NEED FOR REED

EXPLORING THE USE OF REED (*PHRAGMITES AUSTRALIS*) IN DIFFERENT BUILDING ELEMENTS AND THE BENEFITS OF LOCAL REED PRODUCTION

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ABSTRACT

This research investigates the possibilities of the biobased material reed of local sources to reduce the embodied energy emissions in the building sector. The drained wetlands in the Netherlands release carbon into the atmosphere leading to the inability of the wetlands to serve as carbon sinks and habitat. The rewetting of polders leads to the opportunity to grow more wetland crops. This research asks what the possibilities of locally harvested reed as a building material and its use in different building elements are linked to the whole lifecycle of reed as a plant. Common Reed (phragmites australis) occurs plentiful in the Dutch wetlands and serves as a valuable habitat for several species. It purifies the water and grows anew each year. However, most of the reed that is used for the famous Dutch roof thatching is imported these days. Thanks to the rewetted polders, more reed of local sources can be used and more broadly applied to other building layers. The research uses the method to follow reed chronologically from its growth, over the harvest to the application in a building until the disposal. In the growth and harvest season the first-hand experience on a reed field was an important insight on the manual labour. With the help of an intense literature study and product analysis the application of reed in several building elements is displayed. The evaluation of the benefits in each element was made following several criteria such as the functionality or circularity of the reed. Innovative applications such as reed as the load-bearing structure or insulation of a building offer insight into the development of reed constructions. This paper provides a starting point into understanding the possibilities of reed as a building material. It adds to the expertise in this field to speed up the transition to biobased materials. It gives an overview of the benefits of reed and analyses the challenges of regulations and the limits of the material. The aim is the reasonable harvesting of reed with a thoughtful application in a building acknowledging its diverse characteristics as a material and as a plant.

KEYWORDS

biobased building material, reed, circularity, lifecycle, harvest, wetlands, local building material

I. INTRODUCTION

The Netherlands has an extensive history of draining wetlands to create new land for agriculture and settlements. What at that time was considered a harmless creation of new nutrient-rich ground led to the disappearance of valuable wetlands. The soggy peat soil stores carbon underground which makes wetlands one of the biggest carbon sinks on earth and an important contributor to the mitigation of climate change (*Peatlands and climate change*, 2021). Staatsbosbeheer already set plans in motion to restore wetlands in the Netherlands recognising their importance for the environment (*Visie klimaatbestendige veengebieden*, 2022).

This research acts within these circumstances. Thanks to the rewetting of polders in the Netherlands for the creation of healthy wetlands, the potential to grow wetland crops such as cattail, reed, or sweetgrass re-establishes itself. Not only does it contribute to the biodiversity of the rewetted areas by providing extra habitats and species, but it also diversifies the local food production with e.g. paludiculture or adds to the growth of building materials. It is not enough to

be able to store carbon in wetlands if the building sector still produces almost half of the greenhouse gas emissions. Thus, it is the architect's responsibility to carefully consider the resources that can be used for the construction. This is due to the fact that the embodied energy during the production of building materials makes out the highest percentage of the greenhouse gas emissions of the building sector ('Why The Building Sector? – Architecture 2030', no date).

Within the building sector, the notion of sustainable building investigates the application of biobased materials in construction. In the last years, rapports by the sustainability firm *nibe*, *Holland Houtland*, and even by the Dutch government shine light on the significance of biobased building. The firm *nibe* defines *biobased* as all renewable resources. A composite material can be called biobased when fifty per cent or more of it is biobased ('Gids Biobased Bouwen 2022', 2022). In nibe's rapport *De potentie van biobased materialen in de bouw* (The potential of biobased materials in construction) they explain that in the current Dutch construction sector only 0.1% of the resources used are biobased materials excluding timber (van der Velde and van Leeuwen, 2019). According to the website *Material District*, biobased materials are the main factor to lead to a circular economy (*Growing Biobased Building Materials*, no date). Thus, biobased materials lead to shorter loops, that can be entirely closed or regrown in just one season, like reed.

Reed (Latin: *phragmites australis*) is a grass-like plant (see Figure 2) that grows along river shores, in marshes and in wetlands. It is found plentiful in the Netherlands. However, the application of it in the built environment is limited to the famous Dutch roof thatching and there, it even is imported from abroad (*Riethandel - Vakfederatie Rietdekkers*, no date). There is a need for biobased locally available building materials that can avoid transportation around the world and lower the carbon emissions of the building sector. Dried reed with its multiple qualities, long-lasting lifespan, and aesthetically appealing appearance is the material chosen to be investigated. This leads to the research question that aims to be answered in this research paper:

What are the possibilities for locally harvested reed as a building material and its use in different building elements linked to the whole lifecycle of reed as a plant?

This research addresses the lack of expertise on reed as a biobased material. The construction sector in the Netherlands is not used to working with biobased materials (van der Velde and van Leeuwen, 2019). Thus, the research creates an overview of the material itself and how it is harvested. It shows the possible applications of reed regarding its valuable features in building elements such as insulation. In the end, it evaluates for which building parts it is the most beneficial and the results will be applied in a design in a Dutch context, the Poelpolder in south-east Haarlem.

II. METHODS

To answer the research question posed above several methods were applied. They follow the chronological process of reed from its growth to its application in construction. It starts as an elaborate literature study on the plant reed with literature diving into the biology of the grass-like plant. Not only were the characteristics of reed of interest but also the impact on the environment. Reed is a valuable player in the wetland ecosystem.

One step further and I found myself in the harvesting season of reed. The main question here was how reed is harvested and how much can be used. For that a thorough desk study with exciting articles from other reed harvesting countries, for example, Finland and Estonia, was useful. To experience the harvesting process myself, I organised an excursion to a Dutch "rietsnijder" to assist a reed cutter and receive first-hand knowledge about this material. The next step after the reed dries is the manufacture of reed. The goal was to learn how to modify reed for its future use. This part of the research included an analysis of products on the market next to the literature study.

The most important part of the design, later on, is naturally the application of reed to the building. For that, the literature study helped to get inspired by projects from around the world. An intense analysis of detailing with reed assisted to understand the material inside and out. To establish in which building element reed is the most beneficial a few criteria showed its value. The criteria are based on the function the building element must fulfil and if reed manages to meet these requirements or even exceeds them. The rating of the application possibilities is based on a careful review of resources, expert opinions, and products.

The methods used for the research paper cover the whole lifecycle of reed as a building material until its disposal. Thanks to reed being a biobased material, it is biodegradable and can be composted in the end to let new reed grow. Thus, the usage of reed as a building material results in a closed loop.

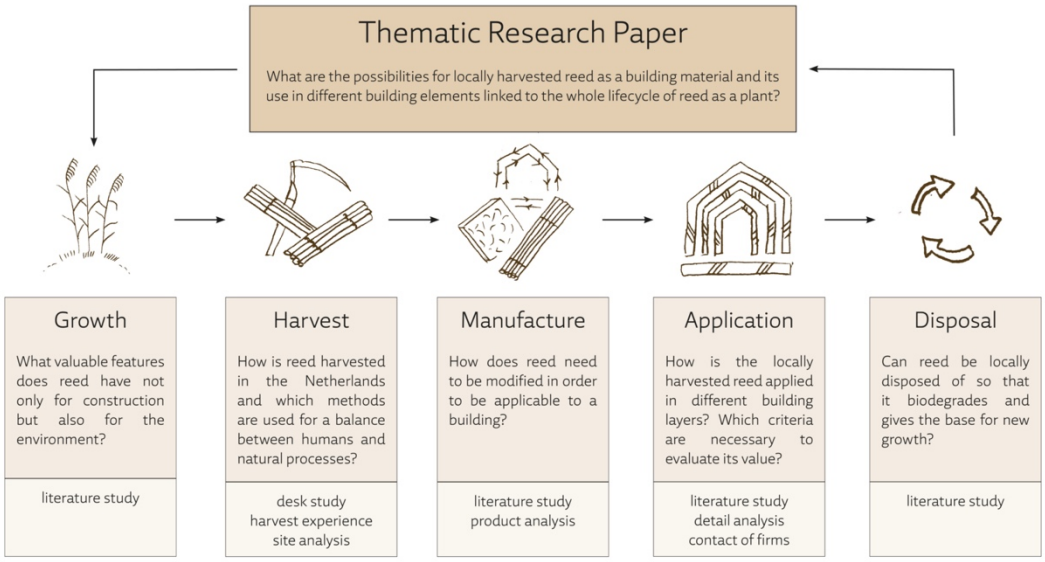

Figure 1. Visualisation of Methods, drawn by author

III. RESULTS

The results of this research shed a light on the biobased material reed with a holistic overview of its lifecycle. This chapter is structured to follow the reed from its growth over the harvesting process all the way to the application in the building and its disposal. It is concluded with an evaluation of reed in all building elements that have been analysed for the application in the design.

4.1 Growth

The Netherlands is by nature a wet area that leads to the natural growth of reed on peatlands. According to vakfederatie rietdekkers, the reed area is 7000 hectare big with 4500 hectare that are harvested every year (*Natuurlijk riet - Vakfederatie Rietdekkers*, no date). Thanks to the vision mentioned in the introduction on the rewetting of polders by Staatsbosbeheer, there is even more space and ground for reed growth in the Netherlands. The consideration of reed as a wetland plant creates a healthy environment with a reciprocity between humans and nature. Not only is reed useful in construction but it also is an important habitat for several species.

Common reed (latin: *phragmites australis*) is a large aquatic grass-like plant (see Figure 2). It grows from one to five meters on marshes, along riverbeds, and in wetlands. The leaves are broad and the smooth stems are hollow (*reed | Definition, Types, & Facts | Britannica*, no date). The

anatomical examination of reed reveals that the hollow reed stems have nodes which give reed its strength with a minimum fibre mass (Fraanje, 1997). The smoothness of the stem makes reed waterproof thanks to the woody epidermis as the outer layer of the stem. It is also logical because reed grows in water. For this reason, reed does not mould easily either. Dried reed's flammability is in the category B2: normally flammable due to its amount of silica (*Material-Archiv*, 2012).

Figure 2. Phragmites australis (Packer *et al.*, 2017)

Even though reed is a wind-pollinating plant which reproduces with seeds, most of the reed spreads vegetatively with its rhizome. The roots of the rhizome spread underground so reed can expand several meters per year. The created reed beds can get dense with around 40 to 100 sprouts per square meter. These reed beds are important habitats for various species (see Figure 3). When their layout is provided in a mosaic way with pools and a diverse structure of density for shelter and openness for light birds, fishes, insects, and other species can find a healthy living environment in the reed beds (Miljan, 2013).

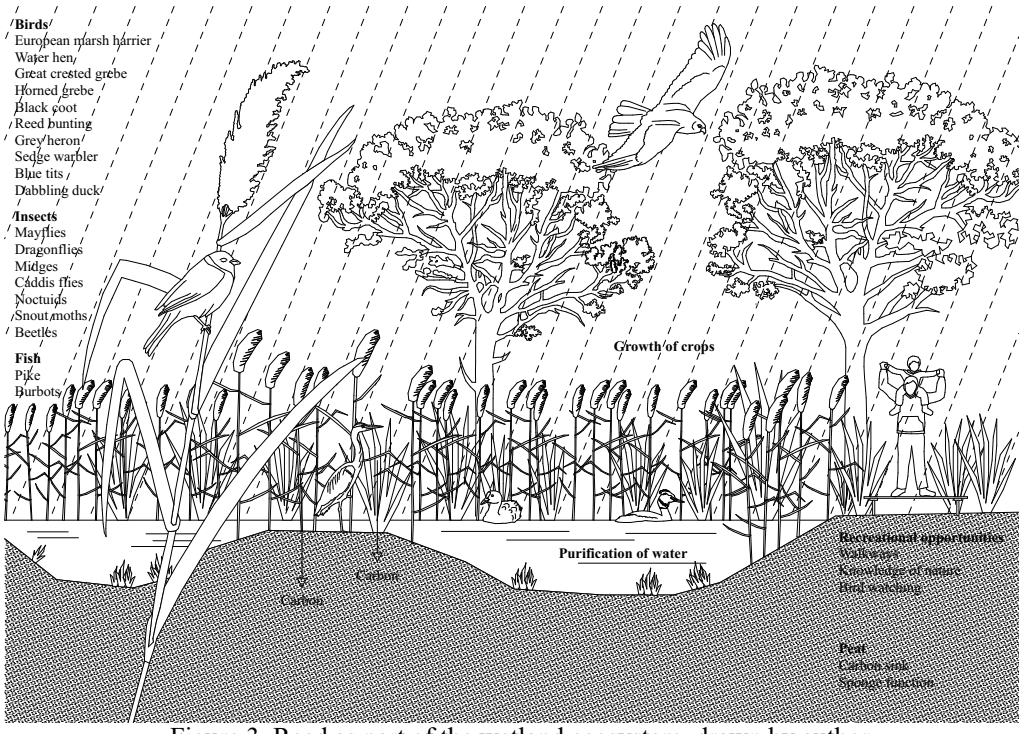

Figure 3. Reed as part of the wetland ecosystem, drawn by author

4.2 Harvest

Biobased materials are produced differently than non-renewable construction materials such as concrete. The amount of embodied energy necessary to mix up concrete can be extremely reduced

by the local growth of biobased materials such as reed. This chapter explains the harvesting process of reed based on the knowledge of Dutch reed harvesters (see field report in Figure 4.), a study of the Turku University of Applied Sciences on reed constructions, and an Estonian guidebook of reed business. The learned knowledge is applied to the context of the Poelpolder in Haarlem in the Netherlands in the design.

The aim of the use of the material reed is not the sole exploitation of reed beds but the balance between a biobased construction material and the acknowledgement of reed beds being a habitat and part of the wetland ecosystem. Cutting reed maintains the fields and preserves good nesting conditions for birds and other species if it gets cuts down in a controlled matter and not over extensive areas, i.e. over 20 hectares. Reed for construction can be harvested in December and January when the reed is dry and the soil is preferably frozen. Depending on the weather conditions the actual harvesting might only take place a couple of days per year (Stenman, 2008). According to Wouter Slors, a reed harvester in Naardermeer, reed is one of the rare plants for which harvesting is necessary to make the new growth even stronger (Slors, 2023). Thus, humans can play an active part in nature.

Reed used to be cut manually by sickle or scythe, but nowadays modern reed harvesters are in use. While traditionally reed could already be selected on the spot, the cutting tractors collect all of it and the selection and cleaning process takes place later by hand as well. All in all, reed harvesting is still deeply connected to manual labour as was experienced first-hand in Naardermeer (see report in Figure 4). To lift reed on piles with pitchforks seemed like hard manual labour but the comparison with the weight of concrete was preeminent. One cannot harvest concrete and throw it through the air on a pile with a pitchfork. It questions the whole production process of a building material and its weight. After the reed has been cut, it gets assembled into bundles. For that, a reed bundle binding bench is used and then the reed is either built up into stacks to dry or gets moved into storage. In a storage facility the reed can stay useable for years provided the building has good air circulation (Miljan, 2013).

Figure 4. Field report written and photographed by the author on 16 January 2023

4.3 Manufacture

The dried reed stacked in bundles in a storage house is ready to be applied in construction. Depending on the building element it needs a different modification for the application. For example, for the traditional roof thatching the whole bundle gets carried on the roof. Or for the use as a reed mat, it gets cut evenly and tied together. The manufacture of reed is very versatile. Especially when combined with other materials such as clay, the options to apply reed in a building multiply. Even the fibres of reed can be used in combination with for example hemp or wood to press together into insulation panels (Farcomeni, 2021). As these combined fabrications would exceed this paper the application of reed in a building is based on the raw material.

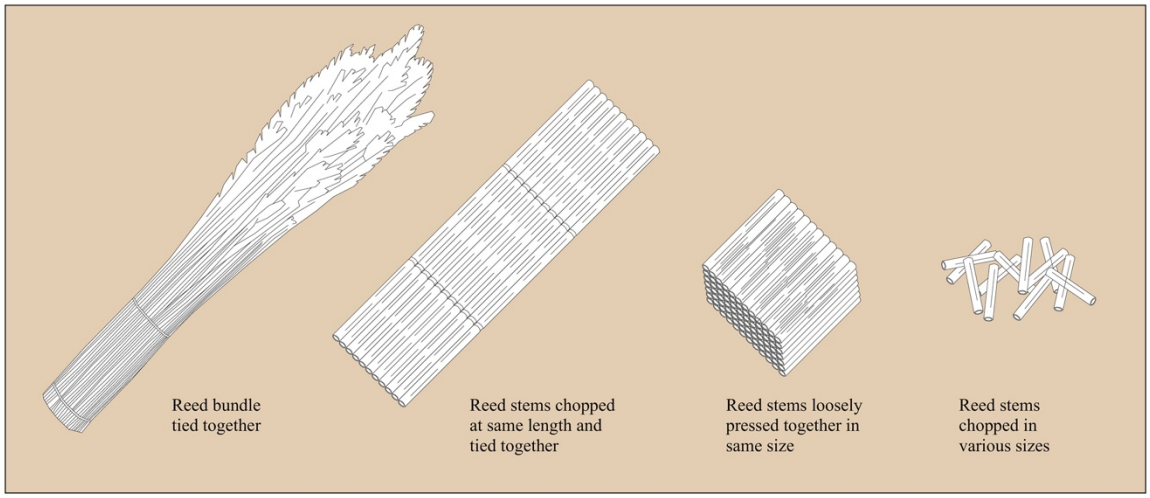

Figure 5. Selection of dried reed manufacture, drawn by author

4.4 Application

Reed as a multifunctional building material has a broad variety of application possibilities. To evaluate the application of reed in each building element equally, a preliminary overview was created (see Table 1 below). The building elements analysed in this research are reed as load-bearing structure, as non-load-bearing wall, as roof thatching, as foundation, as insulation, as exterior and interior finish. The criteria are chosen to be the functionality, durability, and circularity of reed for each building element. The functionality evaluates if reed can meet the requirements of the building element. For example, if it is used as insulation can it meet the insulating standards of the Netherlands? The durability established how long-lasting reed is in the building layers and how resistant it therefore is. The circularity of reed focuses on the removability and biodegradability of the used reed in a building layer which can also be strongly influenced by the design and detailing. This evaluation results in a rating of + , +/- , - per category, according to found literature, experience reports and products. The decision if the application of reed is feasible and desirable in the design in the rewetted Poelpolder is closely connected to the previously mentioned criteria. The discussion per building element sets its priority on the elements chosen to be beneficial in the design.

Application Criteria / Building Element	**Functionality** + Meets requirements +/- Under circumstances - Does not meet requirements	**Durability** + Long-lasting +/- Under circumstances - Needs replacement often	**Circularity** + Easily removable and biodegradable +/- With effort - Not easily replaced	**Application in Design** + Definitely +/- Depending on biobased alternatives - No use
Load-bearing structure	+/- Flexible and stable for its light weight. Cannot carry much just stacked but in bales similar to straw	+/- If assembled correctly and covered with a protective layer of plaster it lasts for centuries.	- Difficult to replace due to its function as load-bearing	- Hardly any built examples found, only with testing and prototyping applicable
Non load-bearing Wall	+/- For a dividing wall in combination with other materials possible (such as timber frames)	+ If not exposed to changing humidity in the interior it lasts long. Protective layer of plaster adds to it.	+ Easily removable if damaged or disassembled.	+ Very beneficial lightweight dividing wall. Examples by Hiss Reet.
Roof Thatching	+ Good insulation, water repellent	+/- Dependent on angle of roof, maintenance necessary	+ Easily removable because other layer of building an not covered with plaster	+/- Application is commonly known with lots of built examples. Not suitable for PV
Foundation	+/- In combination with biomass it can be used on wetlands	- A new layer of reed needs to be added because it quickly biodegrades	+ Easily biodegradable	- Replacement of foundation necessary every couple of months results in high maintenance
Insulation	+ Thermal conductivity of around 0.05 W/mK comparable to other insulation materials	+ If not exposed to changing humiditiy it lasts long with a protective layer of plaster.	+/- Easily disassembled but dependent on other building elements	+ Good in combination with a loadbearing timber construction as filling element.
Exterior Finish	+/- Meets requirements the same as roof	- Needs protecting roof otherwise mould growth is fast	+ Easily removable because other building layer	+/- More resistant facades give building a longer lifepan
Interior Finish	+ Pleasant climate, good acoustic qualities, normally flammable	+/- At walls not resistant to damage and dirt, on ceiling more beneficial	+ Loose material that can be biodegradable and replaced	+ Good natural sound absorber results in a comfortable inner atmosphere

Table 1. Overview of reed application possibilities, edited by author

As load-bearing structure

Reed for the load-bearing structure of a building goes back to traditional vernacular reed huts on the Al-Tahla Floating Islands of the Ma'dan in Iraq or the floating islands of the Uros in Peru (Watson, 2020). In Peru Totora Reed stalks were used which are taller and bigger than the Common Reed from Europe. The same applies to the Qasab Reed for the huts in Iraq, it resembles bamboo more than straw (see Figure 6). As a load-bearing structure, the dried reed is used as columns and beams in bundles that are tied into arches (Watson, 2020). The construction is then covered with reed mats which results in the assumption that the reed structure cannot carry heavier roofing. In more recent projects the use of straw bales as load bearing structure (*Atelier SCHMIDT GmbH | Ökologie | Stroh | Autarkie*, no date) is interesting to compare to a reed block as both types of grasses have similar characteristics (see construction in Figure 7). However, no specific data was found on the load-bearing capacities of reed blocks. An elaborate testing of Common Reed as a load-bearing structure would exceed this research paper.

Figure 6. Reed as structure in Iraq (Watson, 2020) and Figure 7. straw as structure (atelierschmidt, no date)

As non-loadbearing wall

The application of reed as filling material for a non-loadbearing timber frame wall is beneficial. It is a lightweight material with good insulating and acoustic properties. A clay plaster can be easily applied onto the reed structure directly (HISS REET GmbH, 2011b). The application is straightforward, the reed gets attached to a vertical wooden post. It results in a comfortable and healthy inner climate without a lot of energy use and easy disposal of the material because nothing is glued but only attached with pegs and wires (HISS REET GmbH, 2011b). All in all, it is a simple-to-install biobased dividing inner wall.

As roof thatching

As roof thatching is not a new innovative use of reed, the elaboration of the use of reed here will be cut short. There are many examples built worldwide and the values of reed were proven a lot of times. The disadvantage of a thatched roof is that solar panels are not possible to apply. The reed underneath would rot and the fire protection properties for that are questionable (rh, 2022)

As insulation

The insulating features of reed are evaluated in several research papers and studies. They all conclude that reed is an excellent biobased insulation material. In *A review of unconventional sustainable building insulation materials* the thermal conductivity of a reed insulation of 14 cm is between 0.045 and 0.056 W/mK (Asdrubali, D'Alessandro and Schiavoni, 2015). Tests by the Technical Research Centre (TRC) of Finland reported similar results. Compared to a mineral

wool insulation which is between 0.032 and 0.038 W/mK, the difference is 1.5-fold (Miljan, 2013). Thus, to have the same insulating properties as a conventional mineral wool insulation of 200 mm a reed insulation would need to be 300 mm. It meets the requirements of an excellent insulation, keeping the building cool in summer and warm in winter. However, reed can be assembled as an insulation in several ways. It can be vertically laid, horizontally laid, in panels assembled or as reed blocks applied. If they result in different insulation properties, a study from the Estonian University of Life Sciences researched with the help of a test house (Miljan, 2013). Of interest was also the time spent building the walls and the amount of material that was used. The smallest amount of reed bundles per square meter laid in the wall was in the vertically assembled reed insulation, but it also had the worst thermal transmittance. They argue that the material was not sufficiently compressed and heat was transferred with a higher convection (Miljan, 2013). On the other hand, a horizontally laid reed insulation has a higher amount of reed used but the smallest thermal transmittance. This goes hand in hand with a comment in *Cascading of renewable resources hemp and reed* by Peter J. Fraanje. He states that the reed stalks insulate better in a direction square with the insulation element. The reason is that the pith of the reed stalk has the best insulation value (Fraanje, 1997). The hollow stems and gaps between the stems capture air which leads to good insulation properties (HISS REET GmbH, 2011a). Naturally, to assemble the insulation horizontally takes a longer time and manual labour compared to blocks of reed stacked on top of each other.

On the market, the products of Hiss Reet show a variety of reed insulations. The range of applications goes from an outer insulation (see Figure 8) to an inner insulation and how they would be connected to the load-bearing structure depending on its material (HISS REET GmbH, 2011a). The reed insulation product of Leo Bodner (see Figure 9) is only attached to the bearing wall with plugs. No glue or other attachment is needed (Terrin, 2023). The characteristics listed on the website also stress the fact that the rough surface of reed is a perfect plaster base (Bodner, 2023). With a protective clay or chalk plaster layer reed can last over centuries in the construction (*Material-Archiv*, 2012).

Figure 8. Hiss Reet Aussendämmung (HISS REET GmbH, 2011a) and Figure 9. Leo Bodner Schilfrohrplatte (Bodner, 2023)

As foundation

The risk of degradation of reed as a foundation material makes it unacceptable as a foundation material. The only example found for reed as a foundation are the floating islands in Peru and Iraq. There, the reed is used in combination with biomass to make the houses float on wetlands. As the reed degrades quickly due to natural processes, a new layer of reed needs to be added every three months which makes a long-lasting building difficult (Watson, 2020).

As interior finish

The sound absorption qualities of reed are good when assembled orthogonally to the incoming sound (Asdrubali, D'Alessandro and Schiavoni, 2015). The aesthetic value was confirmed in the natural pavilion (see Figures 10 and 11) at the Floriade Expo 2022 in Almere ('Materialisatie', 2022). The pattern of different-sized reed stems creates a pleasant interior finish that is CO_2 negative. Reed is according to Material Archiv normal flammable in category B2 the same as wood (*Material-Archiv*, 2012). This is sufficient for an inner wall.


Figure 10. and Figure 11. Side and front view of reed wall in the natural pavilion, photographed by author, 13 October 2022

As exterior finish

The application of reed to a facade can be handled as roof thatching. However, to make it long-lasting it needs a large roof to protect it from weathering. Exposed to the outer climate the risk of mould growth and destruction make it less profitable for a design (Miljan, 2013).

As bioenergy

Next to the various applications of reed as a building material, an important part of a building is its energy demand. Reed can also contribute to that. Different technologies for biomass fuels show the use of reed for solid or gaseous reed fuels. The reed harvested in the winter can be used for pellets (see Figure 12) or the cut-short reed stems can be pressed into bales. The condition to use reed as pellets is that it needs to be dry. For biogas, the moister reed harvest in the summer is more suitable but is difficult to balance with the habitats and nesting areas of species. In conclusion, the advantages of reed fuel are that it has a high calorific value and a high ash melting point. But it also varies a lot in composition, irregular particle size, and high ash, chlorine, and sulphur levels. In combination with wood pellets, its use can be more advantageous (Miljan, 2013).

Figure 12. Reed pellets (Miljan, 2013)

4.5 Disposal

To delay the disposal of reed the cascading of the dried reed stems is important (Fraanje, 1997). The goal would be that if reed is used on the roof and needs replacing, that the cut-away reed can find a second life in a fibre board or pellets for bioenergy, as mentioned before. If one would follow the cascading principle, the lifespan of reed can significantly increase (Fraanje, 1997).

Thanks to reed being a biobased material, if the disposal is necessary it can lead to a circular process in nature. Traditionally, reed that was left over on the reed fields got spread out in the forest. It would decay and serve as manure for nutritious soil for plants to grow (Slors, 2023). However, the way Wouter Slors described the process nowadays implies an over-regulation of natural processes by the Dutch government. Reed that is not harvested for construction and left behind gets picked up by a heavy vehicle bringing the reed to the nearest compost facility (Slors, 2023). To use reed as a natural manure for a closed loop of the biobased material reed, the processes of the harvesting and the natural circularity of the plant need to find their way back into the regulations of reed cutting.

IV. DISCUSSION

The deeper the investigation dove into the material reed the more challenges, opportunities, and discussion points surfaced. While there are already a lot of theories and rapports about the use of biobased materials in design, the implementation is often lacking. The process takes time and a rethinking towards the planet's resources available is necessary. In this research paper, the challenges and benefits of the biobased material reed are displayed to speed up the change in architectural design. However, preventing the subsidence of soil with the rewetting of polders and the new growth of reed sounds straightforward but it is a long way through a jungle of politics, economics, and changes to realise such theories. Not only the application of reed in the construction sector is important here, but also the harvesting process and the whole lifecycle of the plant.

The methods applied in the research lead to an elaborate overview of reed as a raw material used in construction. The extensive list of literature showed how much is already known and what is still missing. The lack of knowledge on reed as a load-bearing structure shows that to advance in the investigation of this building element the comparison with bamboo or straw could be useful. Generally, the comparison between similar construction materials would add to the trust in reed. Due to the lack of built examples, there are no regulations on reed construction yet which makes the broader application even more difficult.

This research lies the focus on the potential of reed as an ecosystem and as a building material to show the perks of wetlands for the building sector. As reed is not the only biobased building material that can grow locally in the Netherlands, for the design other biobased materials will also be applied. Especially for the building elements for which reed was not evaluated as beneficial a replacement is necessary. For example for the load-bearing structure black elder or a stable oak wood would be more suitable (Köbben, 2021). The research not only shows the advantages of reed as a building material but also shows the benefits of a healthy reciprocity between humans and nature. With the knowledge of the resource used in construction from its growth over its harvest and application until its disposal a balanced cooperation comes into being. This lifecycle is the goal in the design that is a prototype of building on wetlands to promote their value and restoration. The design not only applies reed as material but also designs the reedbeds for harvesting in harmony with the habitats of species. It finds a place to store reed to dry and, in the end, supports the social interaction of the neighbourhood with nature.

Finally, the research is a mere glance into the diversity of the material reed. Per building layer there is more to research, investigate and test. There are also more application opportunities such as furniture or flooring and in combination with other fibres and materials such as wood and hemp

reed becomes even more versatile. With extensive testing and prototyping, more possibilities will occur but that would exceed this research. Northern-European countries like Finland and Estonia, in which reed already experiences a wider application, are pioneers and can be role models for the Netherlands. The possibilities of reed as a biobased construction material need to find a bigger platform to be explored and this research adds to the expertise and resources to re-reed architecture.

V. CONCLUSIONS

All environmental issues of the drainage of polders cannot only be solved by the promotion of reed growth on wetlands alone but this research is an insight into the endless possibilities of one wetland crop. The conscious use of land and the natural resources used for construction are all little factors in a balanced interdependency between nature and humans.

Coming back to the research question posed in the introduction, it can be established that reed, with the consideration of its whole lifecycle, can be applied in multiple ways to a design. Elements such as the roofing, insulation, and interior finish are already more known than the load-bearing structure, inner walls, or the use of reed as bioenergy. There is, however, more to the application than just the dried reed in a building. In the process of this research, it became clear that the growth of reed and the harvest needs careful consideration as well as the final application in a building. Reed is one of the most valuable crops growing on wetlands, purifying the water and granting valuable habitats for several species. Harvesting is necessary for the appropriation of a healthy habitat if it is done in a balanced way with the natural growth and cycles of the species involved. When the reed is harvested it also needs a dry space to be stored for a long time. To design such a storage space well is essential for the further use of reed. The dried reed can then be applied in various building layers and stores CO_2 during its whole lifetime. When applied correctly, reed can last in the construction for centuries.

VI. REFERENCES

Asdrubali, F., D'Alessandro, F. and Schiavoni, S. (2015) 'A review of unconventional sustainable building insulation materials', *Sustainable Materials and Technologies*, 4, pp. 1–17. Available at: https://doi.org/10.1016/j.susmat.2015.05.002.

Atelier SCHMIDT GmbH | Ökologie | Stroh | Autarkie (no date) *atelierschmidt*. Available at: https://www.atelierschmidt.ch/oekologie (Accessed: 7 January 2023).

atelierschmidt (no date) *Überbauung Bombasei-Areal | 0477_Bombasei_AG*, *atelierschmidt*. Available at: https://www.atelierschmidt.ch/bombasei-naenikon?pgid=jdvecqct-2f96b83f-7dd1-4f8c-8d50-8bc755dfe53c (Accessed: 8 January 2023).

Bodner, L. (2023) 'SCHILFROHRPLATTEN', *Leobodner*. Available at: https://www.leobodner.it/de/produkte/schilfrohrplatten/ (Accessed: 5 January 2023).

Farcomeni, E. (2021) 'Food community house in the Brettenzone: the local circular economy approach to reduce our environmental footprint'. Available at: https://repository.tudelft.nl/islandora/object/uuid%3A4a303a12-afbe-4c46-bd8f-96d494732e36 (Accessed: 8 January 2023).

Fraanje, P. (1997) 'Cascading of renewable resources hemp and reed', *Industrial Crops and Products*, 6, pp. 201–212. Available at: https://doi.org/10.1016/S0926-6690(97)00009-5.

'Gids Biobased Bouwen 2022' (2022), September. Available at: https://www.hollandhoutland.nl/gids2022/ (Accessed: 6 December 2022).

Growing Biobased Building Materials (no date) *MaterialDistrict*. Available at: https://materialdistrict.com/article/growing-biobased-building-materials/ (Accessed: 21 November 2022).

HISS REET GmbH (2011a) *Hiss Reet Platte - Die ökologische Dämmung*.
HISS REET GmbH (2011b) *Hiss Reet Wand - Die ökologische Trennwand*. Available at: https://www.hiss-reet.de/baustoffe-aus-schilf/trennwand-system (Accessed: 5 January 2023).

Köbben, R. (2021) 'Farm of the Future: a possible solution to the contemporary urgent issues in het Groene Hart, The Netherlands'. Available at: https://repository.tudelft.nl/islandora/object/uuid%3A20f019f6-0a50-4d44-8dc1-3c83b8743fad (Accessed: 13 December 2022).

Material-Archiv (2012). Available at: https://materialarchiv.ch/en/ma:material_1390/?q=reet#ma:material_1390-ma:has_general_information (Accessed: 7 January 2023).

'Materialisatie' (2022) *The Natural Pavilion*. Available at: https://www.thenaturalpavilion.eu/materialisatie/ (Accessed: 31 October 2022).

Miljan, J. (koostaja) (2013) *Guidebook of reed business*. Eesti Maaülikooli maaehituse osakond. Available at: https://dspace.emu.ee//handle/10492/4490 (Accessed: 15 December 2022).

Natuurlijk riet - Vakfederatie Rietdekkers (no date). Available at: https://www.riet.com/riet/natuurlijk_riet.html (Accessed: 6 December 2022).

Packer, J.G. *et al.* (2017) 'Biological Flora of the British Isles: Phragmites australis', *Journal of*

Ecology, 105(4), pp. 1123–1162. Available at: https://doi.org/10.1111/1365-2745.12797.

Peatlands and climate change (2021) *IUCN*. Available at: https://www.iucn.org/resources/issues-brief/peatlands-and-climate-change (Accessed: 29 October 2022).

reed | Definition, Types, & Facts | Britannica (no date). Available at: https://www.britannica.com/plant/reed-plant (Accessed: 26 October 2022).

rh (2022) *Photovoltaik passt nicht auf Reet | SHZ*, *shz.de*. shz.de. Available at: https://www.shz.de/lokales/sylt/artikel/photovoltaik-passt-nicht-auf-reet-41774389 (Accessed: 5 January 2023).

Riethandel - Vakfederatie Rietdekkers (no date). Available at: https://www.riet.com/riet/de_rietbranche/riethandelaren.html (Accessed: 24 October 2022).

Slors, W. (2023) 'A conversation with a reed cutter in Naardermeer'.

Stenman, H. (2008) *Reed Construction in the Baltic Sea*. Turku University of Applied Sciences.

Terrin, M. (2023) 'Reed Panels - Schilfrohrplatten'.

van der Velde, O. and van Leeuwen, M. (2019) *De potentie van biobased bouwen*. Available at: https://www.nibe-sustainability-experts.com/nl/news/de-potentie-van-biobased-materialen-in-de-bouw (Accessed: 6 December 2022).

Visie klimaatbestendige veengebieden (2022) *Staatsbosbeheer*. Available at: https://www.staatsbosbeheer.nl/over-staatsbosbeheer/blijf-op-de-hoogte/nieuws/2022/06/visie-klimaatbestendige-veengebieden (Accessed: 24 October 2022).

Watson, J. (2020) *Lo-TEK: design by radical indigenism*. Cologne: Taschen.