the wooden pallet in generally are investigated. For this part of research the features, (dis-)advantage, anatomy, different kinds and the dissecting of the wooden pallets are shown and explained. For the second part of the research paper the use of wooden pallet as building material is explored. For this part the different possibilities of how we can re-use old wooden pallets is shown. These are wooden pallet using as facade element, as floor or roof element, as wall element, but also furniture is possible. Then a number of case studies are analyzed to see what kind of demountable wooden pallet constructions are exist and to see how the wooden pallets in each typology is assembled. For all these case studies the construction, detail, foundation, skin and building physics like insulation, windproof and waterproof are investigated and finally compared. Finally for the coastal area the assignment is elaborated and then a number of possibilities for the use of wooden pallets as foundation, wall, floor and roof is shown. We can conclude from the research that wooden pallets has a lot of potential to use it as building material.

KEY WORDS: wooden pallet - beach house - temporary - demountable - coast

INTRODUCTION

The introduction of this research paper provides general background information about the research subject. Firstly, the chosen location will be described with the present problems. Afterwards, the design aim of the research with the belonging research question will be explicated. After this the methodology of the research will be explained.

Background

The chosen area for this graduation project is the Dutch coastal area. The Dutch coastline along the Southeastern part of the North Sea is approximately 350 kilometres long. This coastline can be divided up into three regions: the Delta Coast in the South, the Holland coast in the center and the Wadden Sea in the North of Netherland. (Mulder, Hommes, & Horstman, 2011) Nowadays, three quarters of the coastline consists of sandy dunes and a quarter is diked. The sandy dunes and dikes form together the first water defense structure which protects the low-lying areas of the Netherlands from flooding by the sea. About 9 million are living in this areas and this part is also the nerve center of our economy. Without the coastal defence structures like dunes and dikes, a large part of the low-lying Netherland would disappear under water. (Rijkswaterstaat, 2007)

Problem statement concerning the coastal area

Efficient coastal management is necessary to keep the coastline stable and strong. One method used by Rijkswaterstaat involves pumping tonnes of sand from the North Sea onto the beaches. This pumped sand should be naturally transported from the beaches into the dunes by sea waves and wind. In this way the low-lying part of the Netherlands should be protected by the sandy dunes when the sea level rises. It's just a constant battle. It is important that the grow of the dunes must keep pace with the rising sea levels. (Rijkswaterstaat, 2007)

Besides flood protection, there is another important problem present in the coastal area. The last years the demand for living on the beach is increased by the beautiful summers and the increased leisure time. Because of this, the distance between the beach houses will be reduced. Beach houses are often positioned in rows or sometimes on high platforms (piles) to stimulate the sand transport. When they are positioned in a row next to each other and in front of the dunes they influence the dynamic of sand and form a blockade for the sand transport from the beaches into the dunes. The current beach houses in the whole Dutch coast are seen as blockade of the sand transport and because of this reason one of the question of Rijkswaterstaat is to find a solution for this problem.

Furthermore, each temporary beach house should be transported every year again and stored in winter season for the next season. This is necessary in connection with the beach house can not stay in the autumn season, because of autumn storms, flooding by sea and spring-tide. The demounting and storing of current beach houses take a lot of time, space and also equipment to move it.

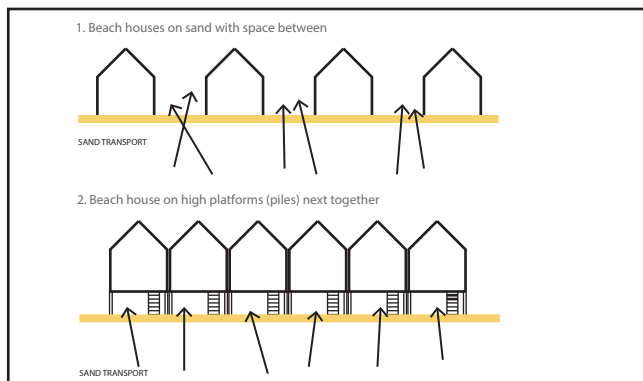


Fig 1. The current way of building in the coastal area. (Own image)

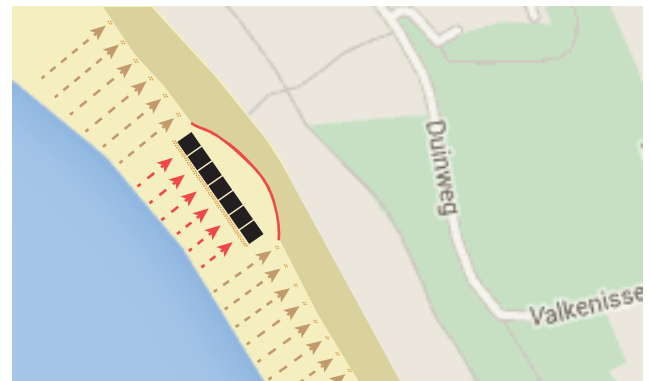


Fig 2. Beach house in front of the dunes blocks the sand transport to the dunes. (Own image)

Problem statement concerning the wooden pallet as building material

For temporary structures a large number of materials are available to use it as building material and after its use they are thrown away. Why don't we use a material that can be recycled after its use? An great example of a material that can be used for temporary structures and recycled after re-use are wooden pallets. When people look at old wooden pallet they see wooden pallets as garbage or they assume that wooden pallets are only possible for transporting goods. In my opinion wooden pallets are not garbage. Wooden pallets are a environmentally friendly material with a lot of potential if we look at the characteristics, but also the characteristics as building material. The biggest problem is that the hidden potential of wooden pallets is not used. In this research paper the use of wooden pallets will be explored as building material for a temporary beach house. The study that are being done does show the hidden potential of wooden pallets as building material.

Objective

The objective of this graduation project is to design a temporary beach house in the Dutch coastal area that doesn't obstruct the sand transport from the beaches into the dunes, and to find a solution for the (de-)construction method, by making them quickly and easily (dis-)assembled and moved. The conceptual idea and main design aim is re-using old wooden pallets, which are already worn or unusable, to find a solution for both problems, sand transport and slow (de-)construction method.

Research question

The research question of the graduation project can be formulated as follows: *How can wooden pallets be reused as building material to create a temporary beach house that is quick and easy to (dis-)assemble?*

This reseach question can be divided into several sub-questions:

CONTEXT

1. *What is the current way of building in the coastal area?*
2. *What impact does the current buildings on the coastal area have on the dunes?*

MATERIAL

3. *What are the positives and negatives of using wooden pallets as building material?*
4. *What are the different types of wooden pallets?*
5. *What kind of edits can be done with wooden pallets?*

CONSTRUCTION

6. *What kind of demountable wooden pallet constructions are exist?*
7. *What are the assembly methods for the wooden pallets?*
8. *How can wooden pallets be connected and disconnected quickly and easily?*

Research methodology

For the research of this graduation project three different methodologies will be used to answer the technical research question. These are literature study, reference study and research by design.

The first part of the sub-questions, that concerns the question of the context, is based on literature study to see how the current buildings in the Dutch coastal area are build and to see what impact these buildings has on the grow of the dunes. These sub-questions will be discussed briefly in the problem statement.

The second part of the sub-questions, that concerns the question about the material, is mainly based on literature study and research by design. The literature study is based on background information about wooden pallets as building material. In this study, there is made use of different kinds of literature, such as books, journals, articles, reports, websites and other academic writing recourses. The research by design is done to see what the (hidden) potentials of wooden pallets are as building material.

The last part of the sub-questions, that concerns the question about construction of the building, is based on literature study and reference study. For sub-question six and seven a case study will be done to see what kind of demountable wooden pallet constructions are exist in the world and to see what the assembly methods of wooden pallets are. The last sub-question and also the most important will be answered with literature study and research by design. Searching for solutions to connect the wooden pallets quick and easy is the main aim of the sub-question.

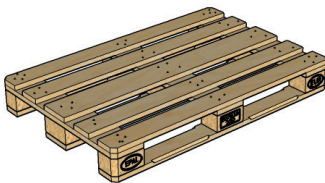
RESULTS

The transporting of products in the country and also around the whole world is constantly moving and changing. The best way to transport anything is by using wooden pallets. Wooden pallets are used for transporting products in small and big companies. (Quality Pallets, n.d.) With the invention of mechanized forklifts and wooden pallets in the 1930s the expense, time and back-breaking of material handling are enormous reduced. (Twede. D & Selke. S.E.M, 2005) Wooden pallets allow for fast and effectively transporting around the whole world and they are everyday bought and used in the industry. (Quality Pallets, n.d.) Besides transport of different kind of products, wooden pallets can be also used as building material. The use of wooden pallets has many advantages. The advantages and disadvantages of wooden pallets as building material will be discussed below.

1. WOODEN PALLET IN GENERAL

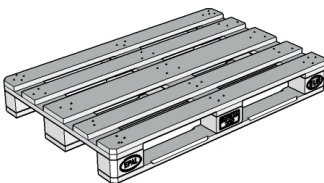
1.1 Advantages of wooden pallets

- Sustainable and ecological material



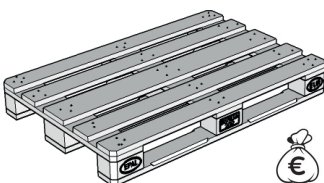
The most pallets in the whole world are made of wood. Wood is a naturally and very sustainable material and gives also character and warmth to the material. A good quality of a product made of wood will, with a little care and maintenance, last a lifetime. It is possible to make the wooden pallets with hardwood or softwood. The advantage of softwood pallets is that this pallets are significantly lighter then hardwood pallets.

- Used, but also so good as new



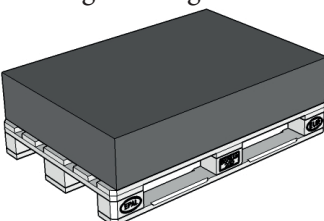
Old wooden pallets that previously are used in transport of goods, still look good. Beside the look, the used pallets offers the same performance as the new pallets.

- Cheap building material



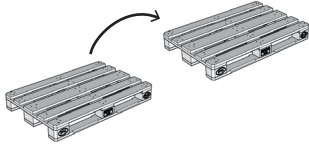
Wooden pallets are generally cheap material. The old wooden pallets are cheaper than the new wooden pallet. Both pallets have still the same level of quality. The cheapest pallets are made of softwood. These wooden pallets are the stringer pallets. Slightly costlier pallets are the hardwood pallets. These wooden pallets are the block pallets. The prices of wooden pallets varies between 4 and 8 euro. (Dongen pallets, 2014)

- Strong building material



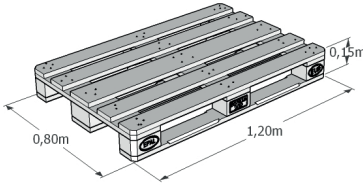
Wood is a strong material, because the wooden pallet must be safe enough to support the desired weights. The pallets have also a high coefficient of friction, that prevents goods sliding off once if they are loaded on the wooden pallet. The load capacity of wooden pallets varies between 1500 and 2000 kg. (Rikipal, 2014)

- Easy to transport



Wooden pallets are easily to transport from one place to another place. Because of the modular character and the smaller size, wooden pallets can be easily transported.

- Available in standard sizes



Wooden pallets are available in the following standard sizes (Rikipal, 2014):

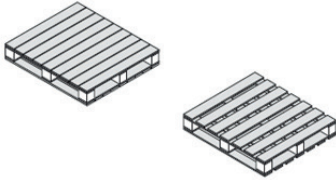
- 0,8 m x 1,2 m
- 1,0 m x 1,0 m
- 1,0 m x 1,2 m
- 1,2 m x 1,2 m

- Easily accessible



Wooden pallets are available worldwide. It is easy to gain access to this building material no matter where you are in the world.

- Different types of wooden pallets



Wooden pallets are the most used pallet type in the world. There are many different types of pallet. The main types of pallets are: the block pallet and the stringer pallet.

- Modular building material



Wooden pallets are modular. Because of the modular character, wooden pallets can be quickly and easily (dis-)assembled.

- Easily repaired



Wooden pallets are easy to repair. They are made of with different parts which can be removed and replaced if the pallet is broken. (Woollard, 2014)

1.2 Disadvantages of wooden pallets applied as building material

- Wooden pallets are very difficult to clean



Fig 3. Old dirty wooden pallet.
Source: (Vietti, 2014)

Wooden pallets are extremely difficult to clean. This is because bacteria and fungus is encouraged to grow when wood becomes wet. (Woollard, 2014)

- Lowered employee safety because of splinters

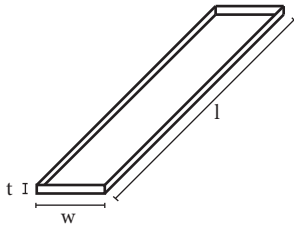


Fig 4. Pallets with splinter and nails.
Source: (El-Rahman, 2014)

The individuals who handle the pallets often experience nasty surprises because of protruding nails or splinters. Needless to say, a nail or splinter digging in your hand is not a pleasant experience. (Woollard, 2014)

- Tolerances of wooden pallets | Deckboards and stringerboards (horizontal)

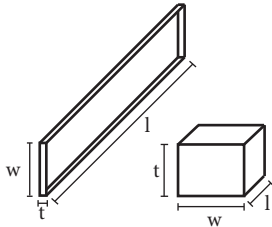
The following tolerances are acceptable tolerances allowed on components of general wooden pallets (National wooden pallet an container association, 2005):



- Thicknesses:	- 1,5 mm		+ 1,5 mm	maximum deviation
- Width:	- 6 mm		unlimited	maximum deviation
- Length:	- 6 mm		+ 3 mm	maximum deviation

| Stringers and Blocks (vertical)

The following tolerances are acceptable tolerances allowed on components of general wooden pallets (National wooden pallet an container association, 2005):



- Thicknesses:	- 1,5 mm		+ 1,5 mm	maximum deviation
- Width:	- 1,5 mm		+ 1,5 mm	maximum deviation
- Length:	- 6 mm		+ 3 mm	maximum deviation

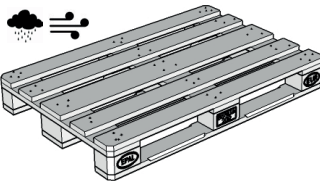
- Difference tolerances wooden pallets versus timber frame.

	Thickness	Width	Length
Wooden Pallet	+ or - 1,5 mm	+ or - 1,5 mm	+ 3 or - 6 mm
Timber frame	+ or - 2 mm	+ or - 3 mm	+ 2 or - 2 mm

What is striking is that wooden pallets are with very small tolerances or deviations produced unlike timber frame.

Table 1. Tolerances wooden pallets versus standard timber frame. Source: (van Doorn, 2012)

- No wind- and waterproof (rainproof)



When we look at wooden pallets the first thing that strikes is that wooden pallets are not wind- and waterproof (rainproof), because of the open character of the wooden pallets. For this problem, a solution will be found after P2 presentation.

- Wooden pallets are heavier then pallets of other material (for example plastic pallets)



Pallets can be made from wood, plastic or metal, each pallet comes with their own advantages and disadvantages. Plastic pallets are approximately 30% lighter than wooden pallets of the same strength. (TranPak, 2010)

Fig 5. Plastic pallet. Source: (TranPak, 2010)

1.3 Pallet structural analysis

There consist different kinds of wooden pallets: heavy pallets, mid-heavy pallets and light pallets. The wooden pallets are distinguished by the thickness of the deckboards and laod capacity. (Suau. C, 2005) The most popular European pallet is the 800 x 1200 mm Europallet. The table below shows a structural analysis of the standard europallet.

PALLET ID: EUROPALLET			
CLASSIFICATION: 800x1200, Block-Class, Double-face Non-Reversible, Full 4-way, Multiple use			
Unit Load type: uniformly distributed - Full Pallet coverage			
Support condition	Save maximum load	Deflection at maximum load	Critical member

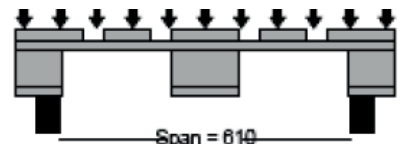
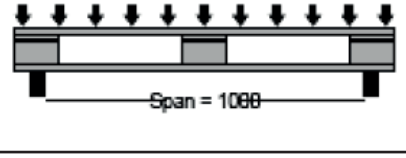
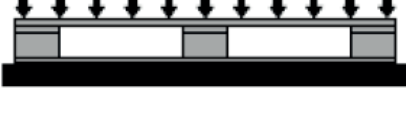
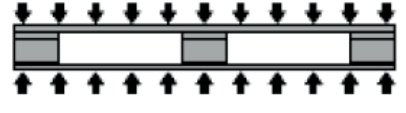
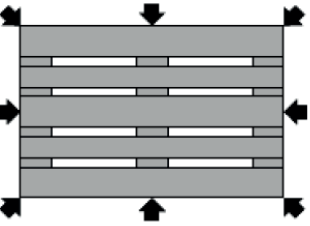
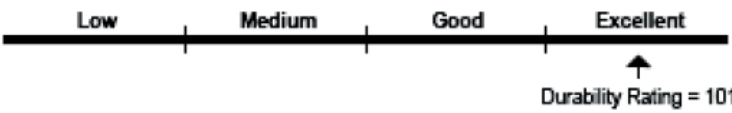
Support condition	Save maximum load	Deflection at maximum load	Critical member
	1042 kg	8 mm	Top stringerboard
	1566 kg	12 mm	Bottom deckboard
	5756 kg	4 mm	Top deckboard
	1853 kg each pallet	6 mm	Center bottom deckboard
PALLET DURABILITY ANALYSIS			
			

Table 2. Pallet structural analysis. Source: (Suau. C., 2005)

1.4 Different types of wooden pallets

In practice, the two most commonly used pallet types are the block pallets and stringer pallets. The stringer pallet is most common pallet in the world. In 2000 about 80% of the produced wooden pallets were stringer pallets. (Twede. D & Selke. S.E.M, 2005)

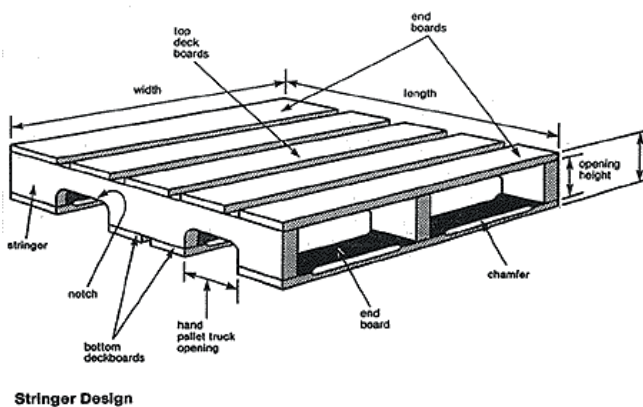


Fig 5. Schematic Diagrams of typical Stringer pallet. Source: (Bhagwan Packaging, 2014)

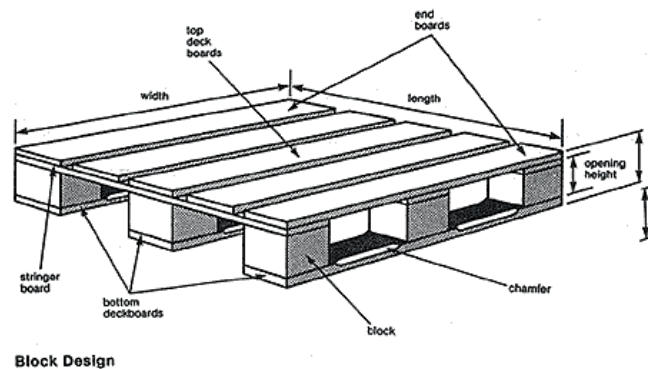
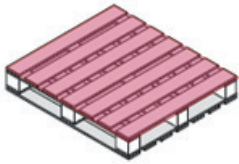


Fig 6. Schematic Diagrams of typical Block pallet. Source: (Bhagwan Packaging, 2014)

1.5 Anatomy of a wooden pallet (Twede & Selke, 2005)

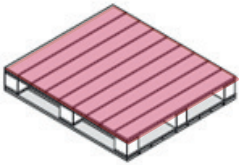
- Deck of a wooden pallet



The deck of a pallet is the top or bottom surface. This surface of a pallet consists of a number of deckboards. The fewer deckboards, the lower the cost of a pallet. Few deckboards ensure a poorer pallet platform and a less-level deck.

Figure: four-way entry pallet, reversible, open boarded deck.

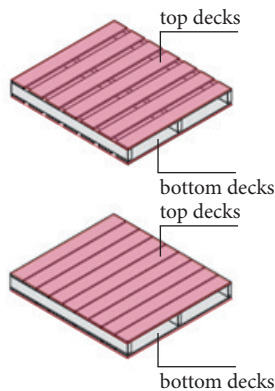
- Top deckboard



The top deck is the upper part of the wooden pallet. Above the top deck, the transport goods rest. A wooden pallet has often more deckboards on the top than on the bottom of the pallet. This provides a more level surface for the stacked packages upon the pallet. A solid either closed deck pallet is made with no spaces between deckboards.

Figure: four-way entry pallet, reversible, close boarded deck with nine top deckboards.

- Double deck

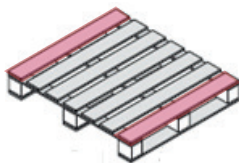


A double-deck pallet is a pallet with top and bottom decks. The bottom deck of the pallet is the load-bearing component to the wooden pallet. When the bottom deck of the pallet has few boards, and stacked on top of another load, the load concentrates pressure on the top of the load below it, whereby the packages can damage at this pressure points. Because of this, single-deck pallets called also single-face pallets or skids. This type of pallets are not used in stacks without the aid of a wooden plate or another strong material. The load of the package should be spread out beneath the stringers of the pallet. Besides single-face pallets, there are also reversible pallets. Reversible pallets have the same amount of top and bottom decks.

Figure above: two-way pallet, reversible, open boarded deck.

Figure below: two-way pallet, reversible, close boarded deck.

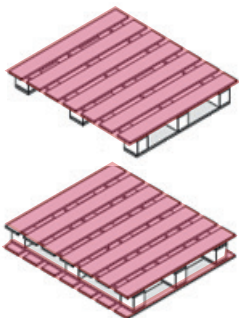
- Lead deckboard or end board



The lead deckboards are the first and last board of the wooden pallet. These deckboards are sometimes wider than the interior deckboards.

Figure below: four-way entry, non reversible, open boarded.

- Wings deckboard

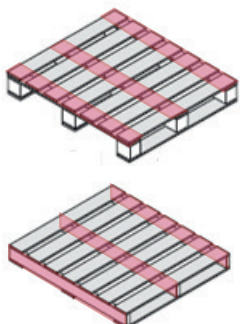


Pallets with wings are deckboards that extend beyond the stringers or stringer-boards. There are both single-wing pallets and double-wing pallets.

Figure above: four-way pallet, non reversible, open boarded, deck wing, single-wing

Figure below: four-way pallet, reversible, open boarded, deck wing, double-wing

- Stringers or stringer pallets

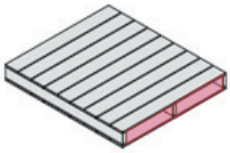


Stringers of a pallet are used to support the deckboard on the top of a pallet. These components are continuous, longitudinal, solid or notched-beam. Stringer is also the name to suggest a longitudinal component in other kind of construction. Each pallet has usually three stringers. Stringers are also used in block pallets. These stringerboard components are the continuous, solid boards which are extending in the length of the wooden pallet. In addition, these components are placed perpendicular to the deckboard and are connected to the deckboard and the blocks.

Figure above: four-way pallet, non reversible, open boarded, block pallet.

Figure below: two-way pallet, non reversible, open boarded deck, stringer pallet.

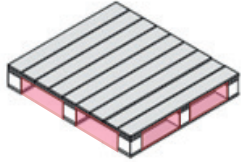
- Two-way pallets



A two-way entry pallet is a pallet with unnotched solid stringers that accessed from only two sides. Besides two-way entry, there are also partial four-way entry stringer pallets. These kind of pallets has notched openings in the stringers. Pallets that accessed from all four sides are four-way entry pallets.

Figure: two-way entry pallet, reversible, close boarded deck.

-Block pallet or four-way pallets



A block pallet consist of blocks and not from stringers, between the pallet decks. These blocks are square or sometimes rectangular. Another important property of a block pallet is that this kind of pallets are always four-way entry pallets. In addition, block pallets are stronger than stringer pallets and therefore more expensive than stringer pallets.

Figure: four-way entry pallet, non reversible, close boarded deck.

1.6 Dissecting the wooden pallets

The wooden pallets can be taken dissecting in many differents ways. This different ways of edits will be showed below.

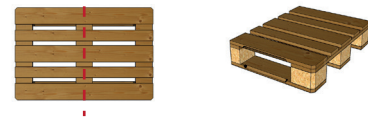
1. Half WP (1)



1. Half wooden pallet - variant 1

The wooden pallet can be cut in the lenght to create a half pallet.

2. Half WP (2)



2. Half wooden pallet - variant 2

The wooden pallet can be cut in the width to create a half pallet.

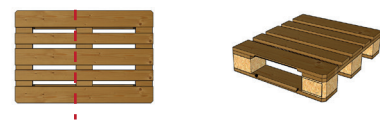
3. Almost half WP (1)



3. Almost a half pallet - variant 1

The wooden pallet can be cut in the length to create a half pallet with three deckboards.

4. Almost half WP (2)



4. Almost a half pallet - variant 2

The wooden pallet can be cut in the width to create a half pallet with five half deckboards.

5. WP without top deckboards



5. Pallet without top deckboards

Disassemble the top deckboards of the wooden pallet.

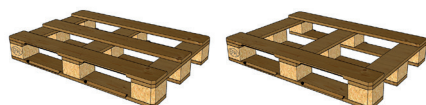
6. WP without bottom deckboards



6. Pallet without bottom deckboards

Disassemble the bottom deckboards of the wooden pallet.

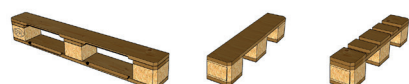
7. WP without two or three top deckboards



7. Pallet without two or three top deckboards

Two or three top deckboards of the wooden pallet can be disassemble.

8. Pallet in smart parts



8. Pallet in small parts

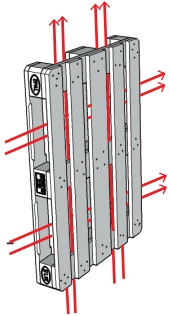
Cutting the wooden pallet in small parts in the length or the width.

2. WOODEN PALLET AS BUILDING MATERIAL

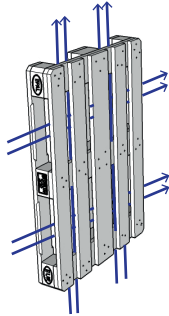
2.1 Given wooden pallets a new life

Old wooden pallets are not garbage. They can be re-used in many ways. Reusing a wooden pallet is in my opinion better for the environment than recycling, where energy in machinery and transportation is needed. The images below will give a fast overview of how old pallets can be re-used.

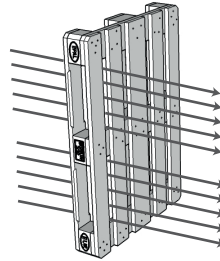
- The wooden pallet can be used as facade element



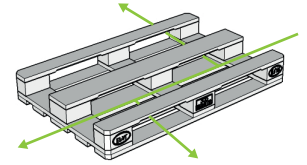
Light up facade



Ventilation

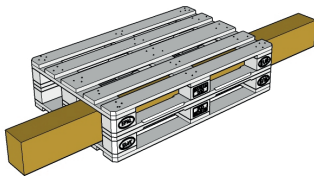


Look through the pallet

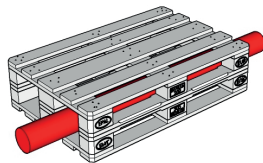


Installation level

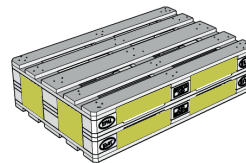
- The wooden pallet can be used as floor/roof element



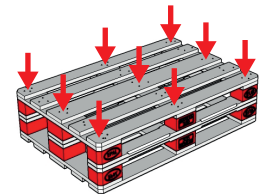
Integrated beam



Integrated pipes

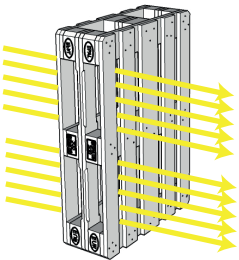


Insulation level

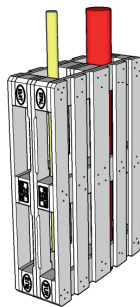


Load transfer ceiling/floor

-The wooden pallet can be used as wall element either sandwich element



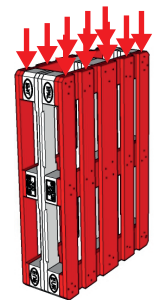
Diffuse light up interior space



Installation level



Insulation level



Load transfer wall

- The wooden pallet can be used as furniture

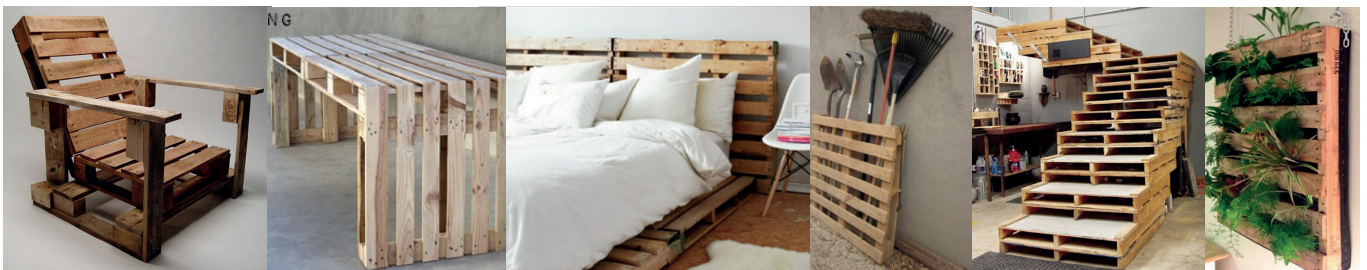


Fig 6. Different kind of wooden pallet furniture. Source: (Design rulz, 2014)

2.2 Existing demountable wooden pallet constructions

In this paragraph a number of reference projects will be discussed on their assembly and disassembly method. There are four wooden pallet construction methods. These are: stacking, with the aid of a support construction, layered wall and a node. For each construction method one or two reference projects will be discussed. All analyzed

reference projects are demountable structures.

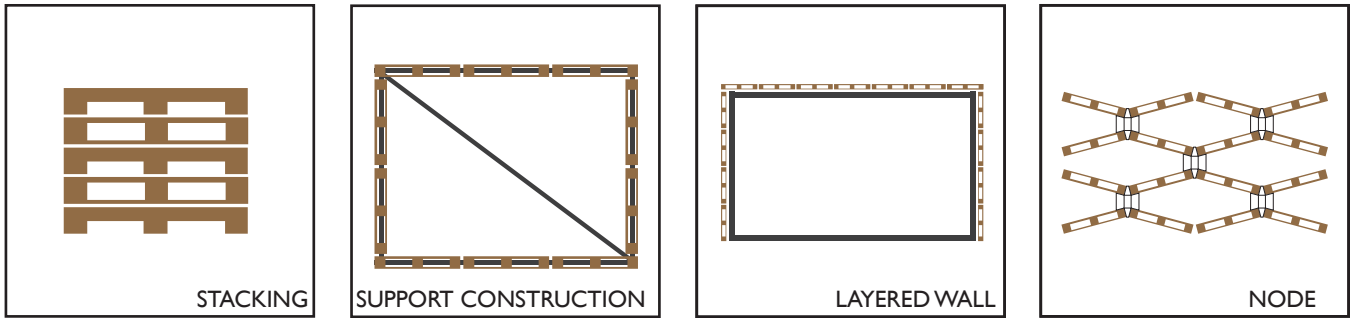


Fig 7. Different assembly methods. (Own image)

2.2.1 Stacking

Reference project 1: The Palettenpavilion

The first reference project I have analyzed is the palettenpavilion in Oberstdorf/Germany, designed by Matthias Loebermann. The palettenpavilion is a temporary meeting place for media and athletes after the World Ski Championships. The structure of the pavilion is made entirely from 1300 wooden pallets, ground anchors and tie rods. The dimensions of the pavilion are 6 m high, 8 meter wide and 18 meter long. The wooden pallets are horizontal stacked on top of each other in a curvilinear line and held together with truck pull straps. The structure of this pallet pavilion is constructed to be easily assembled and disassembled, and then after uses entirely recycled. The horizontal stacking of the pallets in a curved line creates an irregular geometric form with an interior cave-like room that fits in the context. (Meinhold. B, 2014)

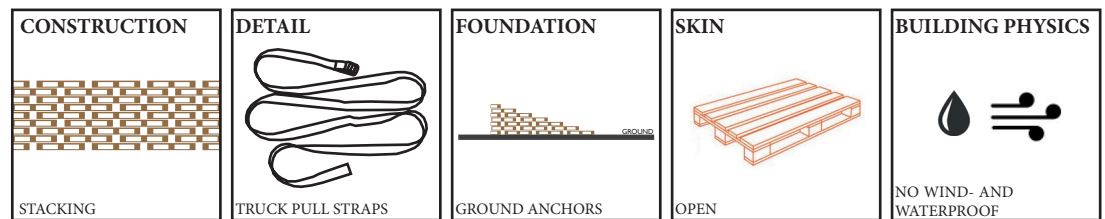


Fig 8. The pallet pavilion. Source: (Meinhold. B, 2014) Fig 9. Connection, detail, foundation, skin and building physics method. (Own image)

Reference project 2: 1x1 Pavilion

The 1x1 Pavilion is a temporary wooden pallet installation in Bratislava, designed by the students of the Faculty of Architecture STU. The pavilion is a temporary platform entire built from wooden pallets for discussion and debates within the faculty of the University and is connected to the faculty of Architecture STU. The shape of the pavilion is an upside-down pyramids. The entire structure consist of four upside-down pyramids in which the top of the platform is covered with wooden plates. The wooden pallets are horizontal stacked on top of each other and are connected by means of cable ties. After use the entire pavilion can be disassembled by cutting the cable ties. (Grozdanic. L, 2014)

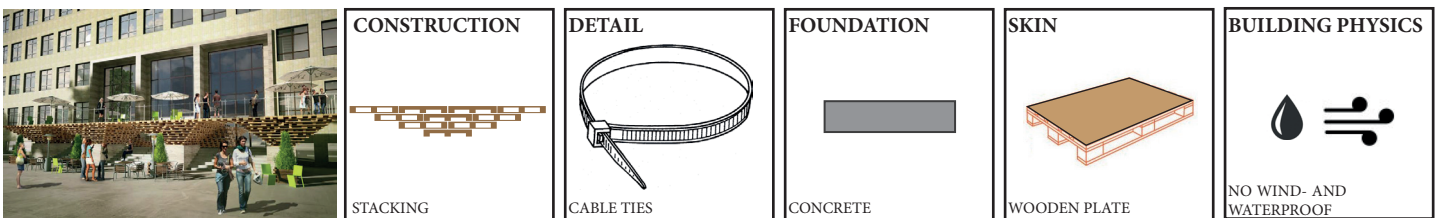


Fig 10. 1x1 Pavilion. Source: (Grozdanic. L, 2014) Fig 11. Connection, detail, foundation, skin and building physics method. (Own image)

2.2.2 Support construction

Reference project 3: The Pallet house

The pallet house is a sustainable low energy and temporary building exhibited at three locations, namely the Bienale in Venice, Vienna and Brussel. The temporary house is designed by Schnetzer Andreas Claus and Pils Gregor. These are two students of Vienna University. The pallet house is a simple modular house which is made of 800 recycled wooden pallets. This building shown the positives of wood constructions and added value of sustainability through reuse of wooden pallets. The main aim of the pallet house is to build a house that are suitable for temporary use at different locations with a less construction time. The use of wooden pallets makes it easy to change the size of the pallet building. Because of this the pallet house can be used as a temporary shelter, a first centre or a family home.

he two layered pallets are connected by timber beams which are integrated between the space of the pallets. Furthermore, the space between the pallets contains cellulose or sand as insulation, cables and lighting. The need for other materials is reduced. (Meinhold. B, 2010)

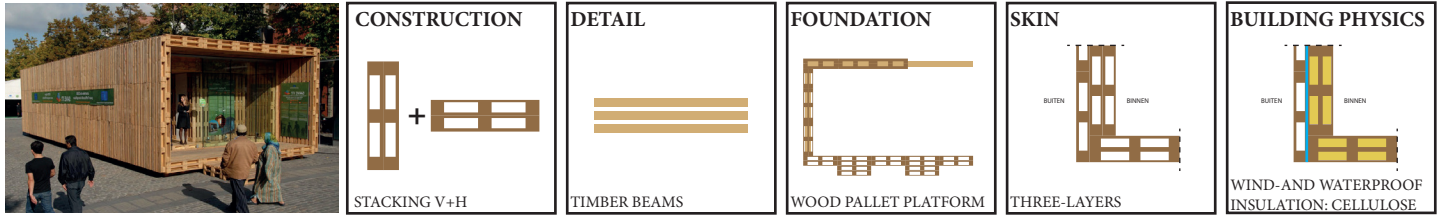


Fig 12. The pallet house. Source: Fig 13. Connection, detail, foundation, skin and building physics method. (Own image) (Meinhold. B, 2010)

Reference project 4: Slumtube

The slumtube is located in Johannesburg and is designed by Andreas Claus Schnetzer and Gregor Pils. The arch shaped structure made from wooden pallets, straw and timber beams can be hand made assembled by local inhabitants. The wooden pallet house is for people from the extremely poor living areas to the south-east of Johannesburg. The inhabitants will be able to build the house for themselves. This project shows the simple construction process by pallets and shows them how useful and suitable discarded wooden pallets can be. (Schittich. C, 2012) The slumtube house is a very stable and resilient structure, as the construction itself is self-supporting. The load transfer goes through the exterior walls of the house. The surface area exposed to wind is minimized by the arch shape of the house. Three timber beams have been placed into the front wall, back wall and roof and joined to form a rigid frame. Besides the timber beams, the wooden pallet is the main structural element of the house. The reused formwork panels connect the wooden pallets at their corner points and maintain the distance between the inner pallet and the outer pallet. (Meinhold. B, 2010b)

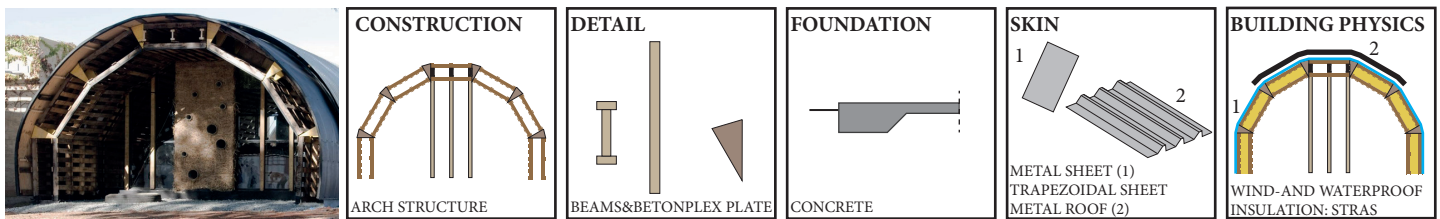


Fig 14. Slumtube. Source: Fig 15. Connection, detail, foundation, skin and building physics method. (Own image) (Meinhold. B, 2010b)

2.2.3 Node

Reference project 5: Temporary Hexa Structure

The temporary hexa structure is located in Marseille and designed by Michael Lefebvre and BC Studies. The structure is temporary and made from completely reused and reusable materials. The structure is entirely made from steel scaffolding components as load carrying structure, wooden pallets as load carrying infill as floor, roof and wall panels. The shape of this structure are reminiscent of a honeycomb structure. This hexagonal structure is intended as short term accommodation, disaster shelters, or simply cool places to hang out. The construction system of this structure is cheap and gives the possibility of adaptation due its modular character. It provide thus accommodation for different functions, such as: an even stage, exhibition space, an bar, a public space, an urban camping dormitory and many more. The standard of the scaffolding, which carried the vertical load, is used horizontally. The ledger component, which carried the horizontal load, is connected to the standard components connection rings (rosette). This is connected under an angle of 60°. The pallets are placed on the ledgers and connected to the ledgers by the use of low-tech fastening techniques only. Furthermore, the wooden pallets are connected to each other to make sure the stability of the load carrying infill. (Starr. B, 2013)

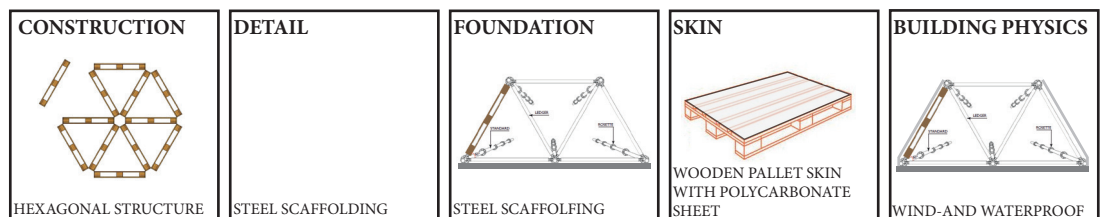


Fig 16. Temporary Hexa structure. Source: Fig 17. Connection, detail, foundation, skin and building physics method. (Own image) (Starr. B, 2013)

Reference project 6: Diamond-shaped pavilion

The diamond shaped pallet pavilion is a temporary pavilion and located in the garden of Villa Romana in Italy and

is designed by Avatar Architettura office. The 100 square meter structure is entirely demountable and is made of prefab diamond shaped wooden pallets and custom made wooden joints. The assembly of this structure takes in total four days. The entire wooden structure is finally wrapped by a PVC membranem, not transparant for the rood and transparant for the walls. (Laylin. T, 2012)

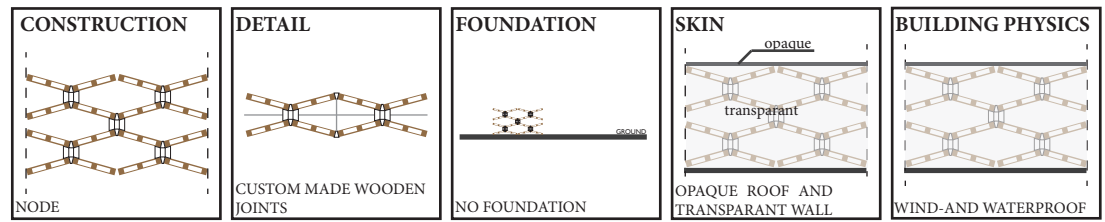


Fig 18. Diamond-shaped pavilion. Fig 19. Connection, detail, foundation, skin and building physics method. (Own image)
Source: (Laylin. T, 2012)

2.2.4 Layered wall

Reference Project 7: Modern manifesto house

The modern manifesto house by James and Mau, and is located in Curacavi, Chile. The Manifesto Hous is modular and eco-efficient structure and is created from three containers. The structure is clad in reused wooden pallets which operate to mediate heat gain in the building. The main aim of the architect is to build cheaply and quickly houses using sustainable materials. (Archdaily, 2009)

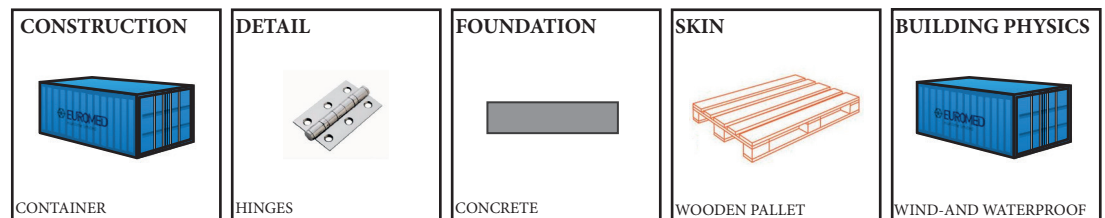


Fig 20. Manifesto House. Source: Fig 21. Connection, detail, foundation, skin and building physics method. (Own image)
(Archdaily, 2009)

2.3 Difference between the different typologies

After analyzing the different case studies will be compared with each other, based on aspect which are important for the study. The comparison of this case studies can be found in table 3 below.

ASPECTS \ TYPOLOGIES	Easily (dis-) assembly	Quickly (dis-) assembly	Number of pallets	Cost	Windproof	Waterproof
	●●●●●	●●●●○	●●●●●	●○○○	●○○○	●○○○
	●●●●●	●●●●○	●●●●●	●○○○	●○○○	●○○○
	●●●●○	●●●●○	●●○○○	●●○○○	●●●●●	●●●●●
	●●●●○	●●●●○	●●○○○	●●○○○	●●●●●	●●●●●
	●●●●●	●●●●●	●○○○	●○○○	●●●●○	●●●●○
	●●●●○	●●●●○	●●○○○	●○○○	●●●●●	●●●●●
	●●○○○	●○○○	●●●●●	●●●○○	●●●●●	●●●●●

Table 3. Comparing the different case studies. (Own image)

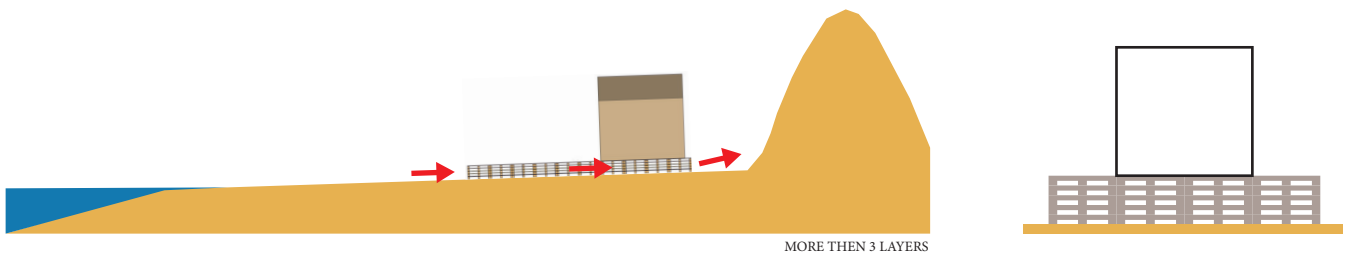
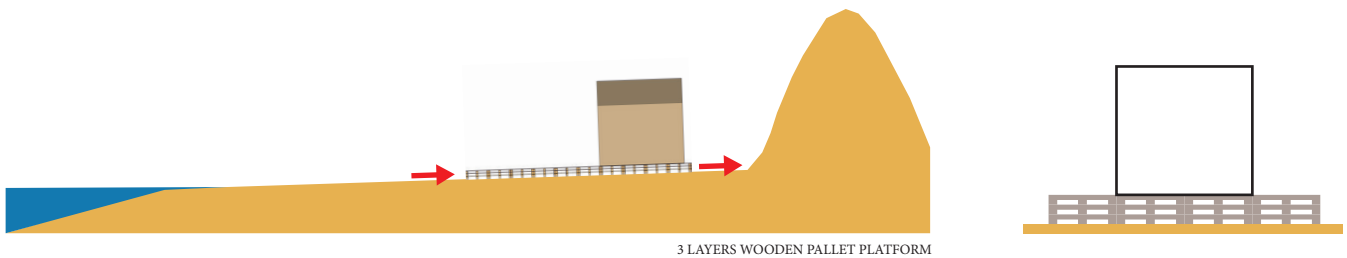
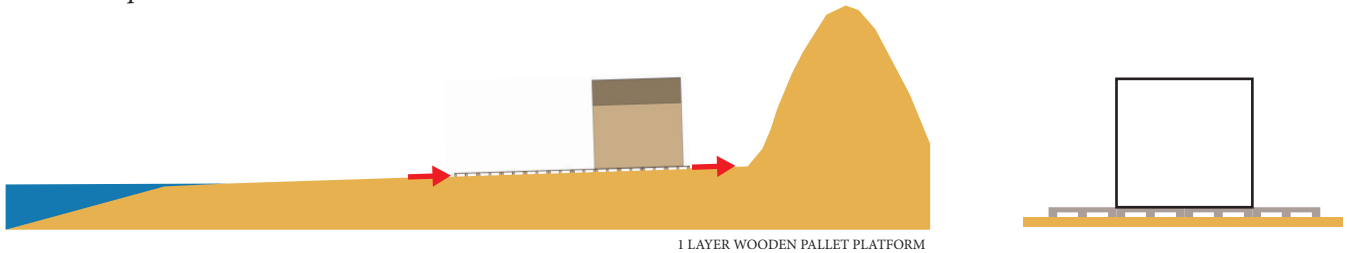
2.4 Connect the wooden pallets

The following research is based on research by design and shows how wooden pallets can be connected with each other. For this study the following elements are explored: the foundation, the floor, the walls and roof and the connection between these elements.

2.4.1 Foundation

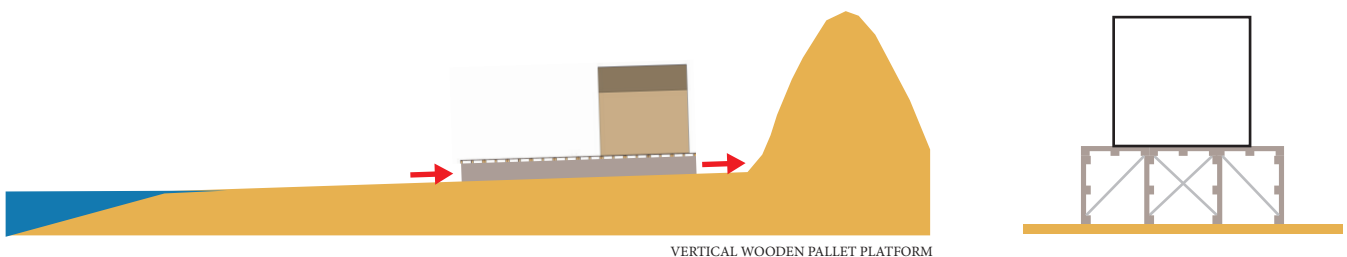
For the foundation of the beach house there are ways: horizontal placement or vertical placement. This can be found below.

Horizontal placement:



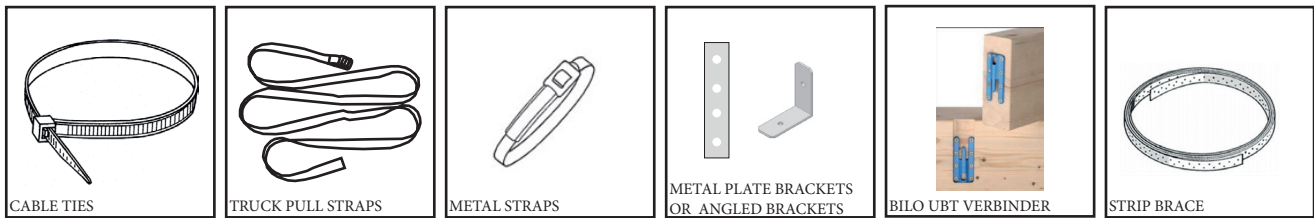
Sand is going through the wooden pallets. The higher the wooden pallet platform, the better the sand transport into the dunes. A disadvantage of horizontal stacking is that there a lot of wooden pallets needed. Furthermore, it takes a lot of time to connect all wooden pallets with each other.

Vertical placement:



Vertical placement will stimulate the sand transport better than horizontal placement, because sand is going easier through the wooden pallets. The advantage of vertical platform is that there is not a lot of wooden pallets needed. The wooden pallets should be embraced with strip brace. Strip Brace provides an ideal embracing system for floors, walls or roofs and can used where a diagonal brace is required.

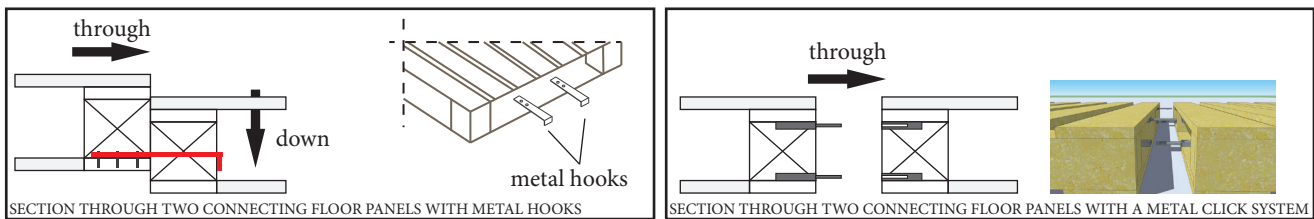
Connect the foundation:



2.4.2 Floor

For the assembly of the floor there are a lot of ways. A number of demountable ways to connect the floor fast and easily are shown below.

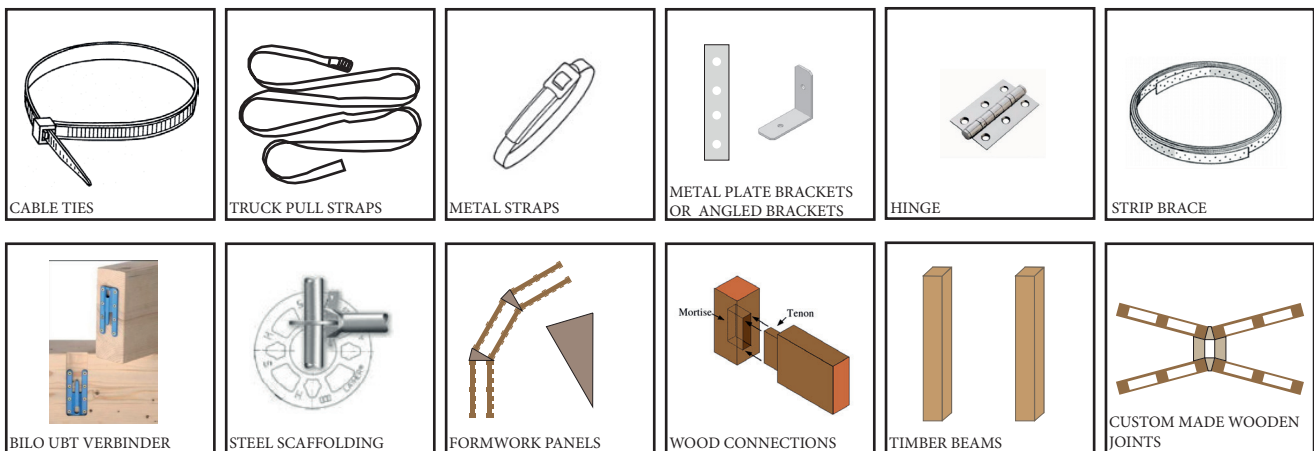
Connect the floor:



2.4d.3 Wall and roof

For the wall and roof several possibilities can be found after the case study of wooden pallets. But it is also possible to invent a demountable connection. For the connections quick and easy demountable construction are most important. The different kind of connections that are possible is shown below:

Connect the wall (wooden pallets parts):



CONCLUSION

The research question of the graduation project is mainly focuses on the aspects of wooden pallets and is formulated as follows: How can wooden pallets be reused as building material to create a temporary beach house that is quick and easy to (dis-)assemble? The first question that comes to mind is then: Can wooden pallets be reused as building material for a temporary beach house? The answer for this question is: yes, it can. This conclusion can be drawn because of the first part of the research, namely wooden pallet in general. Wooden pallets can be reused perfectly for temporary structures, because they are cheap, strong, modular, easily accessible and they are easily transportable from the one place to the other place. But when we use pallets as building material, the beach house should be made waterproof and windproof through the open character. There are different types of wooden pallet available like reversible, close boarded with no base board and other one with base board, wing type and other with the perimeter base. After doing this research we can conclude that pallets with closed boards can be used as closed wall element or for floors, and pallets with open boards can be used when we need daylight, for view or for ventilation. Furthermore, the wooden pallet can be taken dissecting in many different ways like a half pallet, pallet without top deck boards or pallet in smart parts. After this general research about wooden pallets the combination of this information will be used on the beach either the beach house. The design of the beach house will be a result of this knowledge.

From the second part of the research, based on wooden pallets as building material, we can conclude that we can't build the beach house entirely from wooden pallets. There is always a connector needed to connect the wooden pallets with each other. One important question that arises out of this conclusion is the quick and easy (dis-)assembly of the beach house. To solve this question, multiple case studies are firstly analyzed and are based on the following aspects: construction, detail, foundation, skin and building physics. From this study we can conclude that there are a lot of ways to (dis-)assemble the beach house (foundation, floor, wall, roof) quick and easy. The connectors of wooden pallets are made of wood or steel. Both of these connectors can be integrated into the design of the beach house. Remarkable was that each typology either case study can be easily and quickly (dis-)assembled, through the modular character of wooden pallets. In addition, the results of the case studies show that when wooden pallets are horizontal placed on each other, that there is a lot of wooden pallets needed than if we placed the pallet vertically.

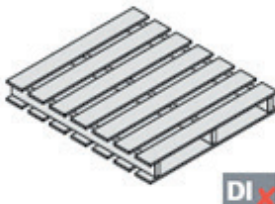
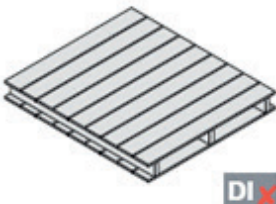
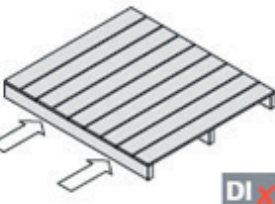
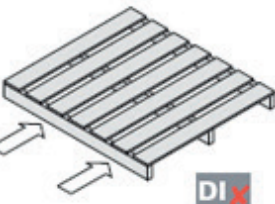
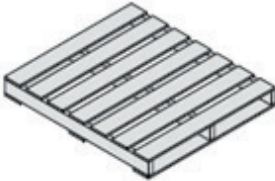
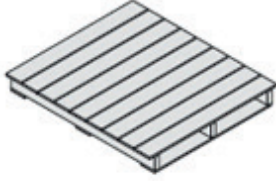
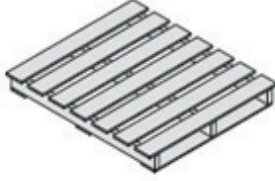
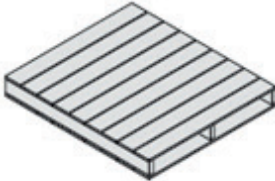
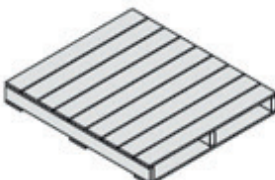
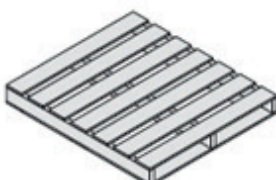
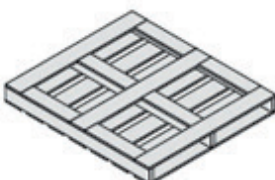
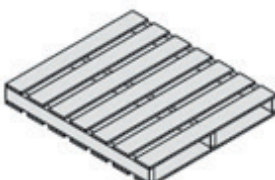
After research by design is done for the connecting of wooden pallet, we can conclude for the foundation of the beach house that vertical placement of the wooden pallets are a better solution than horizontal placement. Vertical placement will stimulate the sand transport better from the beaches into the dunes. For the floor, wall and roof of the beach house we can say that there exist a lot of ways to connect the wooden pallets. But which connection we can use is dependent on the shape of the beach house.

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Types of Two-Way Entry Pallet

			
Two-Way Entry Pallet, Reversible, Open Boarded, Deck-Wing.	Two-Way Entry Pallet, Reversible, Close Boarded, Deck-Wing.	Two-Way Entry Pallet, Single Sided, Close Boarded Deck.	Two-Way Entry Pallet, Single Sided, Open Boarded Deck.
			
Two-Way Entry Pallet, Non Reversible, Open Boarded Deck.	Two-Way Entry Pallet, Non Reversible, Close Boarded, Deck-Wing.	Two-Way Entry Pallet, Non Reversible, Open Boarded, Deck-Wing.	Two-Way Entry Pallet, Reversible, Close Boarded Deck.
			
Two-Way Entry Pallet, Non Reversible, Close Boarded Deck.	Two-Way Entry Pallet, Non Reversible, Open Boarded, Deck-Perimeter Base.	Two-Way Entry Pallet, Non Reversible, Close Boarded, Deck-Perimeter Base.	Two-Way Entry Pallet, Reversible, Open Boarded Deck.

Types of Four-Way Entry Pallet

			
Four-Way Entry Pallet, Reversible, Close Boarded Deck.	Four-Way Entry Pallet, Reversible, Close Boarded Deck.	Four-Way Entry Pallet, Non Reversible, Close Boarded, Deck-Wing.	Four-Way Entry Pallet, Non Reversible, Close Boarded Deck.
			
Four-Way Entry Pallet, Non Reversible, Open or Close Boarded Deck, Cruciform Perimeter Base..	Four-Way Entry Pallet, Non Reversible, Open or Close Boarded, Deck-Perimeter Base.	Four-Way Entry Pallet, Reversible, Open Boarded, Deck-Wing.	Four-Way Entry Pallet, Non Reversible, Open Boarded.
			
Four-Way Entry Pallet, Non Reversible, Close Boarded, Deck-Wing.	Four-Way Entry Pallet, Non Reversible, Close Boarded, Deck-Wing.	'Euro Pallet', 1200 x 800, Four-Way Entry, Non Reversible. Marked 'EUR' on	