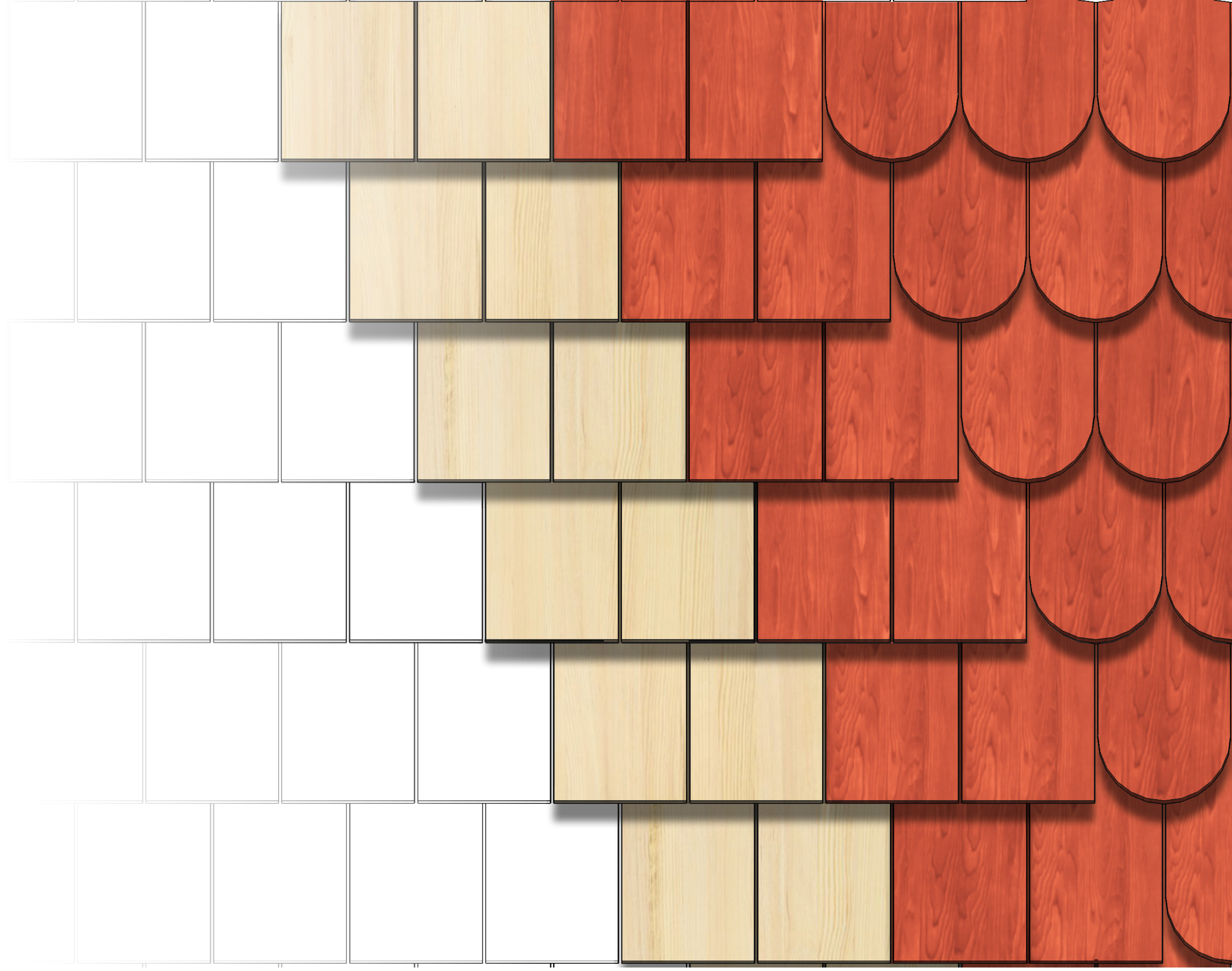

A tale of shingles

The making of a durable wood cladding

Antonio Toledo Plata

Chalmers University of Technology
Department of Architecture and Civil Engineering

Supervisor: John Helmfridsson
Examiner: Paula Femenías

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The making of a durable wood cladding
Author: Antonio Toledo Plata
toledooo92@yahoo.com
Institution: Chalmers School of Architecture
Examiner: Paula Femenías
Supervisor: John Helmfridsson
Architecture and planning beyond sustainability

Abstract

The building industry is currently aiming to adapt its principles to mitigate the current global warming scenario. Multiple attempts are already on their way to generate alternatives to reduce the negative impact that this sector has had in the last century.

This research is an attempt to present an alternative to potentialize the sustainable use of wood in cladding systems in Sweden. It proposes the creation of a new dismountable wood facade system, whose components may disassemble without going through a high energy and destructive demolition process. It centers on the idea that durable wood can be an exceptional material for sustainable construction if it is properly treated, maintained and if it is set be reused multiple times.

This research starts by showing an analysis that gives a solid base to the design proposal. This analysis covers the importance of wood within sustainability, the material approach (how wood can be selected and worked to be more durable), the traditional practices within cladding systems and shows how the modern industrialized systems are built up in the current times.

Besides that, a design proposal is carried as an exercise to summarize the lessons learned from the previous analysis. This design proposal presents the design of a cladding system that centers on the concepts of optimal material quality, material treatments and optimal system assemblies. In addition to this, the system is tested with the redesign of a facade of an existing medium residential project. The project chosen is one six (a project included in the case studies section), with the intention to improve the different expressions that the system can have, and also to develop the adaptability to different situations in the surface.

Finally, there is a set of conclusions that give an answer to the two research questions, and there is also a set of reflections on the challenges and opportunities found in the creation process of the wooden facade system.

Keywords: wooden facade, long-lasting wood, wood treatment, traditional wood facade system, modern wood facade system, design for disassembly.

To my brother MD. Diego T. and my parents Ana and Antonio,
the distance was tough but I made it with you.

Thank you

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Muchas gracias a todos.
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About the author

Antonio Toledo Plata graduated from the Instituto Tecnológico y de Estudios Superiores de Monterrey in 2015, with the BA. in Achitecture. After that, he worked as a junior architect in Mexico city for an architectural firm for 3 years. Then he studied the master programme of architecture and planning beyond sustainability in Chalmers.

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Background

The building sector is one of the biggest contributors of global warming. Its current procedures have been responsible for the generation of large amounts of green house gas emissions.

According to the United Nations Environment Programme, it is known that this sector is reposible for approximately 39% of the total emissions produced in the world, besides that it is also known that 11% of these emissions are found within the building material industry (United Nations Environment & IEA, 2017).

For the matters of this research, it is important to point that the sector is currently orienting to produce bigger volumes of timber. Nowadays, the material produced has a higher demand and thus the wood has to be harvested at an early stage. This phenomenom has modified the quality of timber and it has affected its durability (Zobel and van Buijtenen, 1989), resulting in an increase in consumption and in an increase of waste.

A model based on a circular economy and a sustainable use of materials can mitigate these effects, nevertheless, there is still a lack of proposals for making systems that aim to have long lifespans and a circular use in the timber industry.

Introduction

Problem statement

The use of wood in construction is being proposed as a solution to the negative effects that high carbon emission materials have on the environment.

However, the wood that is produced to create construction elements is generated in a short period time. This has caused that these elements have a short durability (Taylor and Franklin, 2011). The wood quality is then overlooked and the life of the wooden elements is reduced.

Today, it is common to see that the wood used to make outdoor elements ends up being incinerated to produce energy at the end of its life. Its lifespan does not extend for more than 35 years (Mayer, 2008).

Motivation

Although the idea of making high durable and reusable wooden elements might sound like something new, it has been found that this has been present since the middle ages.

One of the clearest examples can be found in the Urnes Stave church in Norway, where it has been found that part of the decorative and contruction elements come from an older church from one century earlier (Unesco,2021).

The new challenge is then looking at how a wooden cladding that now tends to wear down quickly, can be designed to last for more than a hundred years, and thus it can also be reused in different buildings.

Aim

This thesis aims to support the sustainable use of wood through the design of a durable and dismountable wooden cladding system.

Research questions

1. What kind of wood should be used and which quality and treatments should it have in order to make durable elements within the cladding system?
2. How can a dismountable and reclaimable wooden cladding system be designed?

Delimitations

The main scope of this research is designing a durable and detachable wood cladding system that aims to promote the reuse of wood in Sweden.

Therefore, an analysis of ideal materials, wood treatments, traditional practices and modern cladding systems is made, along with the formal experimentation.

The scope in detail is defined below by using the waste management pyramid scheme.

The analysis present in this thesis research aims to support the decisions made on the final design proposal. The Analysis show all the different approaches that were considered before the making of an actual proposal.

The wooden cladding

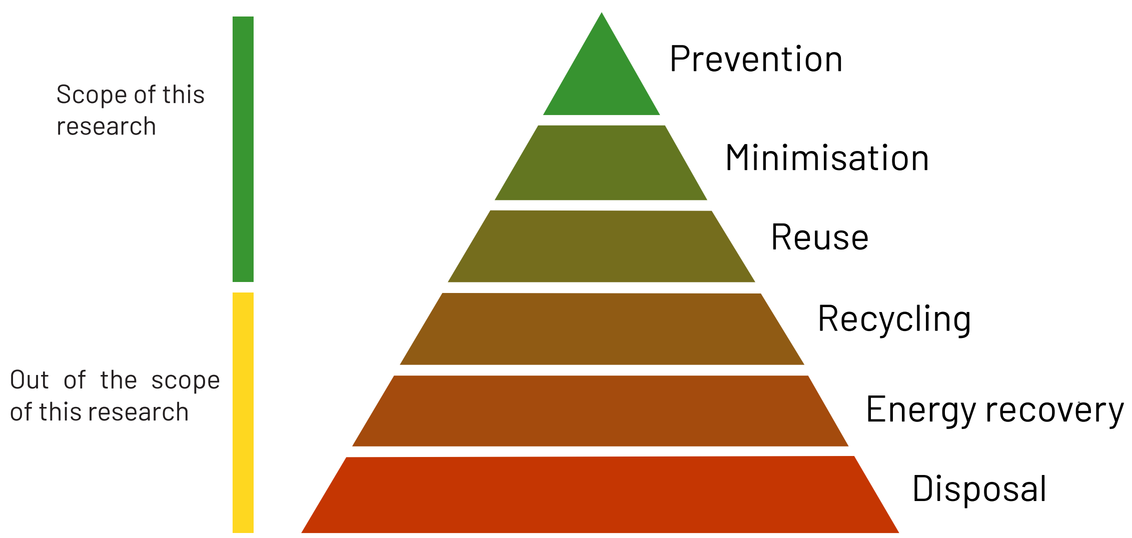


Fig.1 Waste management pyramid (Oregon state university, 2020), A hierarchy created in 2012 to trace the life of consumer products.

This project then pretends to explore:

Prevention

The quality within the wood material has to be optimal in order to achieve a long durability, the elements and the material have to be treated and prepared to last for at least the same time than the rest of the building where it is hosted. The elements must resist the effects of weathering, UV degradation and biological degradation.

Reuse

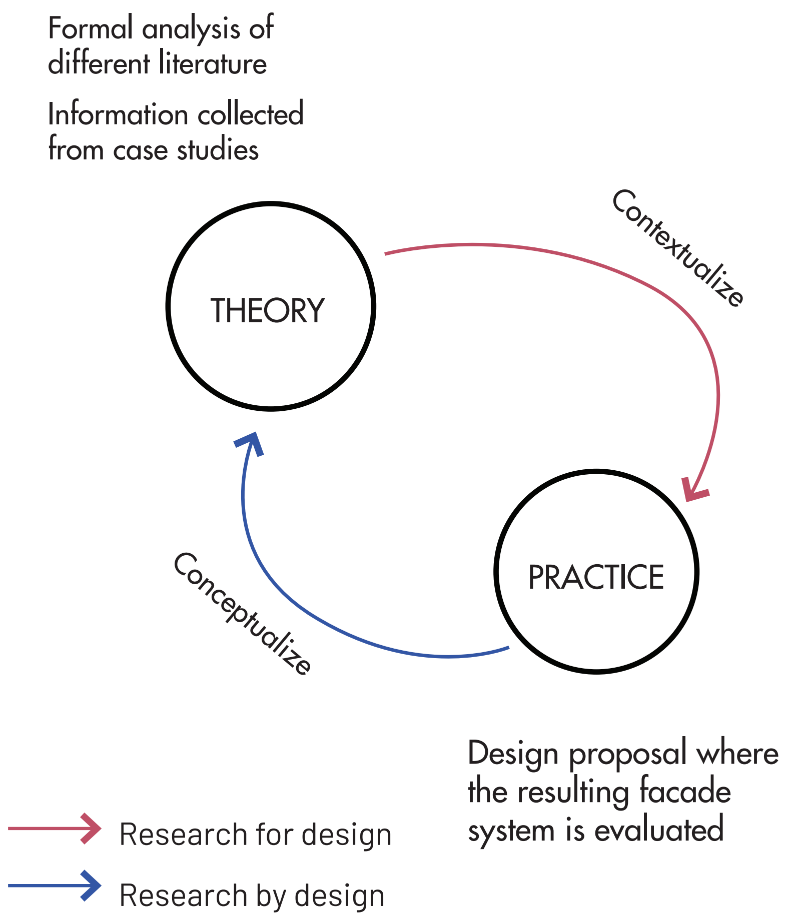
The system itself should be adaptable to be able to get dismounted and re-assembled in an easy way. The adaptability is fundamental for an optimal reuse in a different project.

Methods and approaches

The methods used in this thesis are predominantly research for design.

The analysis of the sustainable use of timber within cladding systems, the wood material analysis, the treatment analysis, the description of traditional practices for building claddings in the region of Sweden and Norway, the analysis of modern facade systems and its technical aspects, are present in the definition of the theoretical framework.

Research by design is also present in a circular reatroactive way, where the design proposal of a facade system can generate new knowledge that can complement the collected theory in this research.



The process in time

1. The delimitation of wood as a material in claddings.
2. Wooden facades systems.
3. Formal experimentation and the design proposal.
4. Evaluation in a facade of a housing project.

Fig.2 The circular process within the methodology

To whom... (Audience)

The work displayed here expects to be a source of inspiration to:

- *Architects and designers* who are interested in the creation of durable and dismountable facade systems. This research might interest to the professionals that are looking for unconventional solutions of wood claddings.
- *Students and researchers* with an interest of how wood can be used effectively as a durable cladding material.

Analysis

The following analysis is my approach to make a solid knowledge base for the design proposal.

It comprises:

1. *A justification in the use of wood for claddings.*
2. *The learnings on the wood as a cladding material*
3. *The lessons from the traditional architecture.*
4. *An investigation of modern cladding systems*
5. *Case examples of traditional and modern architecture.*

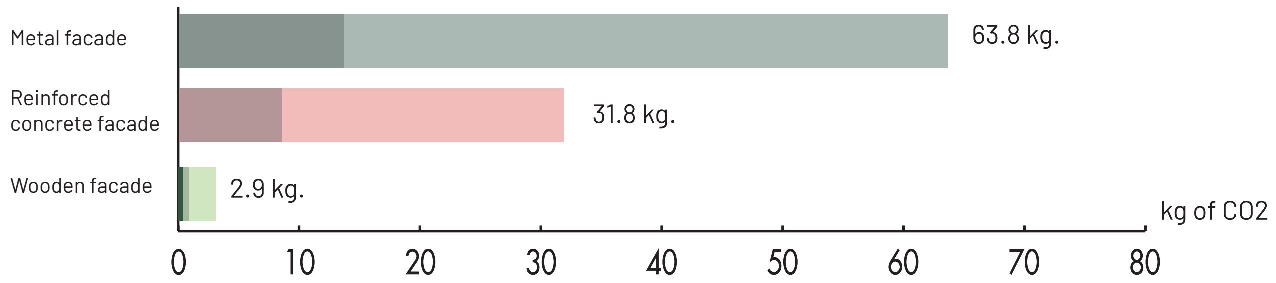
Wood value in sustainable construction

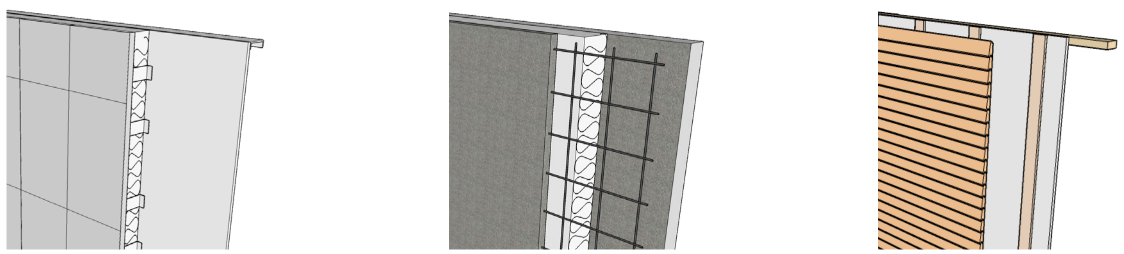
The use of wood in construction has been recovering relevance since the second half of last century, and the reasons are clear. On one hand, with current negative effects of the current global warming scenario where the carbon concetration in the atmosphere is dangerously warming the world, wooden construction is presented as an meaningful alternative.

Within the use of claddings, wood is an alternative to lower the carbon concentration in the atmosphere for two reasons.

1. Low carbon emissions

Wood is known for requiring a low amount of energy compared to other systems and then the emissions produced are significantly less, its lightness and the simplicity of the system assembly constitute the main reasons (Coulson, 2014). The chart below exemplifies this point by showing the emissions in the materials of modern cladding systems.





Aluminum cladding

Fastenings of stainless steel L- shape angles and bolts. - 13.6 kg CO2

3 mm aluminum panels - 50.2 kg CO_2

Reinforced concrete cladding

Steel connectors - 8.5 kg. CO2

70 mm concrete layer - 23.3 Kg. CO2

Wood cladding

Steel nails (5 cm long) - 0.5 kg. CO2

50 mm. x 25 mm. wood battens fixed each 40 cm. - 0.2 kg. CO2

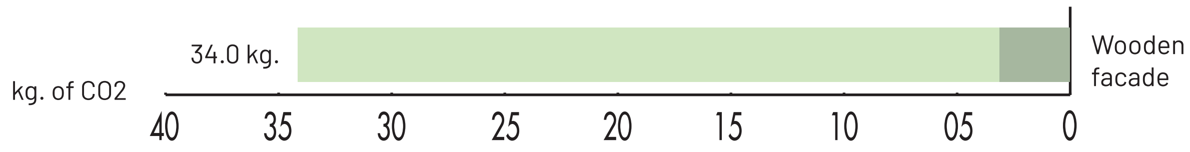
38 mm shiplap wood planks - 2.2 kg. CO2

Fig.3 CO2 Emissions per m^3 of materials of modern cladding systems. The data shown here was obtained by doing an LCA calculation. The material data was extracted from the IBO database 2021.

2. Carbon storage

Wood is a material that stores carbon, and this is evident since trees use carbon to produce cellulose and grow. This process ends up been reflected in the generation of wood in trunks, stems and roots of a tree. The carbon stays storaged in wood even after the tree has been felled (Coulson,2014).

The carbon storage within wood can also be measured, the chart below applies for conventional wood facade systems.



38 mm Wood planks - 31.0 kg. CO2

50 mm. x 38 mm. wood battens fixed each 40 cm. - 3.0 kg. CO2

*The carbon stored can easily compensate the carbon emissions.

Fig.4 Storage of CO2 per m^3 of conventional facade systems. The data is obtained by doing an LCA calculation. The material data is extracted from the IBO database.

This phenomenon can also be analyzed at a broader scale. The forests are responsible for removing large amounts of carbon from the environment. In the following pages there is an analysis on the forest value and its implication in the mitigation of carbon emissions.

The forest value

The great value of forestry, comes from the potential that trees have to store a big amounts of carbon inside wood. According to a study made on 2014, one cubic metre of stem wood can store between 700 and 900 kg of CO_2 (Lundmark et al., 2014), and in a bigger scope an hectare of forest in the Nordic region can annually store the equivalent of about 4 tonnes of carbon dioxide (Nordic forest research, 2017).

This strong fact justifies the recent interest on developing a responsible forestry. A forestry that is constantly being regenerated after each harvesting process.

Another significant value is that forests produce a material that is carbon neutral. Even though, at the end of its life, wood ends up releasing all the carbon that it stored, it means no addition to the atmosphere.

The carbon stored in the forests, was already out before being absorbed by a tree. In comparison, other materials add carbon to the atmosphere since the carbon they have is geologic (carbon that was originally stored underground).

Therefore, the use of wood avoids the addition of geologic carbon into the atmosphere. This phenomenom is known as substitution, and in the conext of Sweden on average about 470 kg of carbon dioxide emissions are avoided for each cubic meter of biomass harvested (Lundmark et al., 2014).

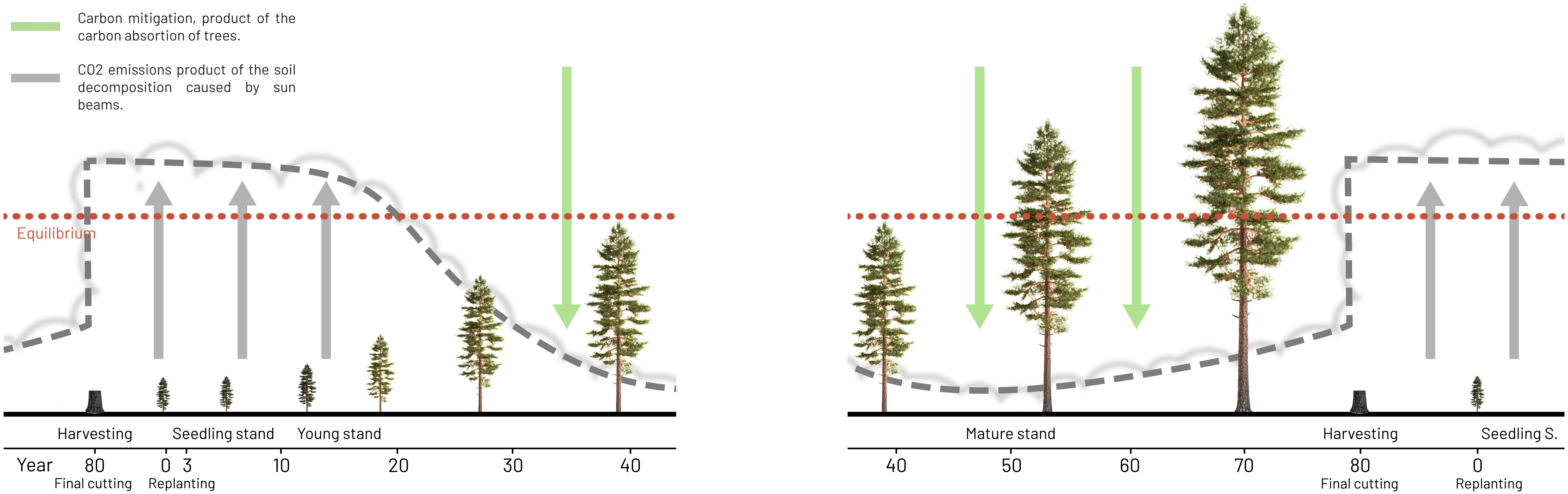


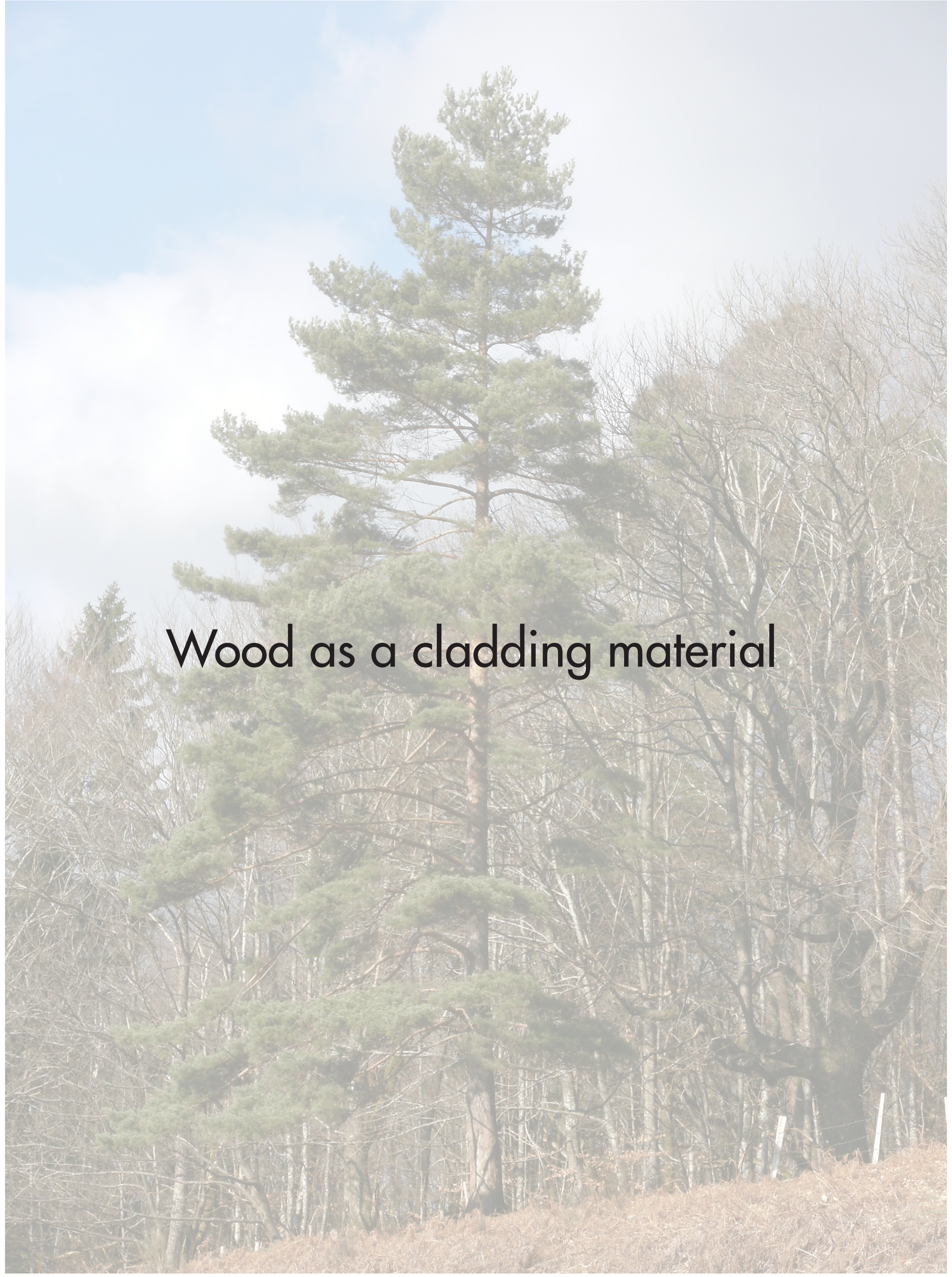
Fig.5 Carbon cycle in a forest. At an early stage, when the tree has been felled, there is more carbon dioxide being released from soil. It is until the tree is 20 years old, that it is able to absorb more carbon than the one that is being released. (Holmen, 2009)

A regenerative approach

It is also worth to point out that these effects can only work in a resposible environment where there is a regrowth of the forestry (Kaufmann et al., 2018). A responsible forestry, where trees are replanted and are allowed to grow enough to store the maximum amount of carbon they can, is necessary to lower the carbon concentration.

The diagram below (Fig.5) is an example of a pine forest, and it shows the carbon cycle that is involved in this process. It is important to notice that trees are harvested when they are 80 years old. This is linked to the fact that after this age, the pines ability to store carbon decreases and they might be subject to dry and die. From a carbon mitigation point of view, it is more convenient to fell them and replace them.

Finally, this analysis concludes that the use of wood has enormous advantages in sustainability compared to the use of other materials such as concrete, aluminum and steel. The potential of wood for mitigating the CO_2 emissions is clear.



Wood as a cladding material

Wood is a versatile material that can be used for making high resistant claddings. Its biochemical properties make it resistant to the natural external conditions.

In Scandinavia, craftsmen have explored its properties and they have created assemblies that with time have become more complex. Traditional Scandinavian wood assemblies like the old cladding of Kvernes church (Fig.6) stand out for their highly resistant wooden layers; layers that were conceived with the right material and worked with the propper treatments and practices.

In the following pages, there is a compendium of different suitable wood species that can be used for making claddings, and a selection of different treatments for wood. Each part has a final selection at the end that shows what will be included in the design proposal.

Fig.6 Wooden cladding of Kvernes stave church built in the 17 th. century in Kvernes, Norway. It is one of the oldest claddings in the Norway. (Godal, 2012)

Wood species

Wood used as a cladding material, provides different characteristics depending on the species.

In the current scenario, wood for construction can be selected from between two groups, hardwoods (product of dicot trees) and softwoods (product of evergreen trees) (Coulson, 2014).

The following species were selected from different literature. The selection was made according to their potential to be used for making cladding systems in Sweden.

Softwoods

Spruce

Spruce is a common conifer in Sweden, whose wood is very dense (Coulson, 2014). This characteristic makes it resistant to weathering and degradation.

The most resistant wood is found in the rotstock (the first third of the tree trunk) (Godal, 2012). This part has been traditionally reserved for making exterior elements in Scandinavia.

Pine

Pine is another common conifer in Sweden, whose main characteristic is that it has a resinous heartwood (central wood). This special feature makes pine wood a high density wood that turns very resistant to weathering over the years (Coulson, 2014). The heartwood naturally gets its maximum resistance when the tree turns 100 years old. These trees can produce durable wood in natural humid and foggy climates with rich soils.

Larch

Larch conifers are one of the two most common species in europe (the other being pine). Their hearthwood is also resinous and it is used for making shingles (Zwerger, 2015), (Herzog et al., 2017). It has a high resistance to fungi, but it tends to be knotty (Reinprecht,2016) and thus not all their wood is suitable for cladding.

Fig.7 Sample species of softwood

Hardwoods

Oak

It is the most durable wood in this selection. Its heartwood can be used outside without preservatives (it is very resistant to moisture and biological pests). Nevertheless in Sweden it is scarce, it can only be found in the south region. (Coulson, 2014)

Besides that, its wood is very acidic (Coulson, 2014) so it may corrode the iron fixings of a common cladding system.

Birch

Its wood is not durable for being used in the exterior (Coulson, 2014). Nevertheless its bark can work efficiently as a waterproof layer. Traditionally, its bark has been used for making shingles in different regions of Scandinavia (Zweger, 2015).

Due to its availability in the swedish context and all the vernacular knowledge around it, pine (Scot pine) constitutes the best option for the proposed system. Nevertheless, further analysis will be made on this species in order to take advantage of all its characteristics. In the next pages, there is an analysis on the forestry practices oriented to produce durable pine wood, followed by an analysis on common preservatives and treatments that address the extension of the life of the wooden elements.

Fig.8 Sample species of hardwood

Forestry practices oriented to enhance pine wood durability

As it was mentioned before, an effective management of the forestry can bring important benefits for sustainability. Nevertheless, it is also worth to point out that there is a big need of practices that focus on the production of durable wood.

In the current scenario, there are practices that focus on the generation of durable pine wood. These practices are described hereinafter.

In a short term perspective

Lightwood generation

This practice is oriented to turn sapwood into light wood (mechanically wounded, resin-soaked wood).

The Lightwood is produced when a mature pine of 40 or 50 years old is longitudinally debarked from one or two sides (Fig.9). In this process, the tree releases high amounts of resin acids, fatty acids and pinosylvins in the debarked areas forming a self impregnated wood (Gustafsson et al., 2003).

This type of wood is waterproof and has a high resistance to rot and decay, and therefore, it can be used for making cladding elements such as planks or shingles.

In a long term-perspective

Effective prunning

This practice consists on the removal of some of the branches on the three, to prevent the aparition of black dead knots which are detrimental for imperviousness.

The moderate prunning in the crown can inhibit the aparition of black dead knots in the trunk, nevertheles as a consecuence the diameter growth is affected (McLean, 2019).

On the other hand, pruning below the crown can reduce the number of black knots, but in return the diameter growth is not affected.

In this way, a reasonable prunning around all the tree is recommended to produce clean pine wood.

Let the forests age!

The demand of wood has shortened the harvesting periods to the time that pines are harvested when they are 80 years old. Nevertheless, if pine trees are kept 20 years more, the heartwood can consolidate more and the quality of the wood can notably increase (Godal, 2012).

Fig.9 Debarking technique in Scandinavia to produce lightwood, also known as pathological heartwood or reaction wood (Gustafsson et al. 2003)

Fig.10 Prunning. This practice is oriented to reduce the amount of dead knots in the wood of the tree by removing the number of branches in the crown. A moderate prunning is ideal in the generation of a high quality wood.

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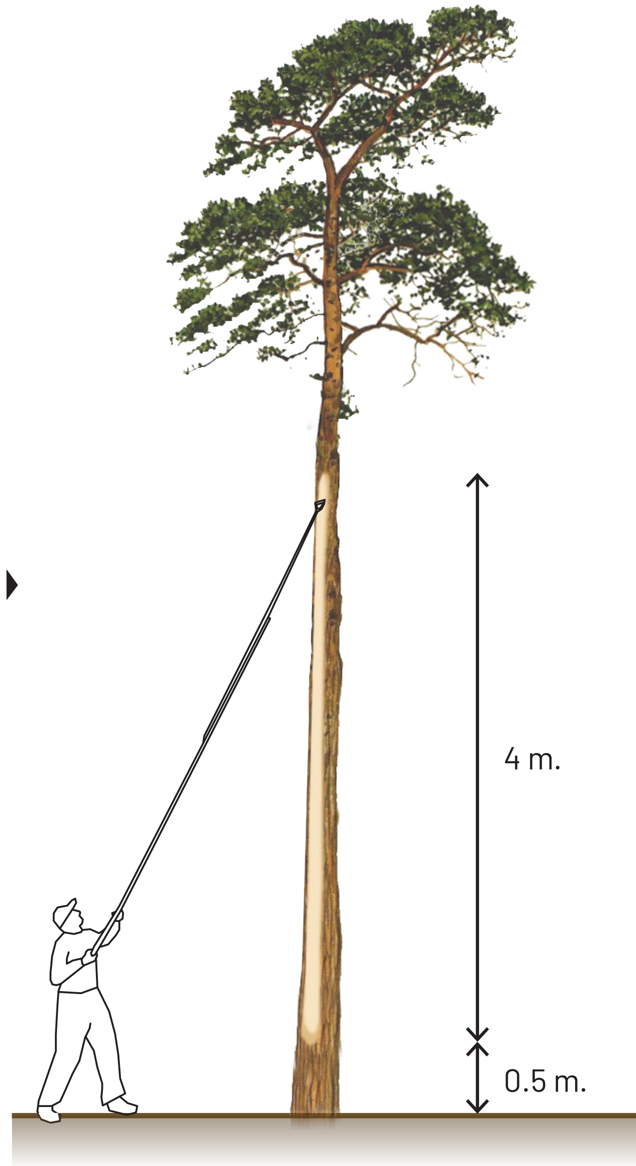

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Treatments to protect wood

Aside the characteristics that exist in the different wood species, it is important to highlight that there are various treatments that can be applied to the wood in order to potentialize its resistance against weathering and UV degradation.

The following treatments were selected based on the effective protection they bring to the exterior wood elements, they are grouped in four different cathegories.

	Name	Description
SYNTHETIC COATINGS	*Acrylic paint*	It is a polymer paint based on different acrylates, its main characteristics is that it is elastic and resistant to weathering and UV radiation (Reinprecht,2016). Nevertheless, recent studies have shown that the natural degradation of this paint is not uniform (Pintus et al., 2016). This phenomenom affects the durability of a wooden facade over time, since the wood surface tends to be sealed unevenly after some reapplications. This negative effect prevents wood from releasing moisture and eventually this can lead to rot.
SYNTHETIC COATINGS	*Alkyd paint*	It is also a polymer paint that is made of oil-modified polyester resins. Its main characteristic is that it forms a film that is permeable (Reinprecht,2016). However, it tends to experience the same degradation problem as the acrylic paints (Pintus et al., 2016), and therefore, it is not a suitable treatment for this project.
NATURAL COATINGS	*Linseed oil paint*	It is a traditional solvent free paint made of triglycerides of palmitic, stearic, oleic, linoleic and linolenic acids (Källbom, 2019). This was one of the most popular options for painting wood facades during the 19th century, before the apparition of synthetic coatings. Linseed oil paints form a film that is weather resistant, ductile, and opyimal against UV-degradation and moisture penetration (Källbom, 2019). It is considered one of the most ecological treatments for being made out of natural oils. (Reinprecht,2016)
NATURAL COATINGS	Röd slamfärg paint	It is a natural red paint that is made of a red color pigment, a binder of rye flour or wheat flour, linseed oils and water. Its main characteristics is that it does not affect the wood capacity to absorb and release moisture and it is considered as a durable finish, since it can last at least 20 years (Swedish National Heritage board, 2013). On the other hand, this coating degrades uniformly over time (Swedish National Heritage board, 2013), and this characteristic makes the maintenance process very simple, since it is enogh to simply brush off the remnants and reapply a new layer.
NATURAL COATINGS	Pine tar	It is a traditional black preservative made out of resinous heartwood of stumps and roots from Scot pine (Egenberg et al., 2003). Pine tar is very efective against weathering and sun radiation. Nevertheles, this protective effect is not durable, it has to be reapplied at least once each three years (Egenberg et al., 2003).
WOOD MODIFICATION	Thermal modification	This is a process that changes the molecular structure of wood through a controlled environment with high temperatures (160°C - 250°C), in a range of time that goes from 15 min. to 24 h. (Reinprecht,2016). This process generates molecular changes in hemicelluloses where acetic acid is generated. This process enhances the wood resistance to biological pests and water (Reinprecht,2016). Nevertheless, on the negative side, the process uses a lot of energy, and the protective effects are not drastically improved.
IMPREGNATION METHODS	Vacuum pressure impregnation	This is a wood treatment where a salt or a solvent based impregnant is added to wood using an autoclave (a high pressure apparatus). The resin penetrates into the wood surface to enhance its durability properties. This treatment is made to prevent decay and cracking (Forest Products Laboratory, 2010). The impregnation method is not effective for protecting wood against UV degradation, so this method has to be combined with a coating.

Based on the previous options, the natural traditional coatings stand out for making no damage to the wooden elements. These organic coatings degrade and get washed out evenly after some years of the application. Synthetic coatings, in contrast seem to brittle unevenly and stay partially in the elements, making the material more prone to rot and decay after the first reapplication.

Slamfärg represents the most suitable option for the system, since it is the perfect match between durability, high aesthetics, and it is also one of the most ecological treatments. The slamfärg treatment will be used in the design proposal.

Wooden claddings

The cladding is the outermost layer of a building, it is the facade protection against weather conditions that take place in the outside (Herzog et al., 2017). In the region of Sweden, wood systems have been studied and developped, coming from early experimentations with manually carved planks and shingles, to refined sawn elements that aim to protect the building (Fig.11).

The following analysis comprises the most relevant data in regards to the swedish and norwegian traditional practices for making claddings, the description of the modern approach and finally some case studies.

Fig.11 Ingatorp tithe barn in Sweden, its shingle cladding is a protective layer that shelters the log walls (Melin, 2019). More information is shown in the case study section.

Traditional practices

The traditional practices on how to build claddings with wood in the region of Sweden and Norway are quite rich. These practices differ depending on the type of wood.

For pines, it is important to start from the selection of trees within the harvesting.

Pine selection

The shape and the age of pines are a crucial factor. Trees that get to live between 80 and 100 years, and get to develop a diameter of 500 mm. in the base, are very likely to have a high content of durable resinous wood.

Keeping the natural growth up to a 100 years is also an important consideration. Early felling prevents the consolidation of high quality wood within the tree. The resulting wood is less dense and more suceptible to decay (Coulson, 2014).

On the other hand, it is also important to look at the number and size of the branches within the trunk. If they are thick and numerous, that means that the wood inside has many big knots, and therefore it is not suitable for becoming a durable element (big knots tend to crack when the wood is worked).

The highest quality pine wood is found in natural environments. These environments need to have a high humidity rate, rich soils and a natural spacing among the trees (Godal, 2012)

After having a high quality piece of wood, the practices differ depending on the elements used in the cladding. These elements are planks and shingles.

Traditional use of pine planks

By looking at the standing examples of wooden traditional architecture from the 17th and 18th century, it is easy to notice that planks were selected carefully.

Most of the original planks that remain from this time, show a smooth texture with very few small knots (Godal, 2012). This characteristic is very valuable since the wood pieces become waterproof, and thus, they are more suitable for the use in the outdoors.

The knots on these planks share the characteristic that they are maximum 3.2 mm. in diameter. The wood with these characteristics can be obtained from the rotstock (Fig.13) of a pine tree (Godal, 2012). This part of the tree stores the highest quality wood.

A rotstock with few or no braches is preferable. But if it shows branches, it is better that they are short, since the knot inside is small and less likely to crack.

Selection was also an important practice, the planks had to be selected based on the previous statements to find the best use. (Godal, 2012) Planks with the highest quality in regards to the knot texture, were designated to stand in the cladding, while the lower quality planks were designated to be secondary reinforce layers.

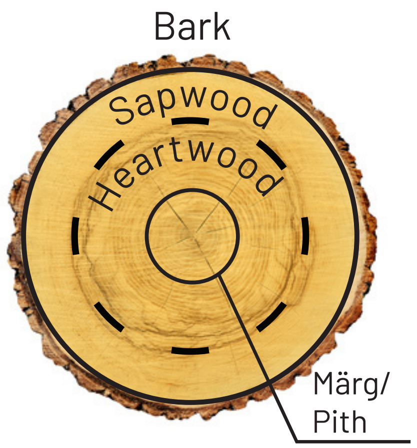

Fig.12 Log anatomy within the pine tree

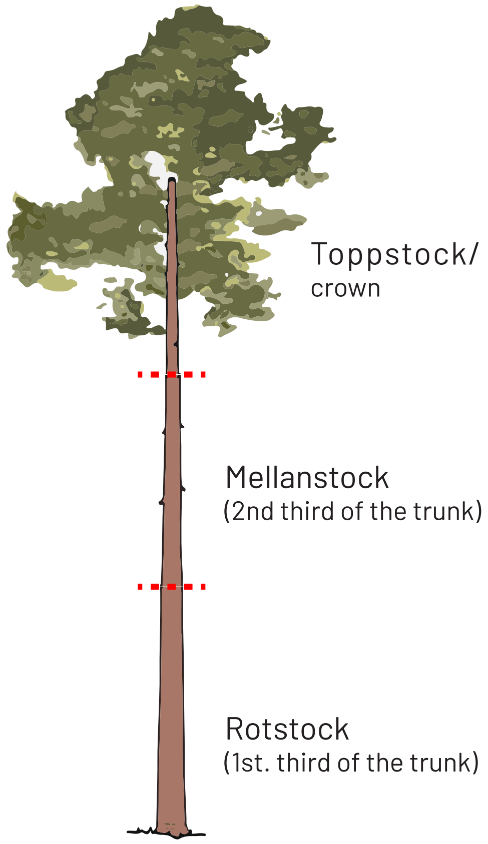

Fig.13 Pine tree division.

Plank arrangements

Edge over edge

This is a common arrangement for some stave churches like the one in kvernes (Fig.6, page 17). The planks are chopped and have a thickness from 5 to 7.6 mm., the long edges are carved down to 3.8 mm.thick, and are placed vertically edge over edge (Godal, 2012). The full cladding is attached with wood dowels that are commonly placed in the center of the width of the plank.

It is important to mention that the direction of how the wood is placed is also relevant for durability. The wood planks are arranged with the root end down and the märg side out (Fig.14), This was based on the principle that the plank would naturally keep the water out, since the branch knots would be facing down and out.

Board on board

This arrangement consists of two rows of standing planks. The first row consists of a layer of planks that stand edge to edge, and the second layer is a set of planks that seal the joints of the first layer (Stockholmlansmuseum,2021).

Moreover, the planks are oriented with the most dense part (märg side) facing outside. This results in a weatherproof wall.

Board and batten

This type of cladding is a refinement of the board on board arrangement. Its arrangement consists of a layer of standing planks that are set edge to edge. The joints are sealed with wood battens, this element is nailed to the base of the cladding (Stockholmlansmuseum,2021). This traditional cladding became popular during the 18th centura and it was commonly painted with linseed oil paints.

Horizontal cladding

In the norwegian context, the first claddings were made with 400 - 500 mm. width planks during the 16th century (Godal, 2012). The planks were placed horizontally, with the edges overlapped. It is considered a good arrangement for insulation, since the plank placement prevented the wind from coming in. The optimal setting was placing the plank with the marrow facing out and preferably in heartwood pine.

The nailing had to be done considering the overlapping of the edges, one nail should never go through two planks (Fig.18).

Fig.14 The most effective method to arrange planks was with the märg facing out, and with the root end down. This plank arrangement forms a dense and durable wall to the outside. (Stockholmlansmuseum,2021).

Fig.15 Edge over edge plank cladding in Folketmuseet in Danielsveit, Trondheim, Norway (Godal, 2012).

Fig.16 Board on board. The back layer of planks work as a gutter. The planks are arranged so that the center of the heartwood (most dense part) face out.

Fig.17 Board and batten example, the battens (läkt) are nailed in the center, so that the nail goes between the cracks. (Herzog et al., 2017)

Fig.18 The horizontal cladding is overlapped from the edges. The plank is set with the marrow (center of the hartwood) towards the outside. The cadding is directly fixed to the logwall.

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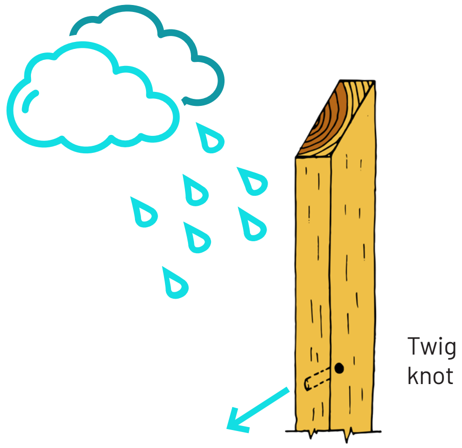

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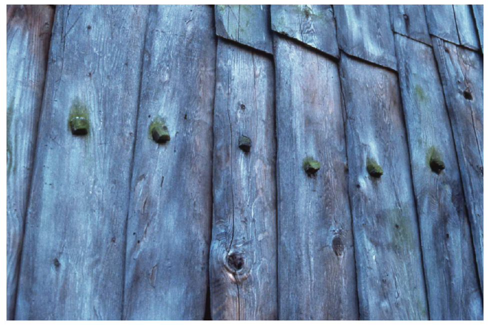

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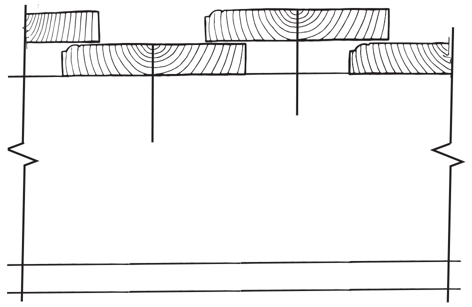

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18

Traditional use of shingles

Shingles have been used traditionally as a protective layer for roofs and exterior walls. (Zwerger,2015),. In walls, this layer was meant to reduce the risk of rot on wooden log or plank walls. The following descriptions showcase the traditional knowledge of church shingles and thin shingles in Sweden and in Norway.

1. Church shingles

Church shingles are thick shavings made of pinewood. Pine is the only tree species that is suitable for making this kind of shingles for its high workability and resistance.

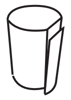
The suitable pinewood can be obtained from trees that are around 100 years old (Godal, 2012), and the reason is the fact that at this age, the tree has less dense sapwood.

Sapwood is not suitable for making shingles, since it is wood with a low consolidation, and thus it is not resistant to rot and decay, compared with mature heartwood.

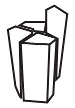
Shingle production

The rotstock (Fig.13) is the only suitable part used for chopping shingles, since it has a high imperviousness.

Carving process:



The rotstock trunk is sectioned according to the length of the shingles. Traditionally, it has been sectioned in log pieces that go from 450 to 620 mm. (Godal, 2012)). After that, the bark and almost the whole sapwood are chopped out with an ax (Samuelsson, 2014). (Fig.20-1).



This resulting log is then cut against its natural growing direction (the wood on top is easier to split). The log is sectioned in half according to the natural crack in the märg (Fig.12). After that, the two resulting parts are sectioned in half (Fig.20-2)(Samuelsson, 2014).

Then the pith of these parts is removed, and from these resulting sections, the shingles are chopped out with a long and sharp ax (Fig.20-3) (Samuelsson, 2014). The chopped shingles, which are from 110 and 210 mm. width, are first cut in the shape of rectangular prisms.

Finally, the shingles are carved forming a final trapezoidal shape (Fig.20-4). The outer edge thickness can be from 25 mm. to 32 mm., while the inner edge is likely to be at least 3 mm thick. (Godal, 2012).

Placement

Once refined, the shingles are fastened to vertical wall planks or log walls with hand craft iron nails or wood dowels (both described in the fastener section). The picture to the right shows an example in the Älgarås church outside Töreboda municipality in Sweden. The shingles were placed from bottom to top and in rows following a vertical overlap arrangement. The pull-up between each row in stake churches gets to be traditionally around 195 mm. (Godal, 2012).

Fig.19 Pine heartwood became a perfect option for shingles, since it could be worked easily, besides it offers a high durability. The image is retrieved from the Gothemburg University, this was a workshop to fabricate wood shingles for the restoration project of the Ingatorp tithe barn.

Fig.20 Illustrated process of the making of church shingles.

Fig.21 Älgarås church, the left image show the close-up of the shingle texture of the facade. The shingles are covered with red slamfärg paint. The right image shows the full building.

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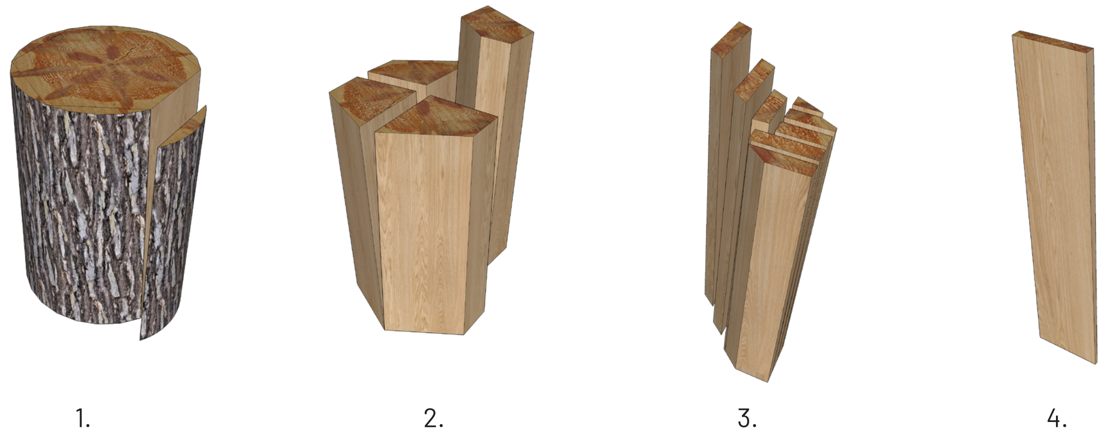

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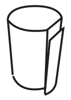
2. Thin shingles:

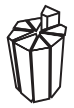
As in the church shingle section, pine wood is also a good option for making thin shingles, since the material can be easily worked. Among the recommendations made by the experts, it is important to look for trees that stand straight, their base has to be circular and clean with no balls or cracks, it should have a soft bark and it should show few or no branches in the lower part. (Godal, 2012)

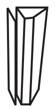
Shingle production

As in the previous example, the rotstokk part of the tree is mostly used to make this kind of shingles due to its big concetration of heartwood.

Carving process


The trunk is sectioned according to the length of the shingles (it could be divided in log pieces of 450 mm (Godal, 2012). Then, the sapwood is almost removed from the trunk, as in the previous example.


The log pieces are sectioned in eight parts, and then the märg of each part is removed, resulting in a trapezoidal shape (Fig.22-2).


Each piece is then set standing in a vertical position, to be sliced with sharp axes. The resulting pieces become the final shingles (Fig.22-3).


The shingles, which are from between 110 and 130 mm. width, are extracted with a trapezoidal thickness. The outer edge is around 6 mm. and the inner edge is around 4 mm (Fig.22-4).

Placement

The shingles are fastened to a vertical edge to edge plank wall with thin nails. The shingles are placed from bottom to top and in rows. They are placed following an edge over edge arrangement.

The shingles are nailed twice to make them stand still, and the overlap is traditionally between 10 to 14 mm. Finally, the pull-up between each row is around 100 mm. (Godal, 2012) The thin shingle arrangement on walls is traditional in Norway, where it is used as a traditional method to reinforce the walls that are more exposed to wind and rain.

Fig.22 Illustrated process of the making of thin shingles.

Fig.23 The image shows a close up of a thin shingle wall. The shingles are overlapped horizontally, but also vertically.

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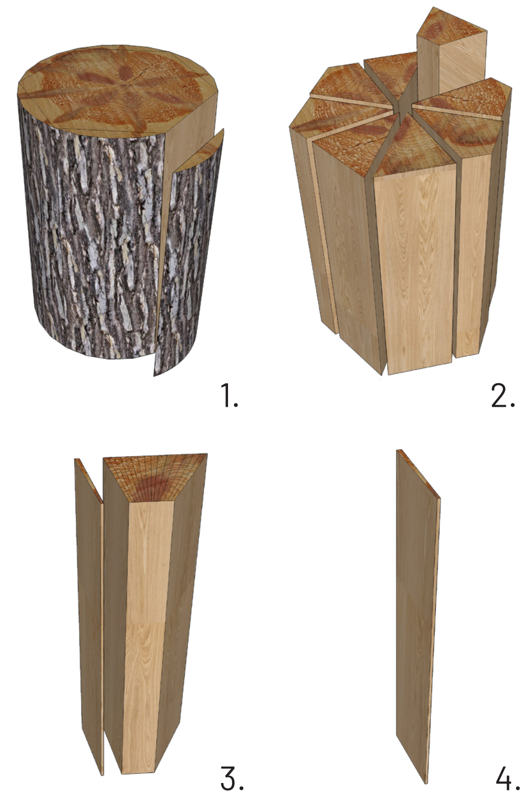

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Traditional fasteners

The fasteners are devices which are used to mechanically attach two objects. In this case, they attach the cladding to a rigid base.

The traditional fasteners are mostly dowels and iron forged nails.

Dowels (Wooden nails)

These are nails used for fixing planks and shingles, which are made from the heartwood of the pine (Fig.24). The fibers run parallel to the length so that when they were pinned in, they get mechanically fixed inside the wooden element. (Godal, 2012)

For nailing, the wooden element was first drilled with a wood auger. Then, the wood nail (sometimes in a conical shape depending on the auger) was pinned in (Godal, 2012). The important thing about this fastening method is that the diameter of the hole had to be exactly the same size of the nail.

Iron forged metal nails

These fasteners were the only metal nails before the invention of the wire nails. This type of nails were crafted by blacksmits and they were made with iron. Their production was expensive and time consuming. (Tekniska museet, 2019).

For nailing elements, the builder should predrill the element just as with the dowels. This was carefully done in order to avoid possible cracks on the wood.

The nails had heads and were flat at the end, and since they were wedged they fixed mechanically to the wooden elements (Fig.25).

Fig.24 The image shows the part of the heartwood that is used to make the wood nails. It was common to have dowels with a diameter of 19 mm. (Godal, 2012)

Fig.25 The image to the left shows the iron nails in elevation. The image to the right shows the placement of a nail in a plank. A hole had to be predilled and the wedge had to be perpendicular to the fibers of the wood.

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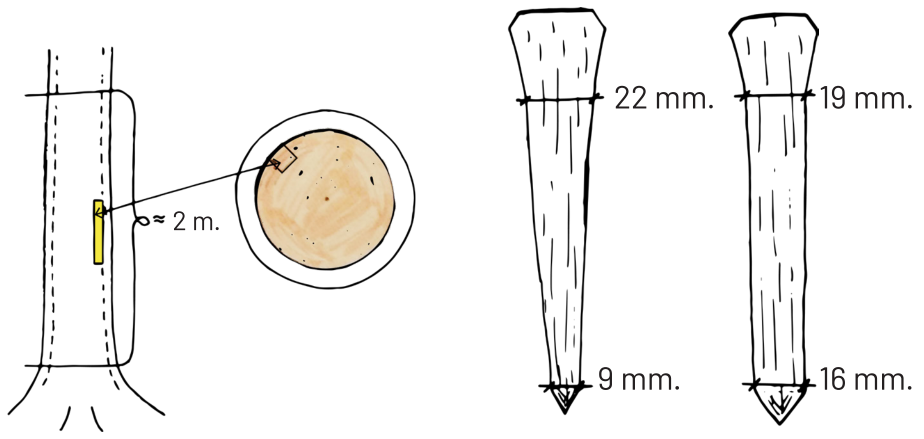

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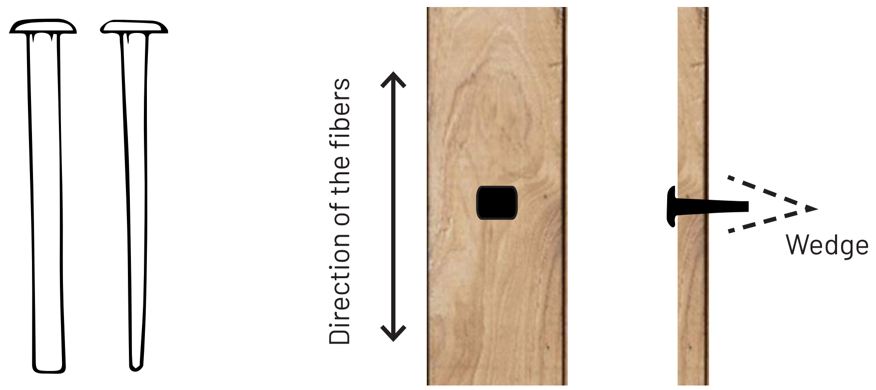

Modern systems

The cladding systems changed since the rapid development of the saw industry. In Sweden, the mass production of planks and fastenings promoted the apparition of the plank-covered trend during the 19th century (Hall & Dunér, 1997). These conditions made wood claddings more accesible to common people.

The modern systems of cladding that exist today are based on sets of layers that are assembled together with nails or screws. The systems are based on the traditional arrangements, nevertheless the wood selection is not regarded as it was before.

Vertical plank arrangements

Vertical Board on board/ board and batten

The planks are arranged in two rows along the wall, just as in the traditional arrangements described before. The difference is that it is nailed to a horizontal structure made of wood battens, that is also nailed to a vertical structure made of wood battens (Fig.26).

Shiplap

Vertical wood plank cladding mounted on a structure made up of horizontal battens, that are commonly placed each 600 mm. This structure is fixed on a vertical structure of wood battens that are commonly spaced from 400 mm to 600 mm. This is made this way, in order to make space for ventilation (Fig.27).

Horizonal plank arrangements

Feather edge

Horizontal arrangement of wood planks fixed on a vertical structure of wood battens. The profile planks are shaped in a trapezoidal way, and the planks are placed partially one of top of another (Fig.28). It is the modern version of the traditional horizontal cladding described before.

Shiplap/tongue and groove

Horizontal arrangement of wood planks fixed on a vertical structure of wood battens. The profile planks have a shiplap shape way, and the planks are placed partially one of top of another. Additionally, there is a variant with horizontal planks that follow a tongue groove arrangement (Fig.28).

Fig.26 From top to bottom and from left to right, board on board detail, board and batten detail and isometric view of the board on board arrangement.

Fig.27 From left to right, shiplap detail and its isometric view.

Fig.28 From left to right, horizontal shiplap detail, tongue and groove detail, feather edge detail, and isometric view of the feather edge arrangement.

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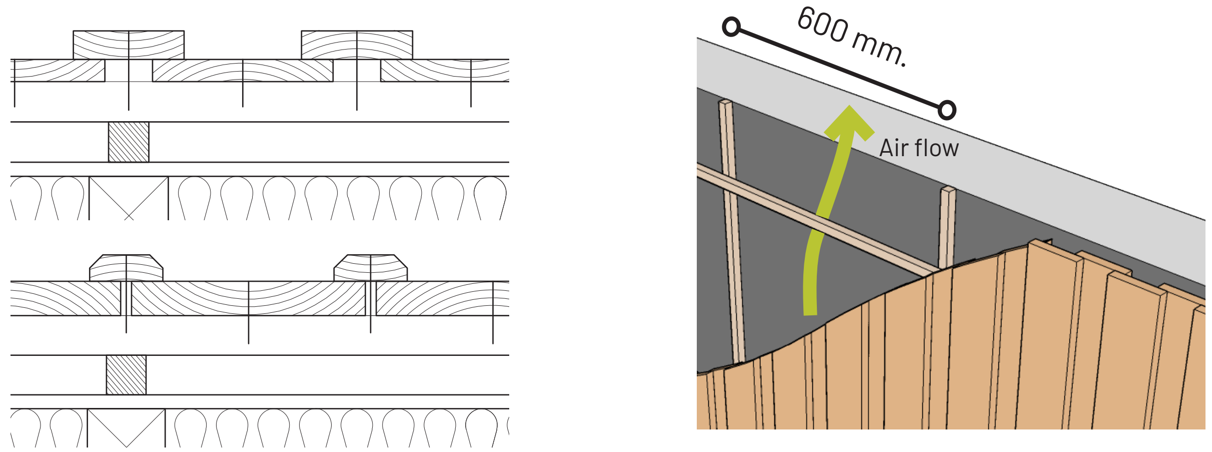

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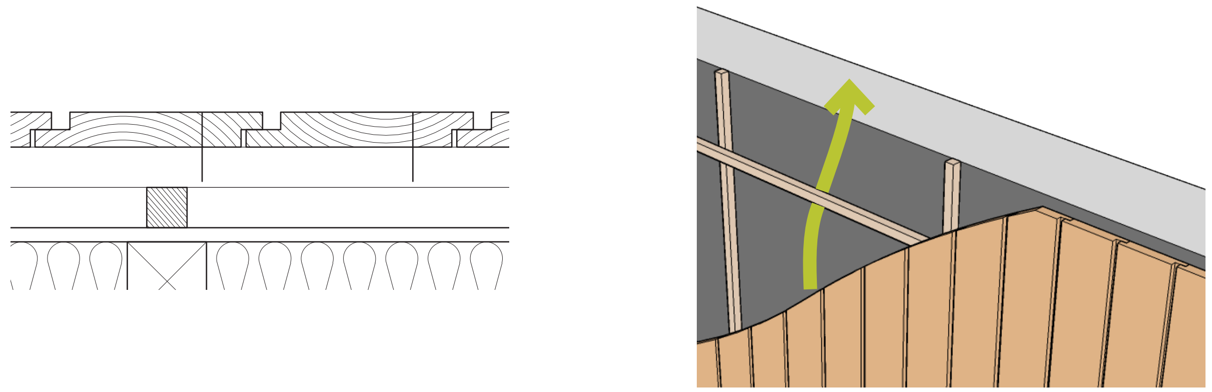

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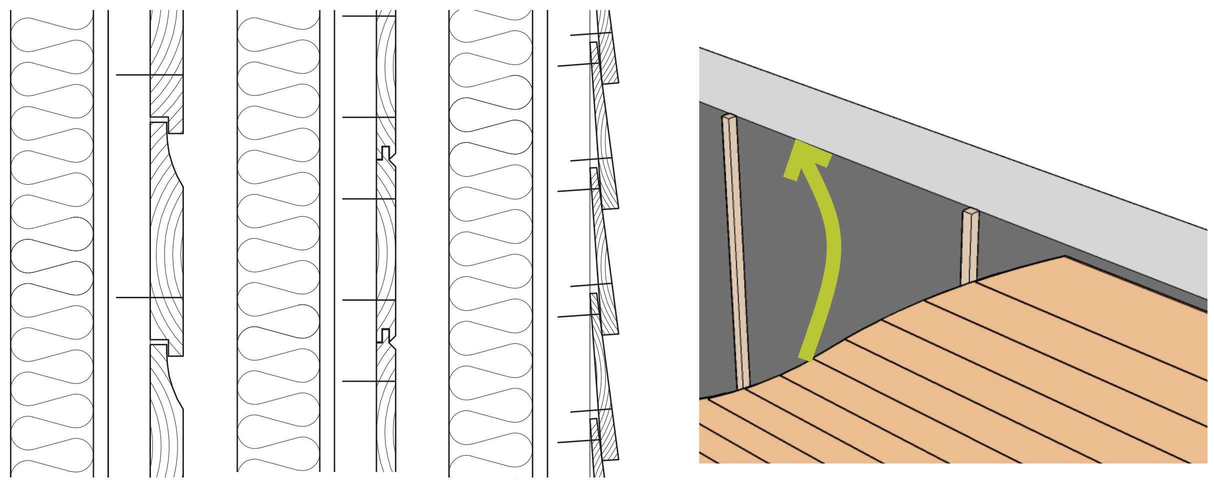

Shingle arrangements

Thin shingles

The modern shingle system is based on the traditional thin shingle system. The elements are nailed either to a structure of battens or directly to a timber sheating (Fig.29).

The shingles may have different dimensions. They are available in lengths of 406 mm., 450mm. and 610 mm., with a variable width that ranges between 55 mm and 350 mm., and they are tapered, so the bottom part can have a thickness of around 10 mm. and the top a thickness of around 2 mm.

Modern fasteners

Modern wood nails (Lignoloc)

This fastening method is a modern system that binds wooden elements through the use of nails of high densified beech wood (Beck,2021)(Fig.30-1).

These nails merge smoothly with the wooden elements, after they are pneumatically nailed at a high speed. The friction generated by the high speed melts the lignin within the nails, and this causes a welding effect between the fibers and the nails (Fig.30-2).

Timber construction screws

These fasteners are special screws that are used for attaching different construction elements. They are made in bronze, brass, aluminum, steel and stainless steel.

The stainless steel screws and silicon bronze screws are the most common ones for external use thanks to their resistance to corrosion. (Nagyszalanczy, 2016)

Fig.29 To the left, shingle placement details, the shingles are fixed with two nails to either a structure of battens or a plywood panel, to the right the isometric views.

Fig.30 The image to the left shows the wood nails system in section, the image to the right shows the welding effect between the nail and the wood fibers.

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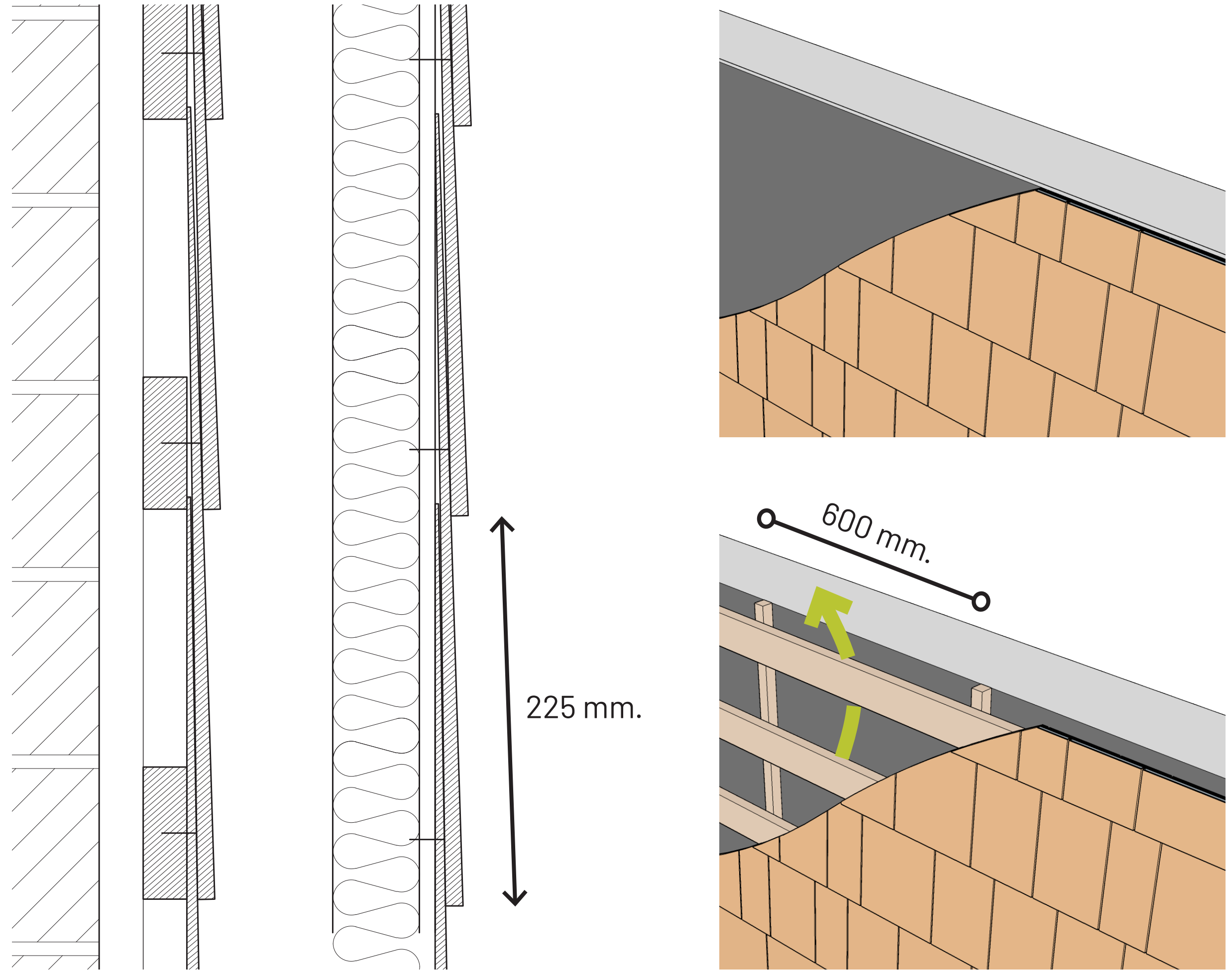

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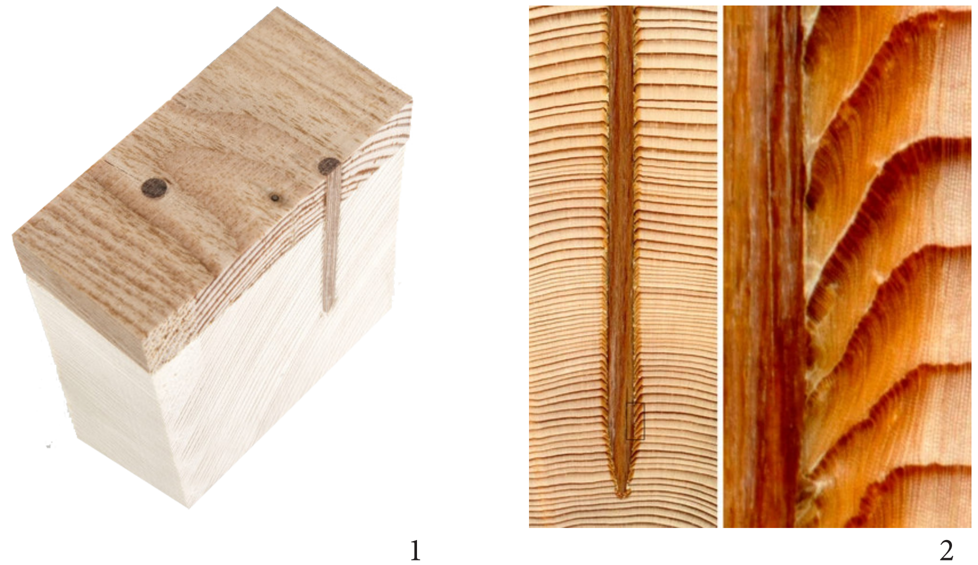


Case studies

Ingatorp tithe barn

Tithe barn is a wooden barn that was built in the 13th. century. The building features a shingle red pine cladding that is attached to the four log walls. The building went through a detailed restoration process in 2011.

Cladding description

The shingle cladding has elements that are from the 16th and 19th century, it is estimated the cladding was an addition to the building that took place between 1560 and 1580 (Melin, 2019). It is believed that this addition was a measure to protect the log building from rot.

The material used for making the shingles is pure pine heartwood. Besides that, the shingles are chopped in a long trapezoidal profile.

The shingles are nailed with black forged iron nails to the log walls. Each shingle is originally fixed with two nails, but since there is an overlap with the row on top the nails that are on top get to pierce the shingles that are below (Fig.33).

The renovation project in 2011

This small building was rennovated in 2011, with the intention to preserve its integrity. The rennovation project was carried with volunteers and experts who remade and replaced some of the worn out elements. All the replaced elements were crafted with the original building technique that they were built.

In regards to the cladding, it is evident that it was carefully inspected and treated. Some of the shingles were dismounted to fix one of the sills in the south wall. Additionally, there was a detailed documentation of all the nails and shingles to be able to re-assemble the building to its original shape.

Fig.31 Ingatorp thite barn shingle wall. The shingles are placed edge to edge horizontally and they are overlapped vertically.

Fig.32 Ingatorp thite barn. The image shows the building after the final restoration process.

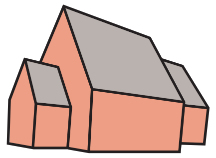
The cracked shingles were replaced for new ones and the missing and broken iron nails were replaced with cut nails (klippspikar) in the four walls. This was carried this way to make a clear differenciation between the original and the added elements.

Finally, all the shingles were covered with light red slam färg to protect them from the UV degradation and weathering.

Fig.33 Restoration works of the cladding. The shingles are nailled directly to the log walls.

Fig.34 Ingatorp thite barn resotration project, the image shows the making of new chopped shingles. 400 new shingles were crafted in a shingle seminar in 2014.

Ramnakyrkan



Ramnakyrkan is a church located in Ramna parken in Borås. It was originally built in Kinnarumma in 1690, but in 1907 the parish in Kinnarumma built a new church and the original was dismatled and handed over to the cultural heritage association. In 1914, it was rebuilt in Ramna parken in Borås, where it stands nowadays.

Cladding description:

The cladding is made out of sawn shingles that are placed in rows. The vertical overlap between each row is 15 cm., and the shingles are arranged so that the joints of two consecutive rows don't end up matching (Fig.35).

The cladding is barely a hundred years old, it was incorporated to the building in the beginning of the nineteen hundreds as a decoration, but also as a protective measure.

The shingles are fastened with long metal nails to the log walls. The length of the shingles is 45 cm., the width varies from 100 to 150 mm. and the thickness is 23 mm at the bottom, and around 5 mm. at the top.

Within the walls, there are decorative diamond patterns (Fig.36-B), and there are also decorative rows at the upper part of the walls, next to the end of the rafters (Fig.36-A).

The cladding is protected with the traditional swedish red falun slamfärg coating.

The western entrance (Vapenhuset) was built in 1930 and it was made using a vertical lockläkt cladding (Fig.37).

Fig.35 Shingle arrangement.

A. Decorative rows at the top of the walls

B. Decorative patterns

Fig.36 Some of the shingles on the facade show different shapes as a way of decoration.

Renovations:

The building has gone through many renovations since its reconstruction in 1914. Nevetheless, there has not been major changes to the cladding on the walls.

The last maintenance works were in 2010 and in 2020.

In 2010, the cladding received a reinforce application of the red slamfärg paint.

In 2020, it received its most recent reinforce application of the red slamfärg, and some rotten shingles were replaced.

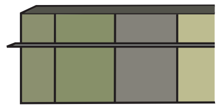
Source:
J. Daun (Borås Museums industrial antiquary), personal communication, march 11, 2021

Fig.37 Entrance view of the church. The entrance door is in a volume covered in planks, that sticks out from the main voulume of the building.

Fig.38 Southwest view of the of Ramna church. The walls are covered with church shingles that are treated with red slamfärg.

Project One six

By Okidoki and Bornstein Lyckefors



This is a revolutionary project of a condominium of six townhouses and six appartments in Central Brunnshög in Lund. These buildings were designed by six diferent architects.

The most remarkable thing for this research project is the design of the wooden facades. Each one of them is designed with different shapes, by having as a general rule the use of wood planks and the green color.

Although the approach didn't focus much on the possible reuse or the durability of the material, the project gets to fit in the reference list because of its innovative cladding arrangement. The cladding is made out of spuce planks that lay on top of a structure of spruce battens.

Facade description

Facade made of 145 x 22 mm. vertical planks with a decorative layer of vertical battens of 22 x 45 mm. and 45 x 45 mm. The cladding is mounted on two layers of horizontal and vertical battens.

Cladding made of 170 x 22 mm. planks that are cut and placed as shingles. This layer of shingles is placed on top of horizontal battens that are fixed to a structure of vertical battens.

Horizontal cladding made of groove-tongue planks of 145 x 22 mm. with a wooden frame of battens on top of 45 x 90 mm. These layers are mounted on top of two layers of horizontal and vertical battens.

Fig.39 Facade description of each house

Fig.40 The images above show the different cladding solutions in the south facade,

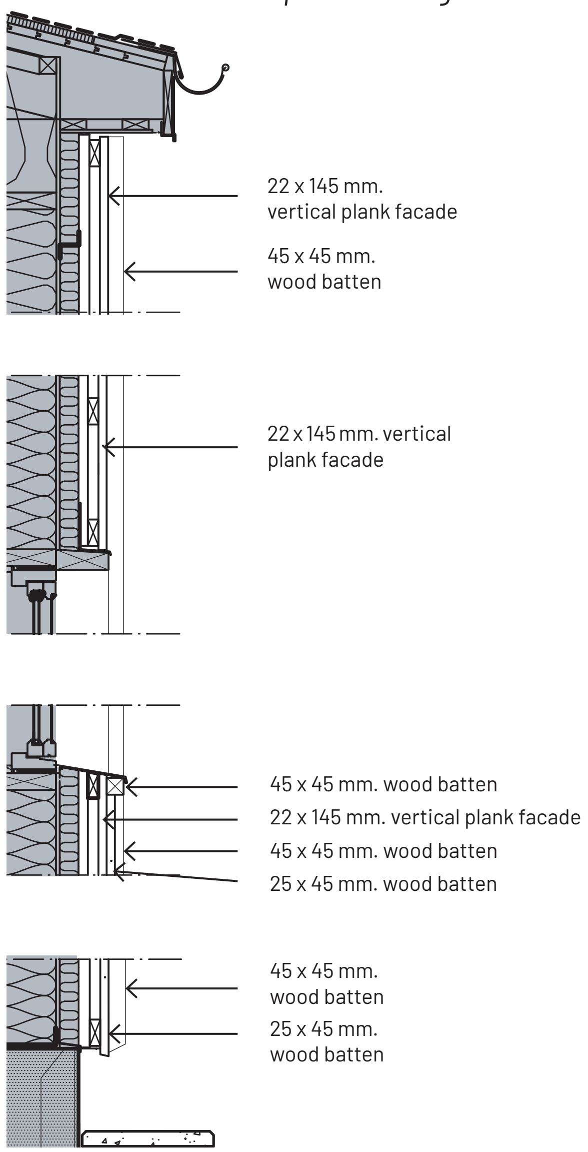
Facade made of vertical 22 x 145 mm planks with a decorative layer of hattprofil(round moulding) on top. The cladding is mounted on a horizontal layer of wooden battens that is also mounted on a layer of vertical battens.

Facade made of 22 x 170 mm. planks arranged vertically with decorative frames of battens of 45 x 45 mm. and planks of 145 x 45 mm. This facade is mounted on two layers of horizontal and vertical battens.

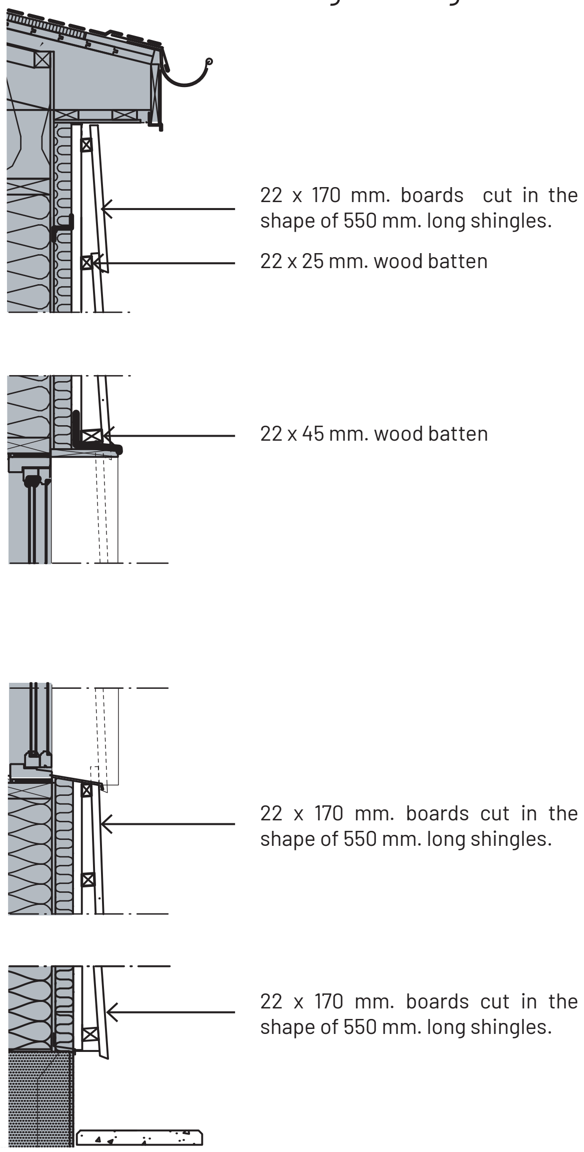
Facade made of 22 x 145 mm. spruce planks arranged diagonally at 45° on top of a horizontal structure of battens that lays on another layer of vertical battens.

Analysis of the different shapes within the facade
(Details drawings courtesy of Oki-doki architects)

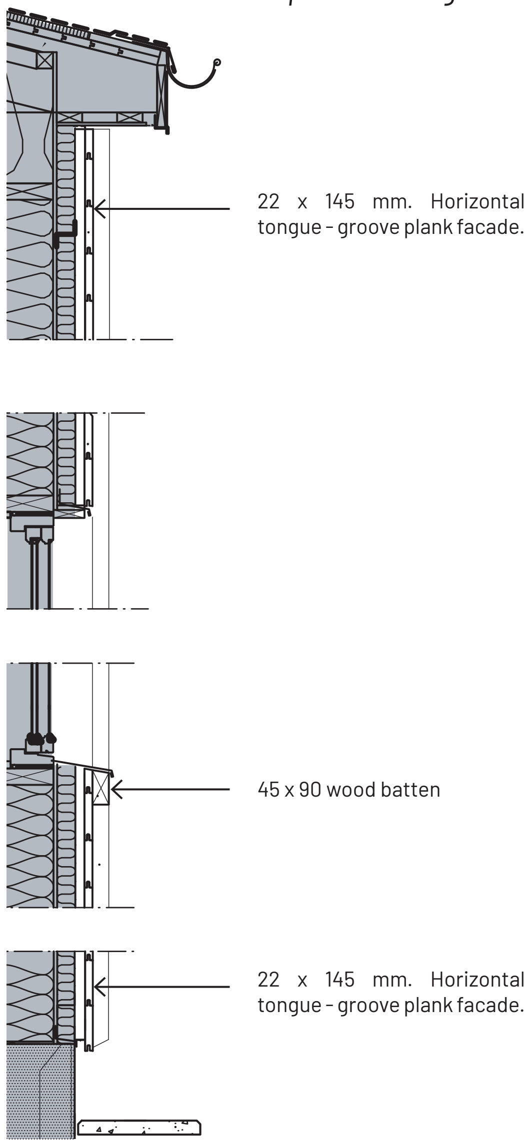
Vertical plank arrangement



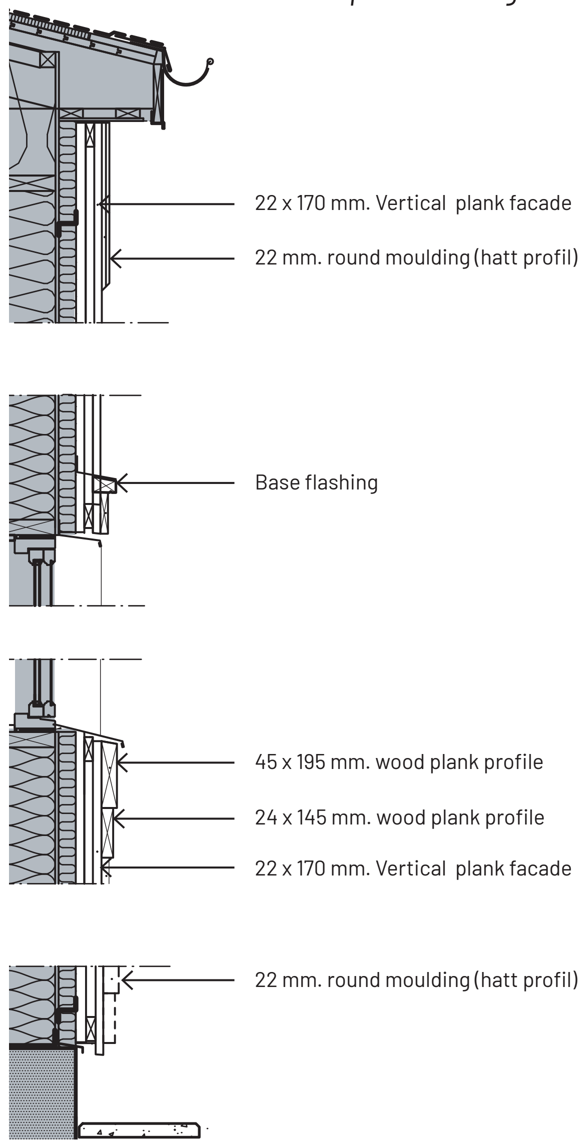
Shingle arrangement

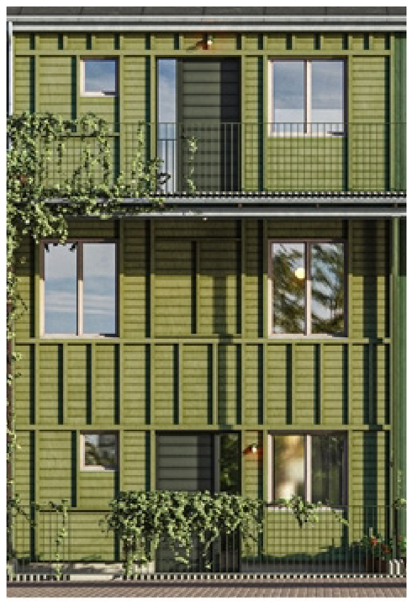


Horizontal plank arrangement



Vertical plank arrangement





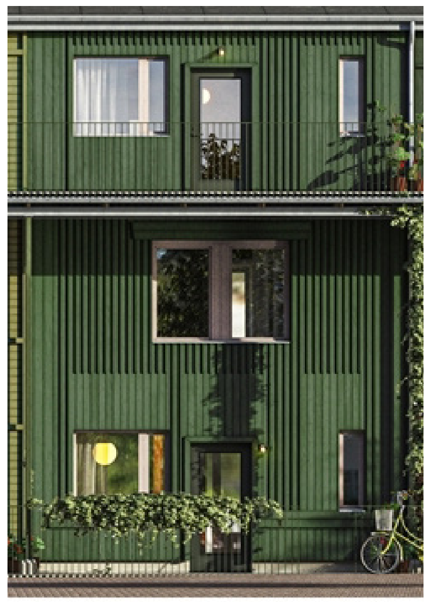
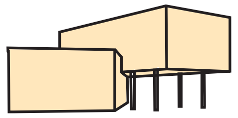


Fig.41 Facade details

Västraffik's travel center at Åkareplatsen



By White Arkitekter

This is a temporary building that houses a terminal for four different bus lines. The project itself hosts a waiting hall, space for staff, a store and toilets. The building was designed to temporary relieve the Nils Ericson terminal, since there will be major rennovations in the main building in the upcoming years.

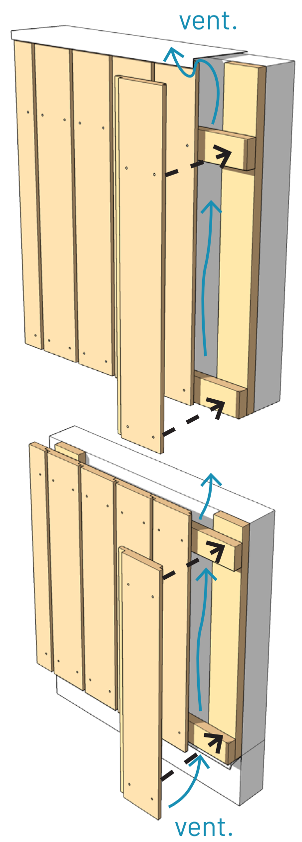
It is remarkable that the building is conceived in wood and it was designed to be dismantled in a period of around ten years. Although the reclamation of the cladding was not included as one of the ambitions of the project, it is worth to mention that the system incorporates screws which make the disassembly process easier.

The cladding material is untreated ore pine heartwood planks, that are screwed to horizontal 28 x 70 mm wood battens. The battens are placed each 600 mm and lay on a vertical 27 x 97 mm wood batten structure.

Fig.42 East view of the building. The project has the shape of two stacked prims which rotated from one of the ends.

Fig.43 North view of the building

The shape of the cladding elements are shiplap planks of 22 mm x 148 mm. The wood planks are fastened with a pair of screws to internal wood battens each 600 mm. (Fig.44).



The planks meet with a metal coping cap to the top. This cap prevents the filtration of rain water into the cladding structure.

The planks are fixed to horizontal wood battens, which at the same time are fixed to vertical battens. This measure allows an internal ventilation.

The cladding is placed above the ground about 15 cm. and it has a metal flashing (plåtning) at the far end.

Fig.44 Detail of the plank arrangement in the shiplap cladding. The quality of the wood is evident (most of the planks were made from the heartwood, and the tangential rings are oriented to the outside of the building.

Design proposal

Remarks for design

- The design of the system should orient to use high quality pine heartwood. Pine wood from trees that had lived for at least 100 years and that have been growing naturally without the use of accelerated techniques as it is pointed out in the beginning traditional practices section.
- The experimentations will be made using a chopped shingle cladding (Kyrkspån). The durability observed in the case studies, along with its high versatility, makes it attractive for being in a dismountable facade system..
- The shingles elaboration will be carried using the traditional chopping techniques, but they will also be sawn, in order to make uniform width.
- The design proposal will also experiment with the modern battens structure. Its simple arrangement shows potential for becoming a relevant part of a dismountable system.
- The design proposal will experiment with the traditional red Slamfärg, as it is a natural wood treatment that extends the wood elements lifespan, at the time it does no harm the wooden elements.
- In regards to the fasteners, modern wood nails (lignin nails) will be tested for the shingle-batten attachment.

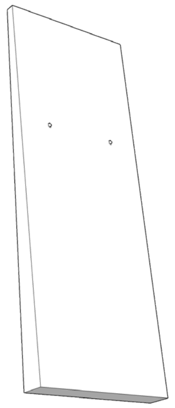
Prerequisites

Based on the previous analysis the system should then:

- Orient to resist to the real exterior conditions.
- Attempt to achieve circularity.
- Promote the sustainable use of wood.
- Aim to last at least the same than the building life where it is hosted in.
- Explore the alternatives within the design for disassebly.
- Orient to use a low amount of energy to assemble and disassemble.
- Experiment with innovative fastenings.
- Explore modularity.
- Experiment with modern elements and traditional techniques, as a way to find viable solutions.
- Orient the design proposal to a mix of vernacular with modern features.

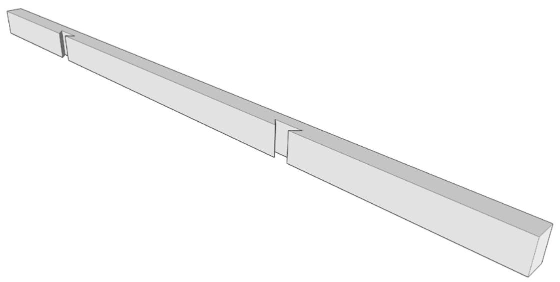
The wood cladding

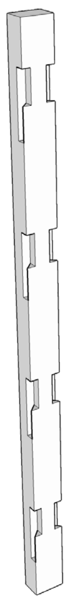
Elements



Chopped shingles with dimensions of 150 x 450 mm. with a thickness of 10 mm at the upper end, and 25 mm. at the lower end.

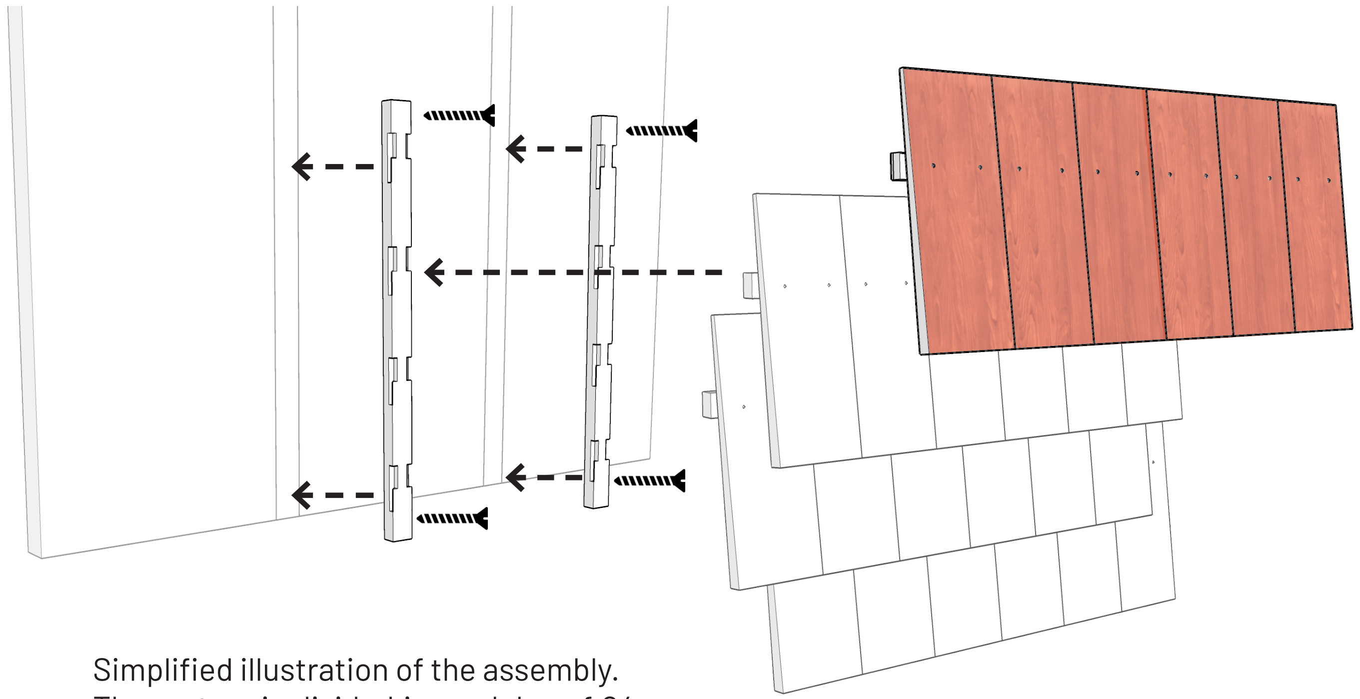
Carved horizontal batten of 38 x 50 mm. (See fastening details)



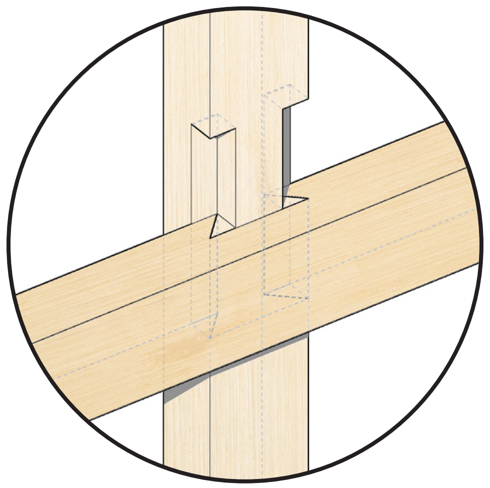


Carved vertical batten of 38 x 50 mm. (See fastening details)

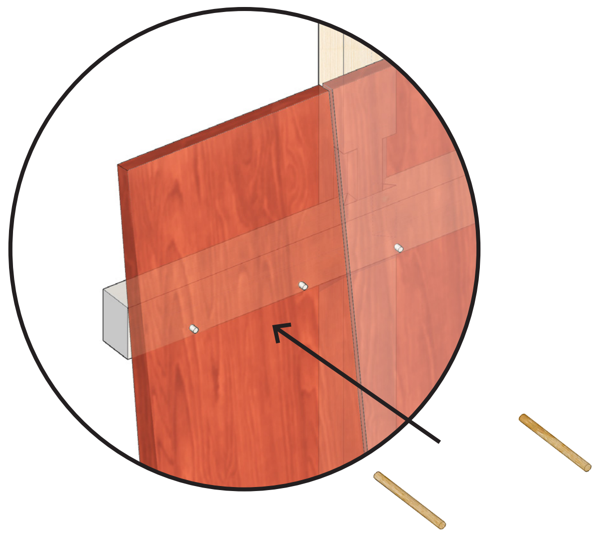
Assembly



Simplified illustration of the assembly. The system is divided in modules of 24 shingles. This module is divided in four horizontal submodules of 6 shingles .

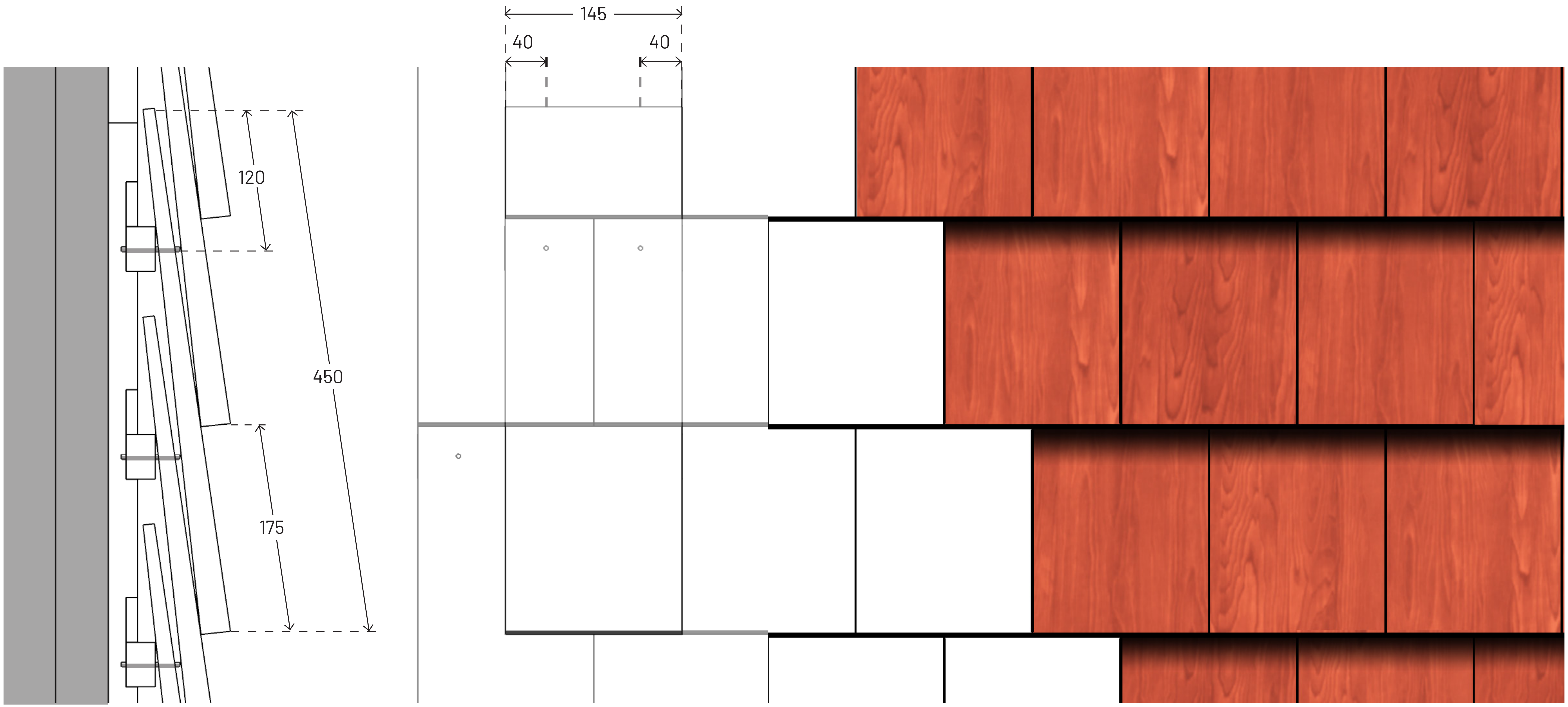


The fastening between the horizontal batten and the vertical batten is solved with grooves made to the elements. (See fastening details)



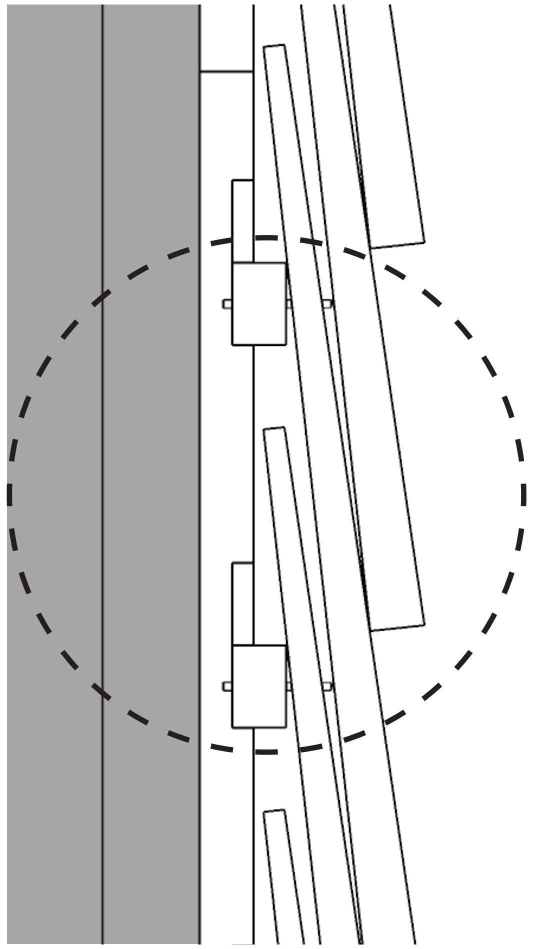
The fastening of the shingles to the horizontal battens is solved with two 50 mm long wood nails (Ø 5.3 mm.). For placement details see shingle details.

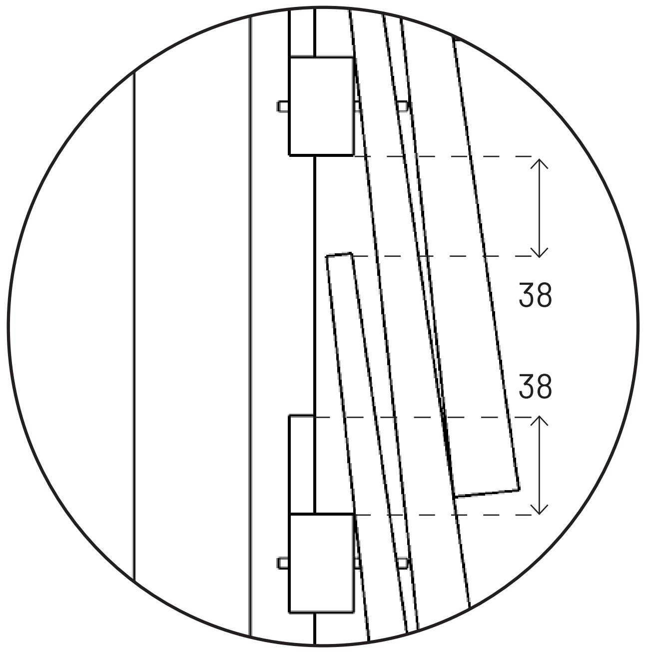
Shingle details

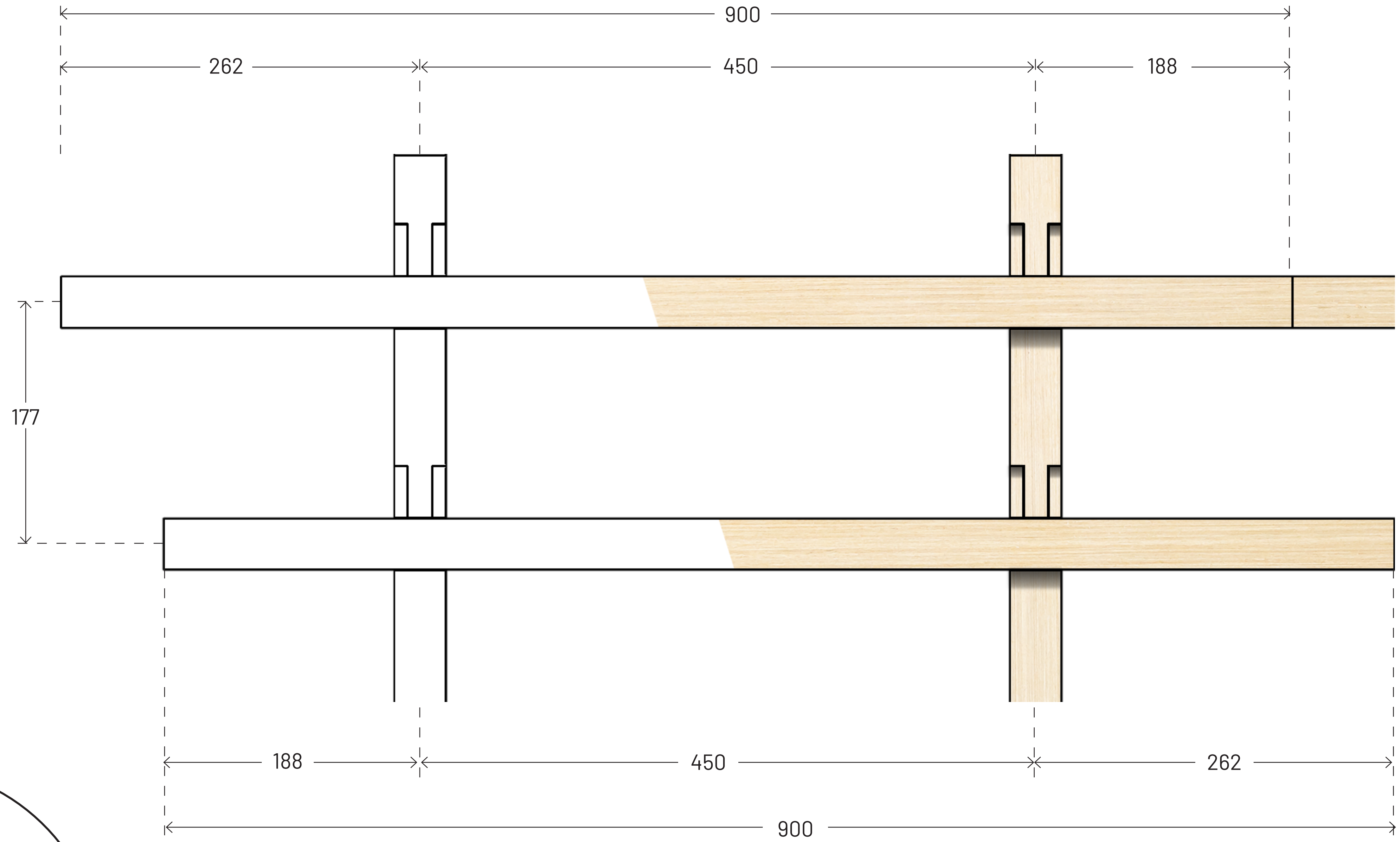


*All the dimensions are displayed in mm.

Structure details



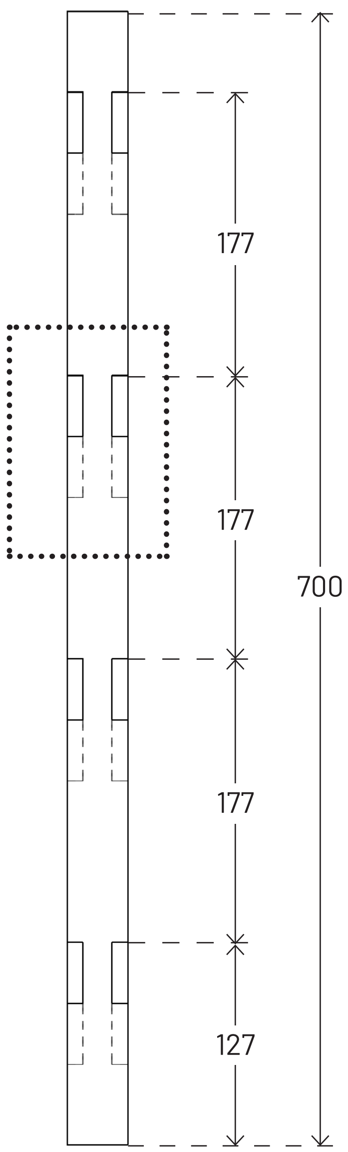


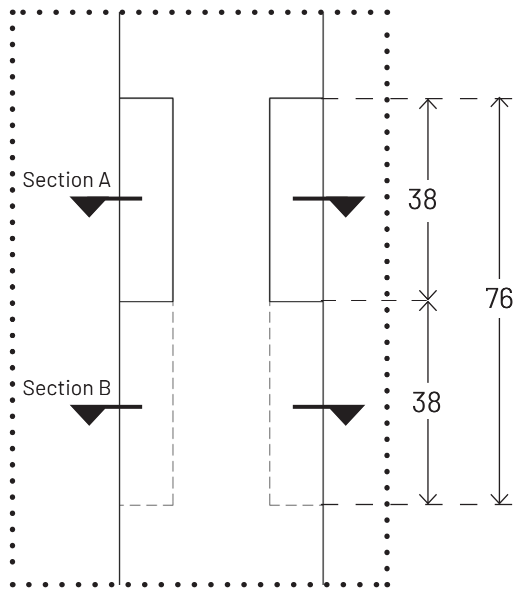


*All the dimensions are displayed in mm.

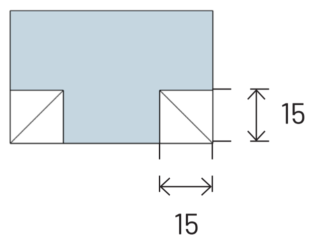
Fastening details

Vertical batten

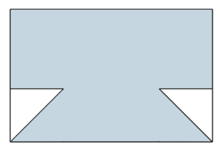




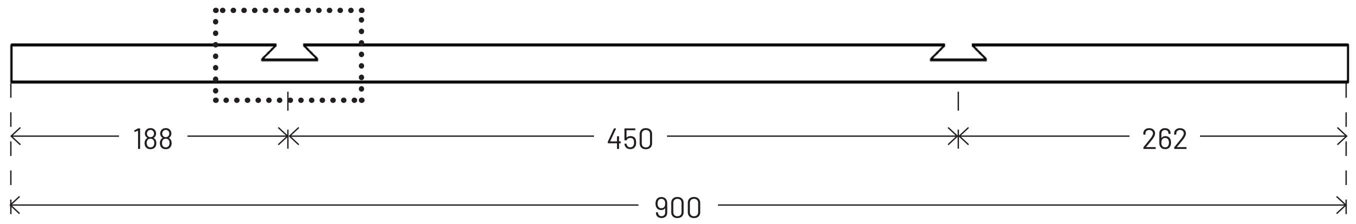
Section A



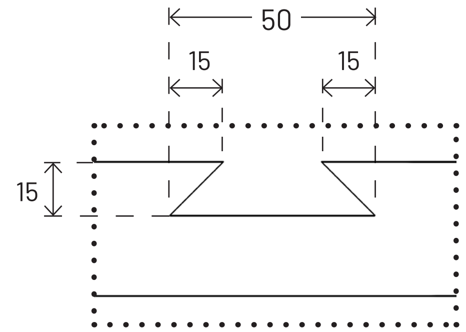
Section B



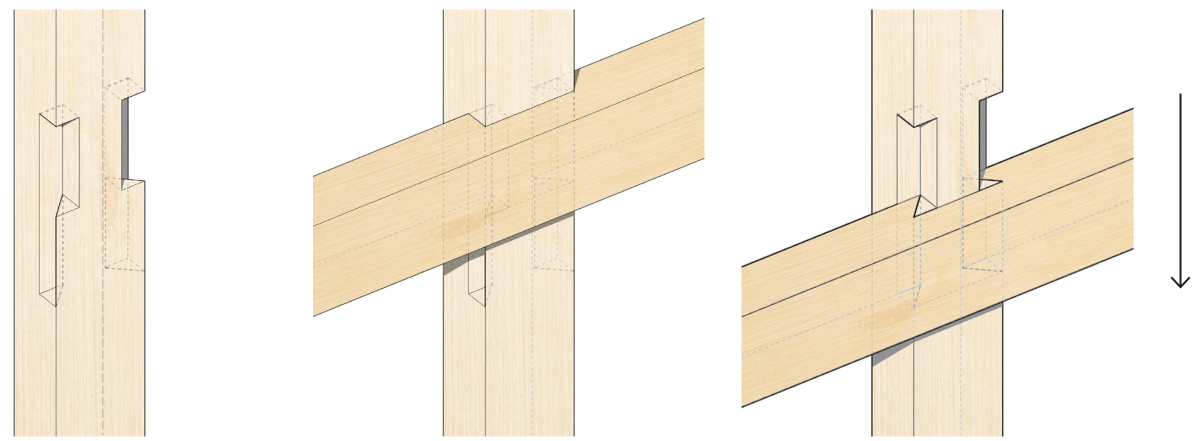
Horizontal batten



The pine battens are carved with a router machine. The fastening system is made with a set of a tongues and grooves that mechanically fix the elements.



Fastening principle



*All the dimensions are displayed in mm.

Discussion

The design proposal shown here is the outcome of an iterative design process.

The proposed model looks at the following concepts:

- *A high quality material*

The proposal highlights the importance of the traditional practices in the generation of a durable material.

By looking at the previous analysis, there is relevant vernacular knowledge that is often overlooked, and that aims to generate a high quality wood. This proposal is oriented to use that knowledge.

- *An aged heartwood and possible alternatives.*

The heartwood proposed for the design proposal is contained in 100 year old trees. This is a problem since there is not that many forests with these assets. Using these few forests might imply a big modification of valuable natural environment.

A possible solution could be to let productive forests grow older, instead of harvesting them at an age of 80 years old or before.

Another solution is adapting the trees to produce a durable heartwood at a younger age. The generation of lightwood could be a solution for now, but there might be other solutions with biotechnology in the future.

- *Shingle fixation*

The standardized shingles are fixed with modern wood nails in an attempt to reduce the metal fastenings to the minimal. Each shingle is fixed with two nails directly to a horizontal batten, that can receive up to six shingles.

- *Modularity*

The design proposals were oriented to create a modular shingle assembly that could be assembled and disassembled without going through a destructive process.

The model incorporates a simple fastening made of grooves and tongues carved in the battens with the intention to simplify the assembly and disassembly process.

- *Red slamfärg application*

The system incorporates the Slamfärg treatment described in the analysis, as a protective treatment to reinforce the shingles.

This treatment is selected from among the other treatments for its effective protection against the weather degratation, and since it also shows the less impact on the physical properties of the wood.

- *Traditional practices and modern industrial processes.*

Some of the traditional practices described in the analysis, are considered as important remarks for the design proposal. Nevertheless, these practices would need to be adapted in order to be present in an industrial manufature scheme, as it was previously mentioned.

The next step of this proposal is looking at how traditional valuable knowledge can be used in a modern scheme. A scheme that would lead to an industrial production.

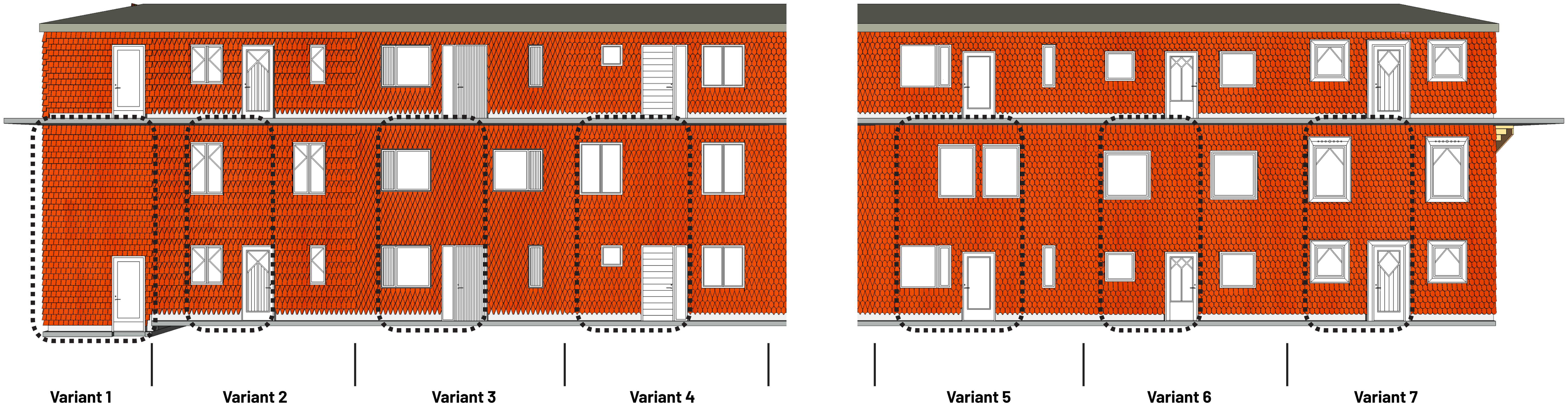
The application on a building

A new facade for a residential building

The project One six (described in the case study section) is selected to be the test model for the cladding system. The shape that the project has, makes it ideal for the system to be tried with six different expressions.

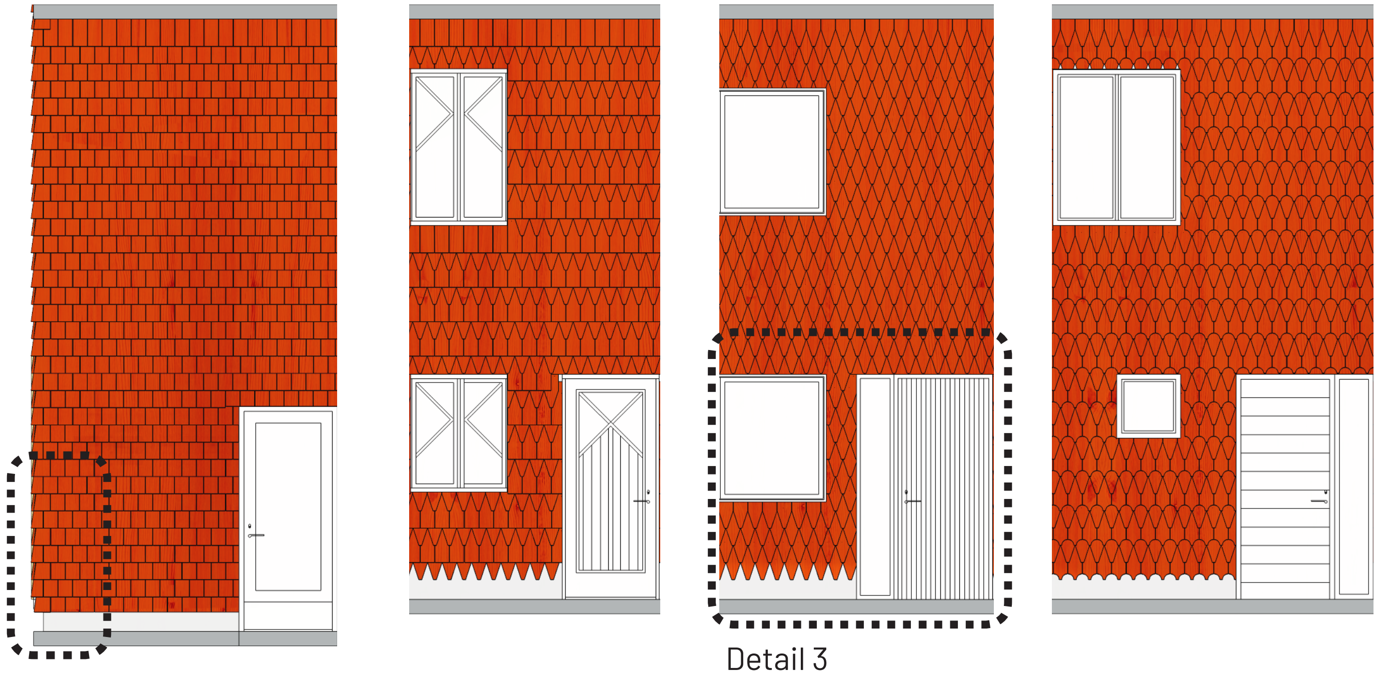
The proposal looks forward to presenting a design alternative to the current cladding. It incorporates the idea of a durable and reusable wood cladding.

The general picture



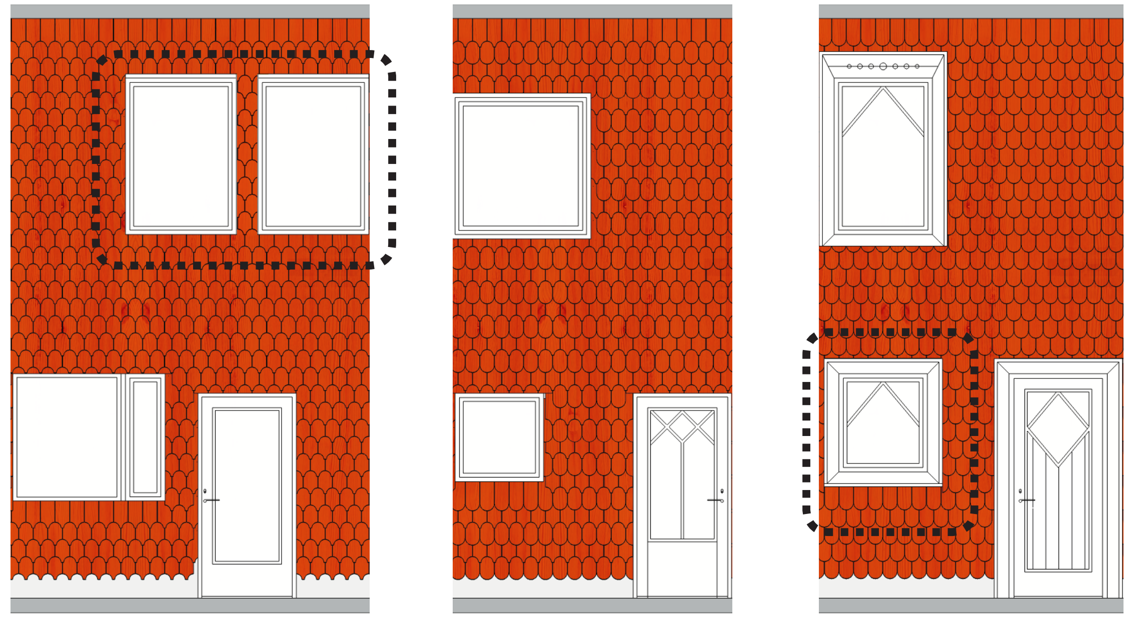
The proposed cladding

Detail 2
(See specific detail section)

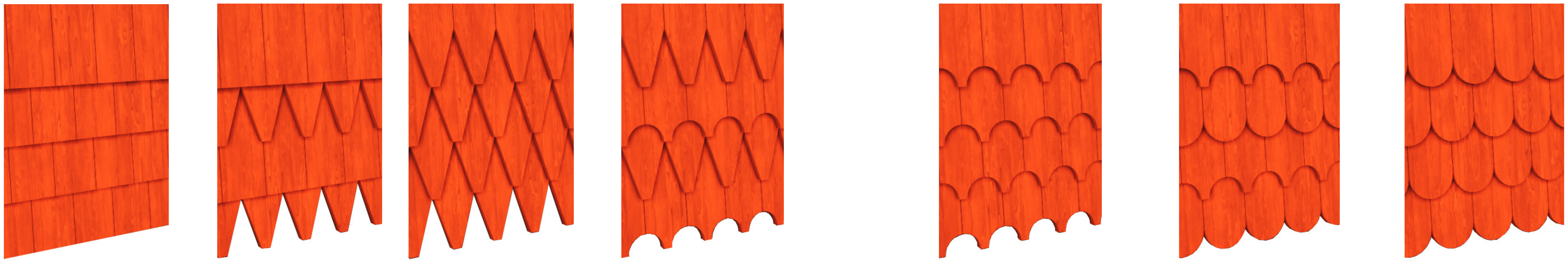


Detail 4
(See specific detail section)

Detail 3
(See specific detail section)



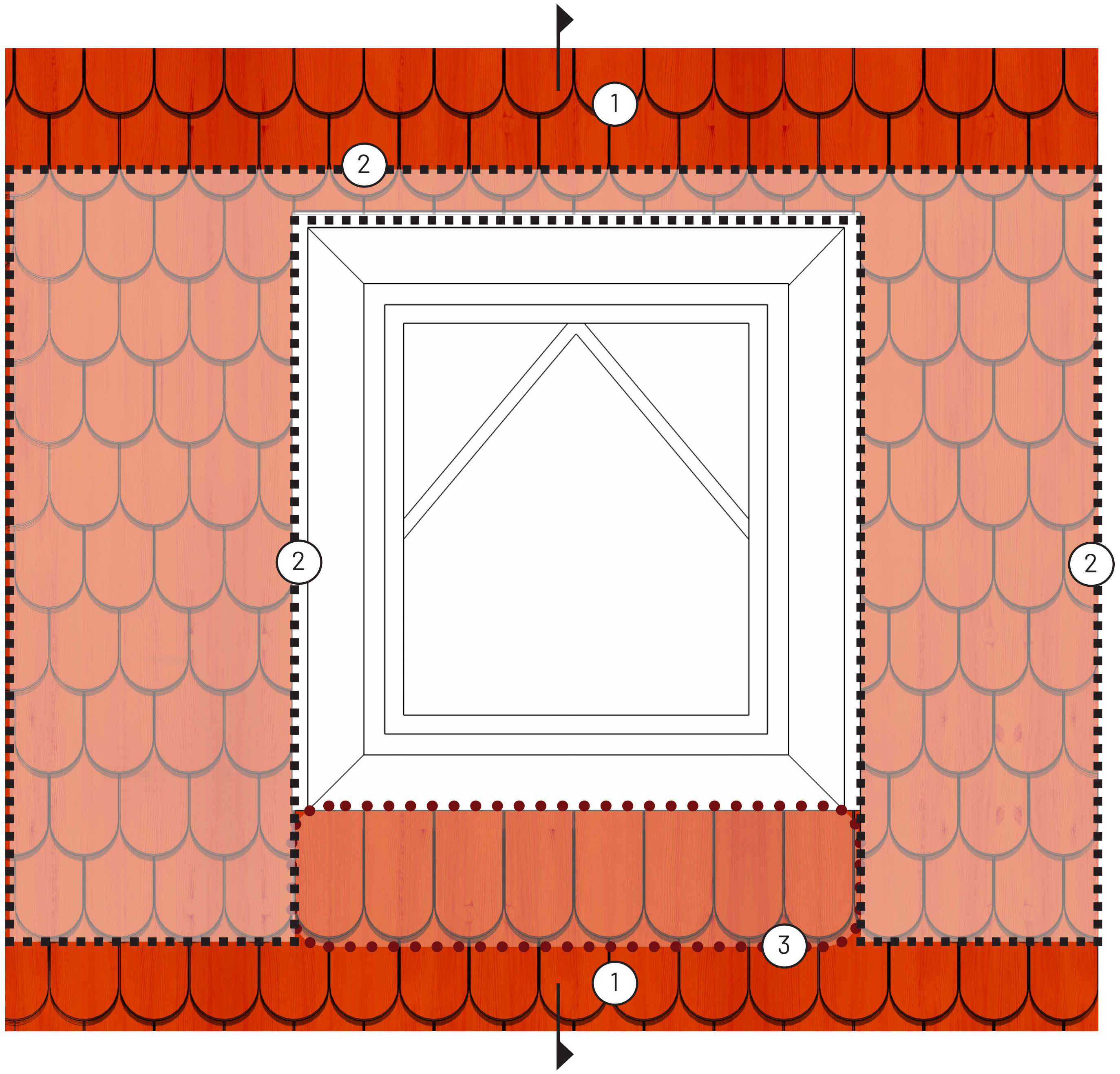
Detail 1
(See specific detail section)

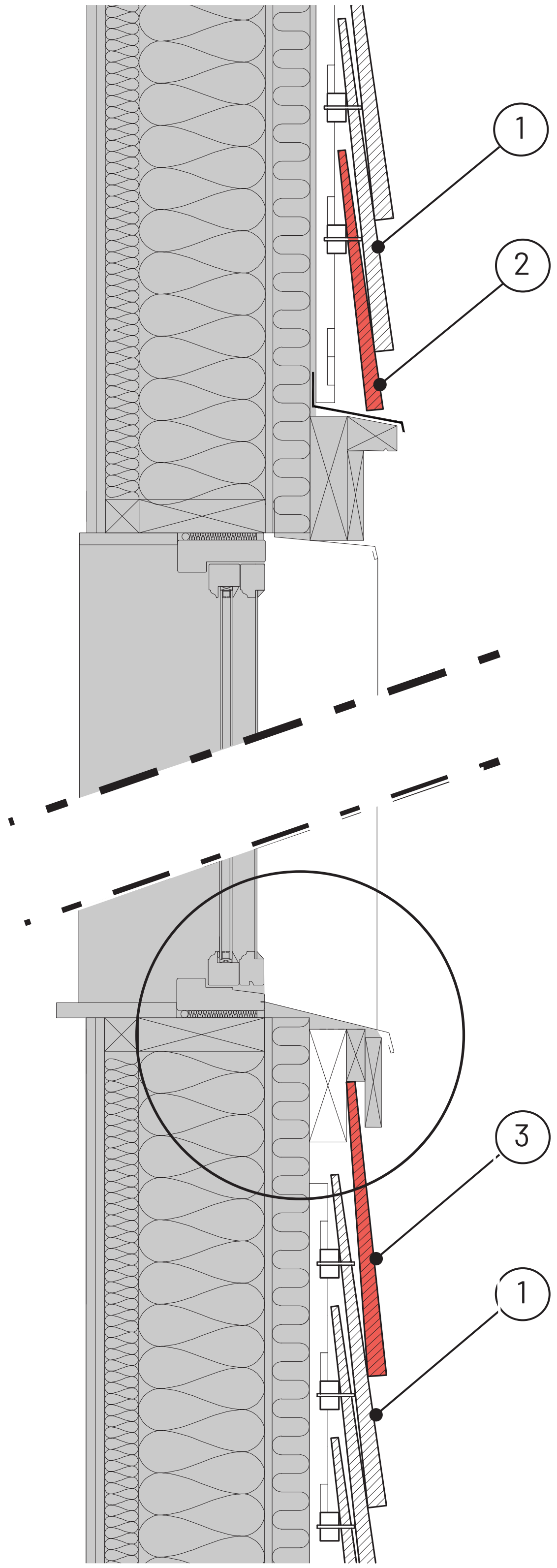


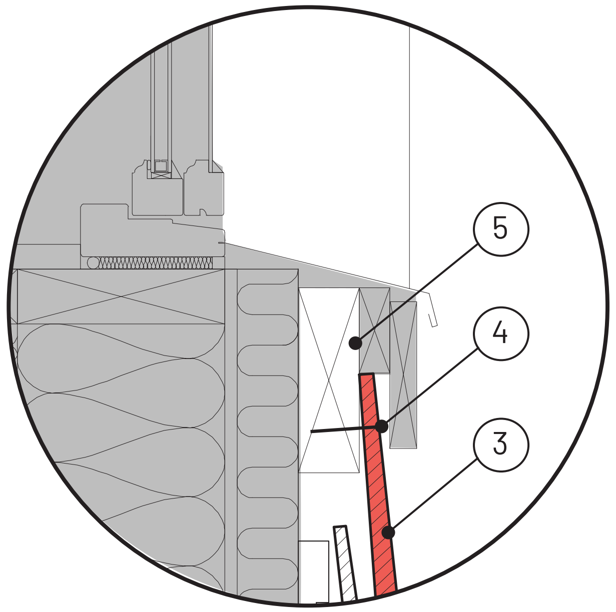
Variant 1 | Variant 2 | Variant 3 | Variant 4 | Variant 5 | Variant 6 | Variant 7

Specific details

Detail 1 - Single window



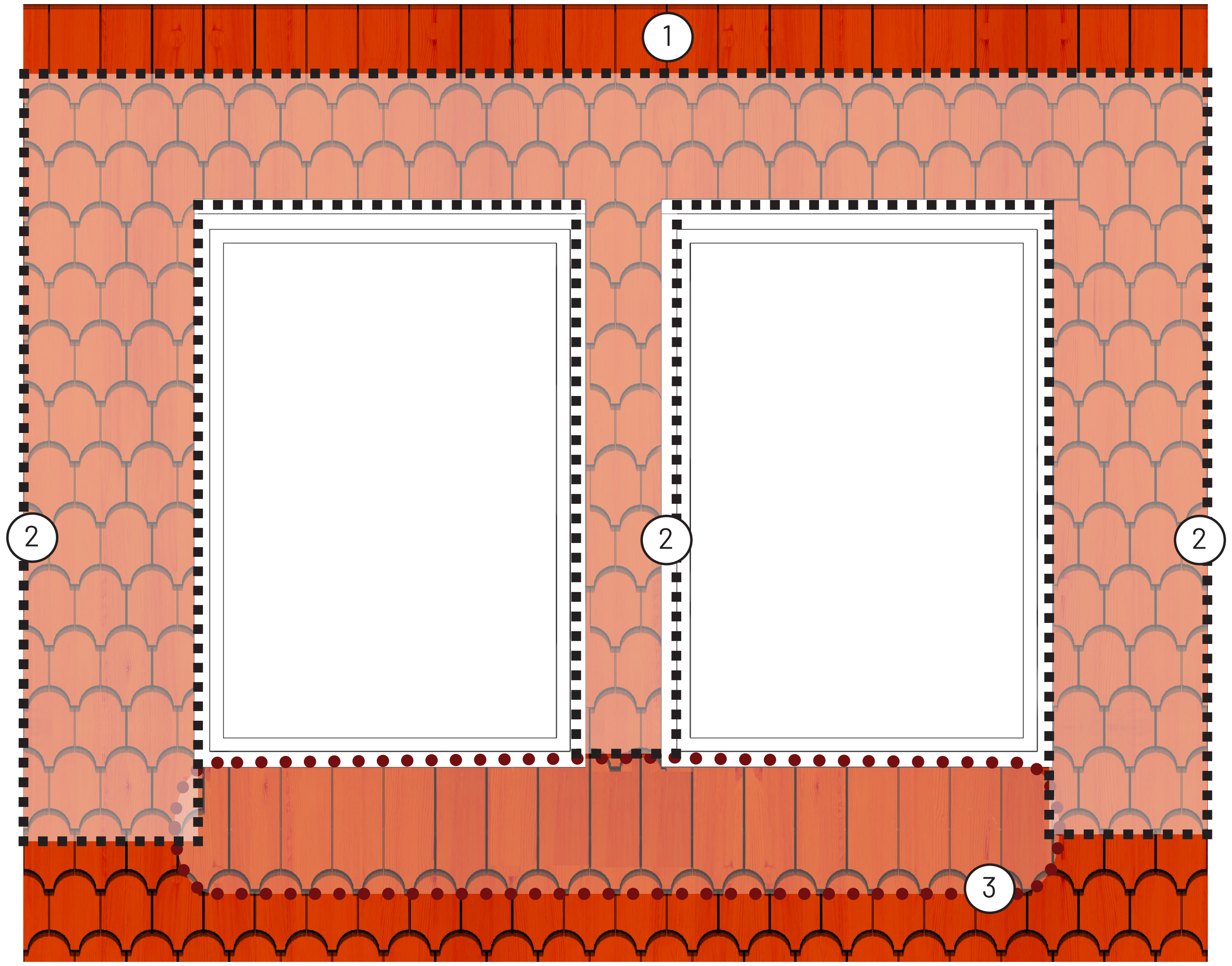




Meeting detail

1. Common modules
2. Adapted modules
3. Adapted fixed modules
4. Wood nail (Ø 5.3 mm.)
5. 50 x 150 mm treated sawn timber

Detail 2 - Double window



1. Common modules
2. Adapted modules
3. Fixed modules

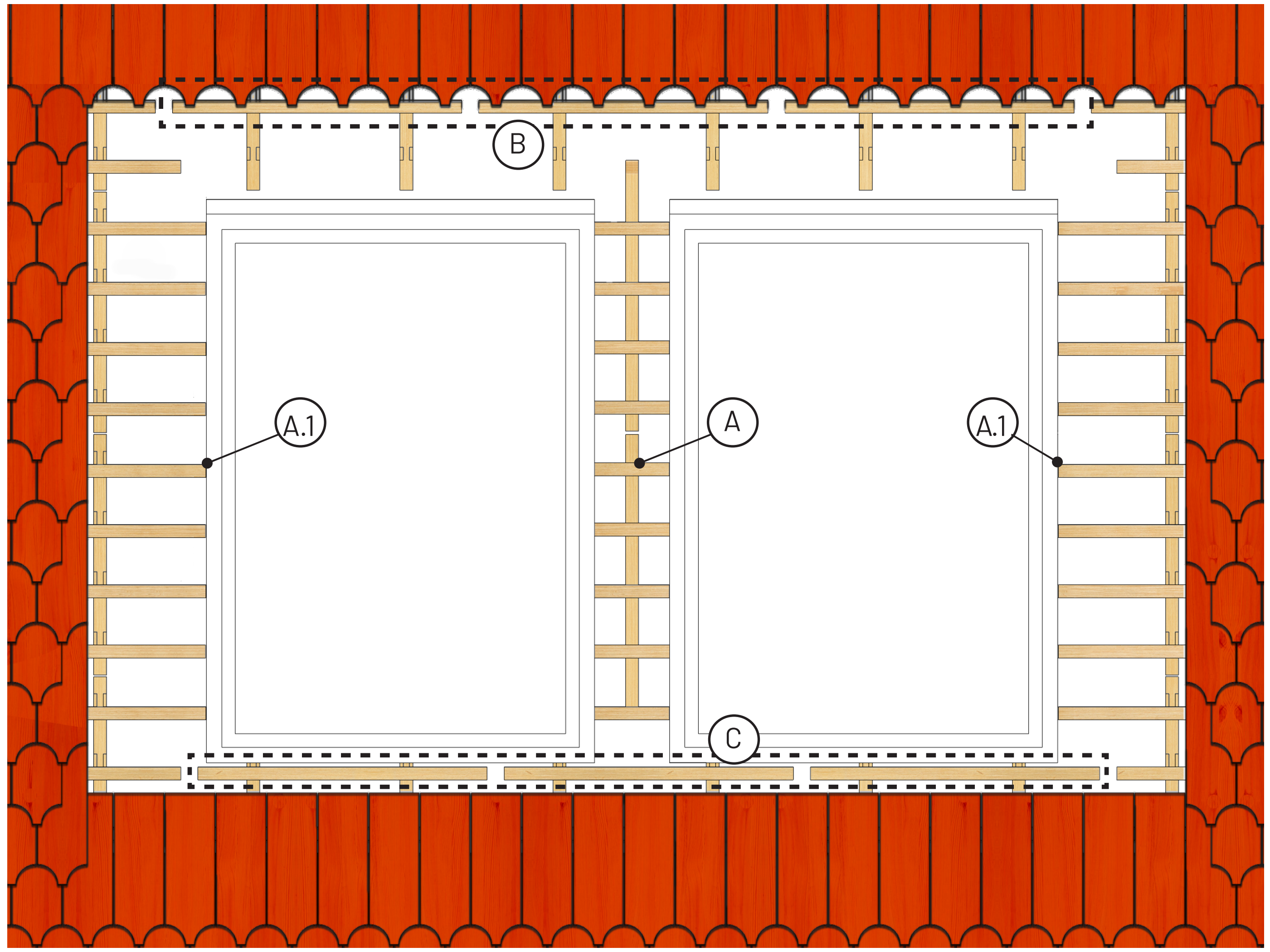
Module adaptation details

A. Side-sectioned modules

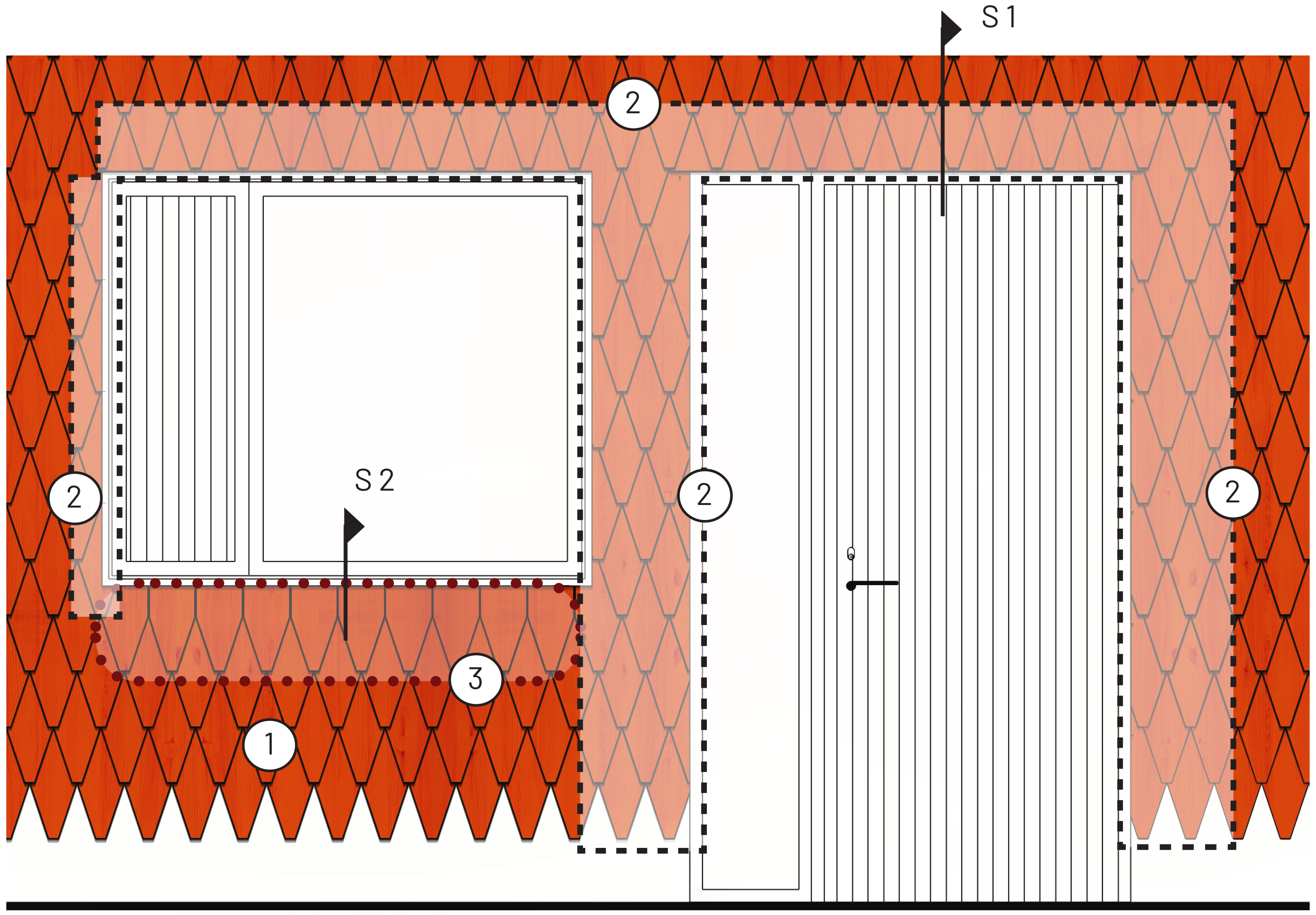
B. Bottom-sectioned module

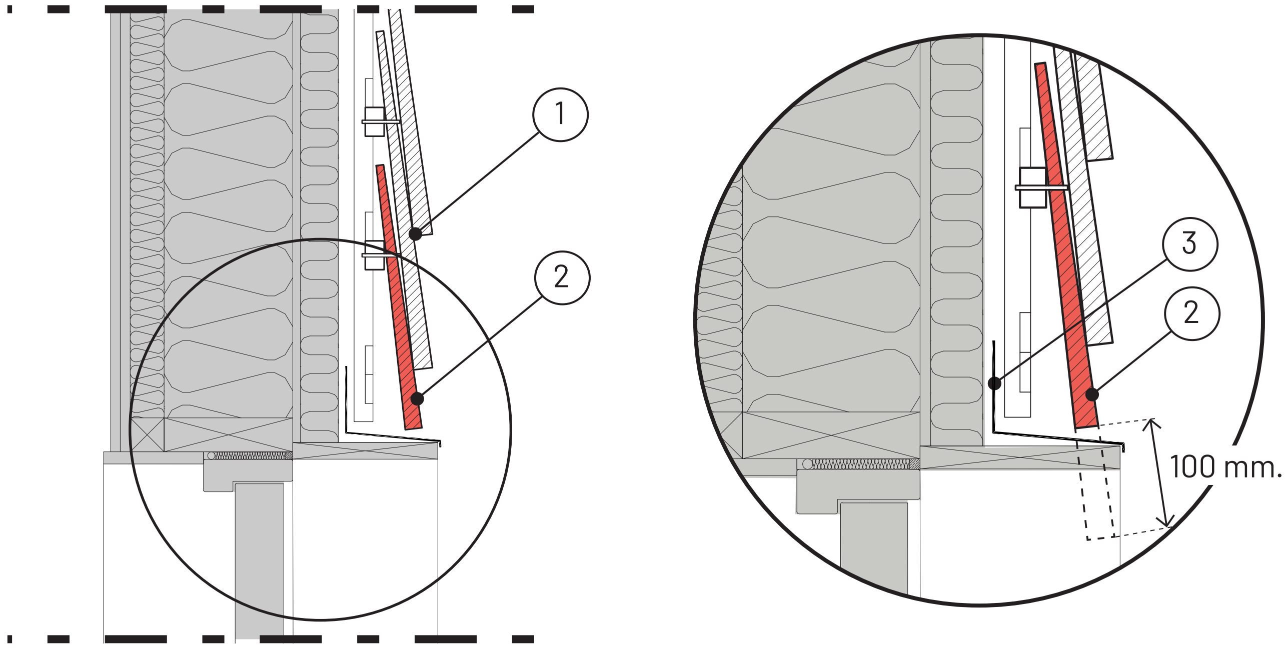
C. Fixed module

A.1 Extended modules

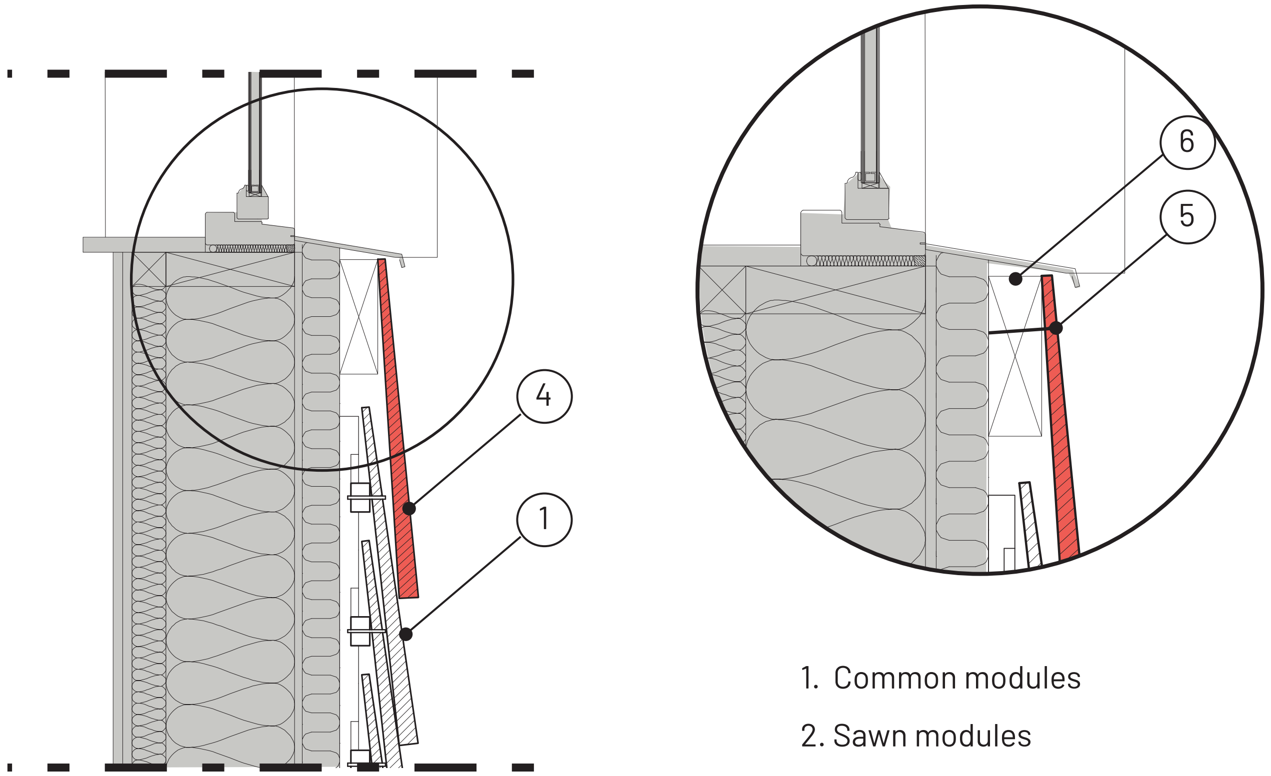


Detail 3 - Door and window





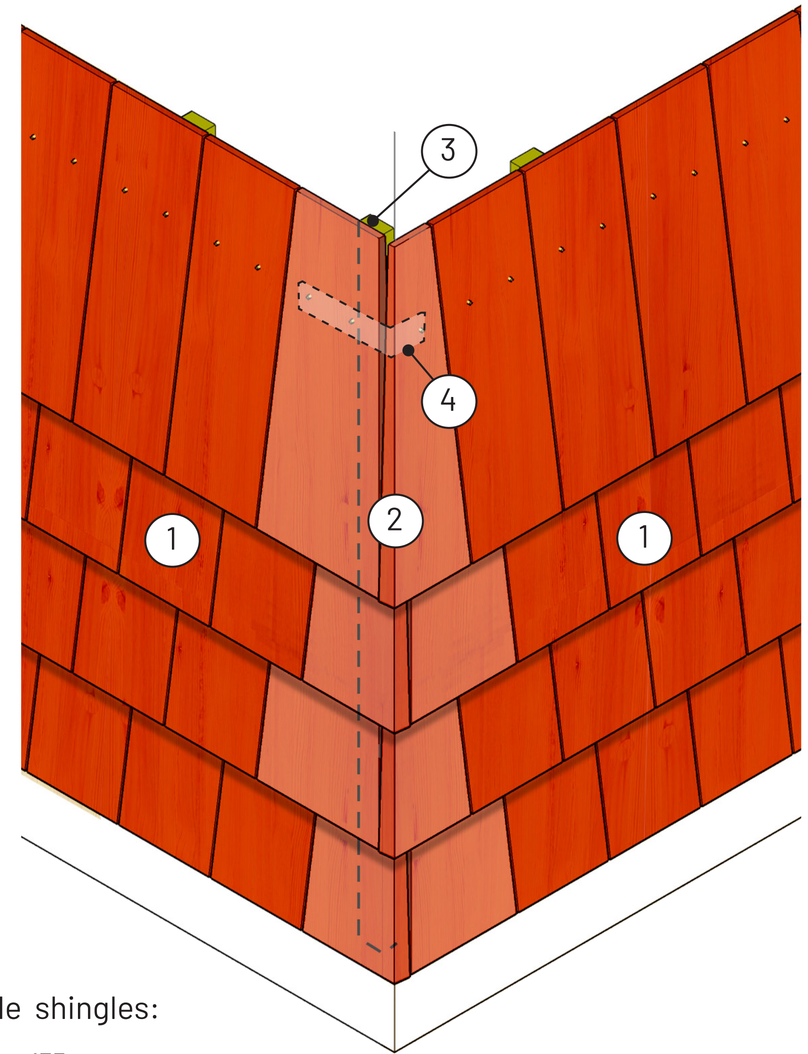
Section S1



Section S2

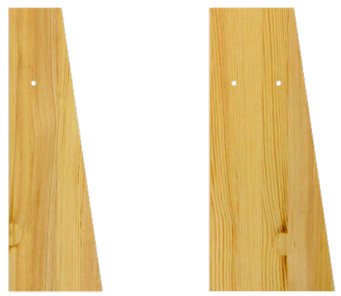
1. Common modules
2. Sawn modules
3. Flashing drip edge
4. Fixed modules
5. Wood nail (Ø 5.3 mm.)
6. 50 x 150 mm treated sawn timber

Detail 4 - Corner arrangement



Corner module shingles:

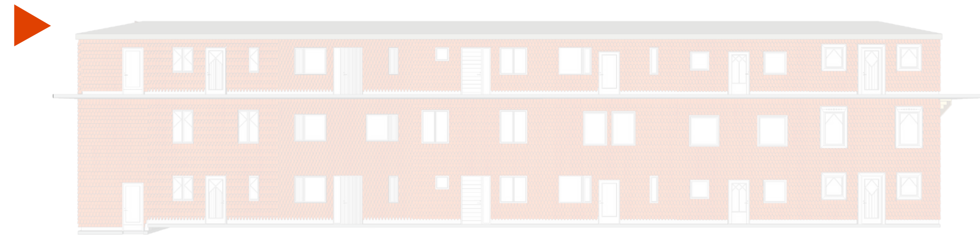
85 mm 135 mm

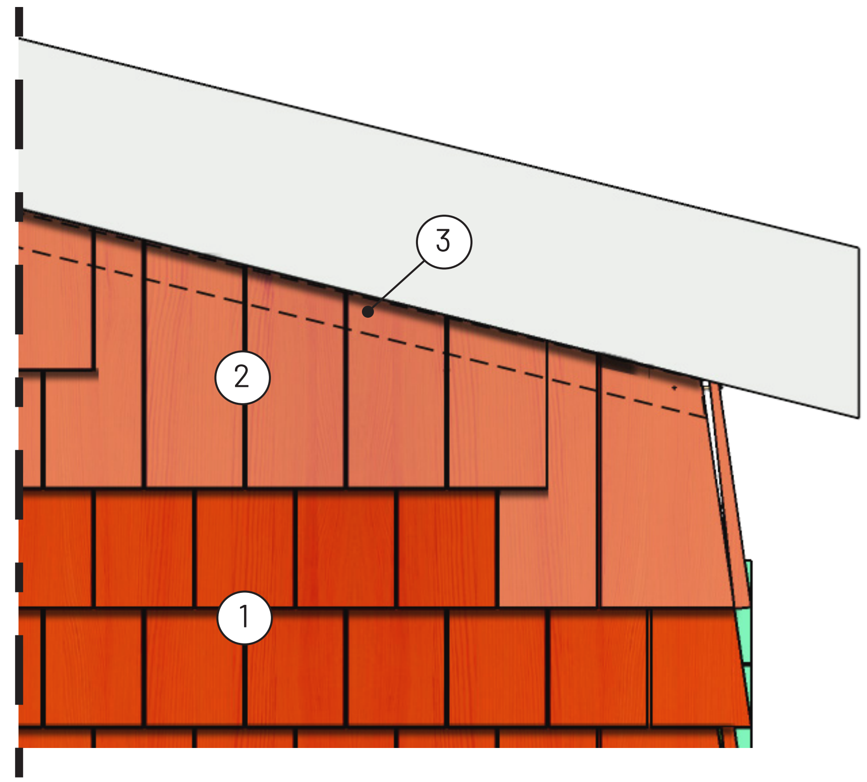


150 mm 200 mm

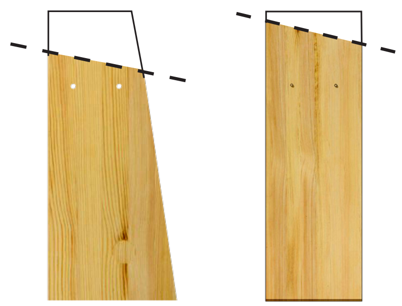
1. Common modules
2. Corner module
3. Vertical wood batten
4. Horizontal wood batten structure

Detail 5 - Top edge detail





Shingles at the top edge:



*Shingles sectioned with an angle of 14° to adapt to the sloped roof.

1. Common modules
2. Sectioned fixed modules
3. 50 x 150 mm treated sawn wood batten

Discussion

This final design exercise enhanced the design of the module in a positive way. Four shape variants were created and there were specific details that needed to be adapted in order for the system to work in different situations.

- *Four shingle shapes*

The proposed cladding also ended up having seven different expressions. These expressions were formed with the combination of the four different shingles.

The different shingles are cut with the aid of a CNC machine, and are grouped in modules of six shingles, in the same way as the basic rectangular shingle module.

- *Three additional modules*

On the other hand, the specific detailing included three new modules. The fixed module, the sectioned modules and the corner module.

The fixed module is a seccioned component that is attached in the sills of the windows and in the upper edge of the walls.

The sectioned module, on the other hand is a normal dismountable module that is sectioned to align the texture with the openings in the facade.

The edge module is a special module that has extended shingles that adapt to an edge of 90°. This module is also conceived to be dismountable for a possible reuse in the future.

On the other hand this design excericise also brought up some topics that have to be taken into consideration. These topics are:

- *A recommended regular maintenance*

This system might need to go through a regular maintenance at least each 20 years to keep it in an optimal shape. This implies the need of a budget for costs on scaffolding, material and maintenance works. This consideration could define the next steps in the way of making a product that could go on the market.

- *The process of transporting and mounting the system*

A more detailed life cycle analysis could be done in the future to define the process of transportation and placement in a building. This definition could bring valuable data for making a detailed CO_2 analysis.

This data would be essencial for creating a product that could be sold in the material building market.

Conclusions and reflections

Conclusions

A wood cladding system

- *Material*

- Pine hearthwood and Lightwood

For a long durability, hearthwood pine wood is portrayed as the most convenient option. In Sweden, the pine heartwood has been used traditionally for making claddings that have lasted more than a hundred years.

This kind of wood is more convenient when the tree has lived in a healthy environment, with a regular prunning and with an age that is around 100 years old.

On the other hand light wood (naturally impregnated wood) can bring good results in the short term. This wood has a high content of resin, which makes it impervious and resistant to solar degradation.

- *Treatments and techniques*

- Red slamfärg

This swedish traditional painting is a coating that protects the wood against the weather conditions. It totally degrades after 20 years and it does not ends up sealing the pores within the wood.

This coating enhances effectively the wood resistance to the solar degradation and the reapplication process does not damages the wood structure.

- Vernacular traditional practices

The selection of old trees that got to be in a healthy natural environment develop a high quality wood. Nevertheless, traditionally there is also a selective process that only looks at the wood that comes from the rotstock (first part of the tree), and that also segregates the knotty wood from the clean wood.

- *The shape*

- A modular system

A module of shingles that has fixed dimensions is proposed. The adaptability to different surface sizes becomes more feasible with a fixed shingle size.

The module measurements are 900 mm width and 980 mm height, and it incorporates four submodules that include 6 shingles each.

- *A dismountable system*

- A special geometry in the fastenings

The design proposal incorporates an internal structure made of carved pine wood battens that can mechanically fasten thanks to a set of tongues and grooves. This feature also results in a simple detachable system.

- *Conclusions on complementary information*

- Carbon storage potential

The use of wood in claddings is benefical to the environment. This material stores big amounts of carbon in its structure.

The proposal to keep carbon inside wood elements for a longer time, enhances the sustainable features of wood.

Reflections

- *Pine heartwood*

One of the challenges in this research was to get to see the real potential of pine wood. After a detailed analysis on different bibliography I got to understand that the potential of the wood durability sometimes is overlooked.

Before going in this process I was a bit hesitant that a wood cladding was able to last more than the conventional 30 to 40 years, but after deep analysis I realized that pine heartwood is a material with a lot of potential within durability.

- *The challenge on improving the wood quality*

One of the major problems of high quality heartwood, is that it takes time to be produced. It is in this scenerario, that the naturaly impregnated wood (lightwood) emerges like a "potential solution".

Nevertheless, from a humanistic point of view, I consider that this practice is a bit drastic. The impregnation process is based on wounding a healthy pine tree, making it go through a stressful process.

Should we wound trees in order to get high quality wood? I think that there is still a challenge to find better ways to produce big amounts of high quality in a short time.

Maybe in the future there will be better ways to do this.

- *Traditional and modern practices*

The rapid development of the saw industry at the end of the 19th century brought more availability of wood elements. From one century to another, craftmen went from entirely handcraft wood, to work more smoothly with saws.

In this way, I see this fact as a tipping point. Before the invention of these tools the work was more artisanal and thus it used to take more time and it used to cost more. This revolution kept developing until the point that building elements became more available.

I consider that this development has been possitive in many ways, but I also think that there is valuable knowledge in traditional practices. By reading to Jon Bojer Godal or to Karl Magnus Melin publications I get to see all the value in the vernacular practices.

- *Personal thoughts on the final proposal*

The design proposal included in this research, is an attempt to meet the best vernacular practices with a modern approach.

The traditional practices here described were replicated to craft shingle samples (pictures included in the appendix). This process made me reflect on actual possibilities, and I got to see that it can become a real model.

- *A tale of shingles*

This model proposal wouldn't make any sense without all the compiled background. To me, all of this makes a story tale, and it is the tale of the *red* shingles.

- *Please make contributions to this research*

Finally, I want to state that this research is open for future contributions. The final proposal shown is a design exercise that is open to critics. I wish that it can also be used as a source of inspiration for other research.

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Appendix

The shingle workshop

This proposal is accompanied by a small workshop exercise that sought to prove the feasability of the system. The shingles produced were cut with the aid of an ax and were refined with band saws.

The following pictures are a summary of such process.

1 Debarking phase and removal of the sapwood

2 The sectioning to obtain the propper shingles

3 The chopped pieces.

4 The refinement of the pieces with a saw.

5 The final result.