Reed as a Façade Material

How can Common Reeds be applied in façade modules
to meet the general functional requirements of a façade?

to promote the use of Common Reed as a sustainable and vernacular building material in contemporary architecture.

Glossary

Adaptive Reuse /əˈdaptɪv riːˈjuːz/
verb
repurpose an existing building for new use.

Façade /fəˈsɑːd/
noun
(derived from the Vulgar Latin *facia*, meaning face) the principal font of a building. A façade is assumed if there are external partition constructions with an angle of inclination greater than 75º.

Functional /ˈfʌŋ(k)ʃ(ə)n(ə)l/
adjective
relating to the way something operates or works in accordance to its objective of invention. A functional invention is something useful and practical based on technical measures.

Module / ˈmɒdjuːl/
noun
a set of standardized parts or components that can be assembled to form a complete, independent structure.

Reed /riːd/
noun
a tall, slender-leaved plant of the grass family, which grows in water or on marshy ground. In this paper, the term *reed* is specifically referring to the species Common Reed *(Phragmites australis).*

Sustainability /səˈsteɪnəb(ə)l/
noun
(criteria) concerned with the act of conserving and maintaining an ecological balance by avoiding the depletion of resources.

Vernacular /vəˈnakjʊlə/
adjective
(Of architecture) concerned with the act of improvising available local resources, such as materials, craftsmanship, technology, etc. Includes the revitalising of olden building practices or techniques, which are relatively primitive but practical. Most of the time, people have simply forgotten that the best resources we have are historical references, neglected in time.

Problem Statement

The development of Common Reed *(Phragmites australis)* into building façade material is of high relevance in mitigating the carbon footprint in building industry. However, to properly apply reed in façade design, many functional issues to be addressed and overcome.

The application of reed in buildings is not a new invention. The usage can be dated back to 64/66 AD according to a text from Pliny, stating "At the beginning of our era, the shelters of the former inhabitants were covered with reeds or straw". The recent unearthing of Roman settlement relicts around Vlaardingen dated back to 75 AD also discovered floors that are made of reeds (Vakfederatie van Riet en Strodekkers., n.d.). According to Van Hemert et. al (1990), reeds are also used as roof thatches at castle, as in the case of Castle Zelhelm as illustrated by de Beijer's drawing in 1745. These structures may have been primitive in form, but the builders, did have great mastery and virtuosity in applying them at a period without formal regulations or institutions.

In contemporary architectural industry, the development of Common Reed (Phragmites australis) into standardised façade modules is of high significance. Firstly, reed is a native crop that absorbs CO2. As a natural sequestration agent, reed absorbs and stores large amounts of atmospheric carbon in the plant tissues through photosynthesis and helps retain the peat soil's carbon content (IUCN, 2017). The procedure of processing reed is also very straightforward, which involves harvesting, drying, sorting before applying on site. Since reed can be cultivated locally, this can largely shorten the logistic chain. These characteristics fulfil the criteria of being a sustainable and vernacular material. Furthermore, reed's relevance to be developed into a façade material is justified by its inherent lightweight properties and excellent performance in thermal and acoustic insulation, which is highly commended in fulfilling its functional requirements.

Corresponding to this, the development of reed façade modules is regarded as a precise answer to Dutch Ministry of Agriculture, Nature and Food Quality urgently calls for the development of high-quality wet crop products (Ministry of Agriculture, Nature and Food Quality, 2021). This development can establish new marketing opportunities to encourage agricultural entrepreneurs to switch to such cultivation. This is crucial in the Netherlands because the cultivation of wet-crops such as reeds can mitigate land subsidence, peat oxidation and greenhouse gas release which is happening drastically in North and West region due to pastoral agricultural activities (Beyer and Kürten, 2020).

Nowadays, with the increasingly complex technical requirements a façade is to provide, vernacular materials (such as reed in our case) lack of standardisation are therefore not considered as an ideal building material: many functional issues need to be addressed and overcome. First, it is important to acknowledge the state-of-the-art: in contemporary Dutch building industry, the use of reed as façade material is low due to a lack of standardised overview showing reed's feasibility in complying with different functional requirements in building conventions. The decision is especially critical when it comes to the issue of fireproofing, thermal insulation, etc. According to Van Hemert et al. (1990, p.9), the earliest record issuing reed's fire hazard can be dated back to 1406, when the city council of Leiden announced that for new houses whose side walls were higher than sixteen feet, a 'hard' roof (made of hard materials such as roof tiles or slates) is mandatory. On 20th May 1450, the use of thatched roof for new houses is eventually banned (Van Hemert et al., 1990, p.9). Although regulations revised and reed thatches reappeared in small domestic projects, we see that there is still a lack of proper documentation on how reed's performance can be technically improved to comply with higher building standards. Due to a lack of standardisation, reed remains a craft of human labour, implying high building cost. Since reed thatches are custom-made by craftsmen, a reed thatch roof can cost around €95.50 per m2 (Vakfederatie Rietdekkers, 2021), compared to €50 per m2 of concrete tile roof or €45-55 per m2 of new bitumen roofing (Dakdekker-Weetjes, n.d.). Hence with its high cost yet debatable functional performance, reed is not considered as an ideal building material.

Recently, scholars, researchers and builders have initiated studies on reed as a building material. In academia, CINARK from Royal Danish Academy, Bouwtuin project from TU Delft and architecture school of Turku University of Applied Sciences has conducted explorations on reed from an architectonic lens. In the building industry, architects such as Kengo Kuma and Dorte Mandrup have also proven the feasibility of reeds in realised architectural projects. However, the technical principles in building with reeds remain relatively constrained within the practice of local thatcher. In other words, the integration between architectural design exploration and practical building requirements needs to be improved.

Therefore, this paper aims to study how reed can be applied in façade modules to meet the functional requirements a façade is to provide from an architectural point of view. These requirements are the general criteria that a façade is to comply with, which includes fire retardance, thermal insulation, acoustic insulation, maintenance ease and operational ease. By giving proper address to these criteria, we wish to promote the use of reed as a sustainable and vernacular façade material while being functional, affordable and architecturally pleasing.

Objective

This paper aims to provide a set of clear design guideline in designing reed façade modules. The term *modular* is highlighted because it involves a standardised fabrication in which procedures can be followed and products can be mass-produced. It is crucial to ensure that the supply can be upscaled to achieve lower unit price, meaning higher affordability. To guide the fabrication process, a set of standardised parameters and design principles requirement to be clarified. These design principles are derived from studying reed's characteristics and physical performances in fulfilling façade's functional requirements. This implies a clear focus to acknowledge reed's strengths and weaknesses objectively. When limitations are identified, vernacular solutions are incorporated for further improvement and optimisation. By accomplishing these, this paper justify the relevance in promoting the use of Common Reed as a competent building material in contemporary architecture.

Research Questions

Design question:

How can façade be adapted to suit a building's new function or programme in adaptive-reuse projects?

Thematic research question:

How can Common Reeds be applied in façade modules to meet the general functional requirements of a façade?

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Sub-questions:

a. What criteria (and its corresponding definition) are considered as general functional requirements of a façade?
b. What are the characteristics and physical performance of Common Reed in regards to the aforementioned criteria?
c. What are the feasible vernacular solutions to overcome the physical limitations of Common Reed in fulfilling the criteria?
d. What are the applicable forms of realised reed façade designs? What can we learn from these designs in relation to its functional performance?
e. How can the efficacy of carbon footprint mitigation in the façade modules be quantified and evaluated?

Further explanation on each sub-question can be referred at appendix 1.

Relation to Design Question

The thematic research is to guide the design project of transforming De Knip in Sloterdijk, Amsterdam from a corporate office into private residences with some mix-used public premises. In most cases of adaptive reuse, interior spatial planning is changed to suit new function, but the façade remained. While some building façades are of high value that should be preserved, most might not have much relevance either in heritage value or supporting its new function. This is understandable because most older building's façade is connected to the structural members in a fixed or wet connection, meaning more implications and costs to disassemble or tear down. Thus, we wish to address how can the façade be adapted to its new function precisely, possibly with the least interference on the structural members.

In the process of reconfiguring the interior spaces, we discovered that the exterior façade should also be adapted to the new function and configuration. Regard to this, we would like to introduce reed, a contrasting material within the Sloterdijk context to create a contrast against the generic office block architectonic to deliberately prompt a new kind of interpretation. It can also be interpreted as a revitalisation of our vernacular way of building which has been practised in the Dutch context since early ages yet being neglected under the pressure of industrialisation. Since in adaptive-reuse projects, functional change is the steering wheel in the design trajectory, therefore we see the relevance of guiding the façade design also from a functional perspective. For instance, in the East façade of De Knip which facing the A10 highway, we see the requirement for higher acoustic insulation in the dwelling units. Whereas in the West façade of De Knip, a stark contrast of daylight condition in morning and afternoon implies a need for an easily operable sun-shielding device at the façade. Therefore, this thematic paper will guide how can these needs be met precisely with reed as a material.

Last but not least, even though the focus is set on adaptive-reuse projects (technically more demanding than new construction), the modules are considered highly applicable in most new constructions.

Key Domain, Terms, Theories

The research is oriented towards aE/Intecture Studio's *Make* domain. It concerns about new production methods, (re)-use and development of materials and systems for existing and new applications (Asselbergs et. al., 2020). To be more specific, this paper is dedicated to learn from vernacular architecture and integrate the acquired knowledge into new façade designs.

This paper includes both quantitative and qualitative research methods. Quantitative research involves the use of quantifiable numbers and statistics, empirically proven in experiments and tests. Qualitative research on the other hand involves the understanding of concepts, theories and experiences, acquired through words or observations. In the first part, the paper emphasis on quantitative research by referring to multiple researches conducted by scholars from relevant disciplines, such as biology, structural and civil engineering. The aim is to understand the physical performances of reeds corresponding to façade's common functional requirements based on established studies. Then, the research will shift towards qualitative methods to explore feasible façade designs.

Methodology

The paper is first set to identify the multitudes of functional requirements a façade has to fulfil, namely fire retardance, thermal insulation, acoustic insulation, maintenance ease and operational ease. The definition of each functional requirement is defined according to relevant regulations and requirements (if applicable) such as Building Decree 2012, nearly energy-neutral new construction (BENG), etc. which directly influence the feasibility of using reed as a façade material (refer Appendix 2).

Next, the paper will study the physical performance of reed corresponding to the aforementioned requirements. The data will be collected through literature and interviews with experts. The manipulating variables which influence reed's performance index will be determined. These will give an overview of which aspect should be given extra attention or has the potential to be improved in the design stage.

Based on the acquired results, the paper will move on to study feasible vernacular solutions to overcome reeds' limitations as shown by previous evaluation. Combined with the previous parts, these findings will be concluded as a list of design principles readily to be referred in the design of reed façade module.

Next, the study will look into realised case studies of different reed façade designs in multiple contexts. The designs will be illustrated in the same scale (1:20) and drawing conventions to be analysed, compared and contrasted. The outcome is a catalogue of illustrated spreadsheets on different façade designs, with annotated exemplary design principles (refer Appendix 3). The efficacy of carbon footprint mitigation in the façade modules be will be calculated and evaluated (refer Appendix 4). This last stage will conclude how the designs fulfil its ecological responsibility while meeting functional requirements and articulating architectural expressions.

Lastly, a performance matrix (refer Appendix 5) will be provided to show an overview of all designs' physical performance. These will address how different designs can result in different performance yields.

Preliminary Conclusions, Choices and Design Strategies

In the preliminary study, fire retardance is regarded as the primary factor which requirements to be resolved in the first place to realise the application of reeds in façade design. A study discovered that untreated reeds constructed in closed construction have a fire-retardant time of 95 minutes as proven in an experiment conducted by Vakfederatie Rietdekkers in Arnhem (Vakfederatie Rietdekkers, 2004). This has substantially exceeded the 60 minutes requirement as stated in the Class B Building Decree 2012 provision. By incorporating other vernacular materials (such as coating the reed with clay), we see possibilities of improving reed's fire retardance. Also, in terms of thermal insulation, a 300mm untreated reed thatch performs well by scoring an R-value of 4.28 m^2K/W. However, it still requires extra insulations to meet the 4.7 m^2K/W benchmarks as stated in new BENG standards. This can be improved through hybrid solutions such as integrating light-earth into the thatch. In terms of maintenance ease, which is targeted to achieve a lifespan of 25 years without a major overhaul, we discovered that reed thatch can be well maintained by having a minimum slope of 45 degrees to ensure optimum water drainage.

Through a comparative analysis of realised case studies, we see how architectural conceptions are integrated with practical considerations in different contexts. One of the exemplary designs includes Kengo Kuma's Yusuhara Marche which scores a 90.47% of reed usage in the façade with excellent operational ease due to its modular configuration. Also, from Forma6's Francoise-Helene Jourda office building, we see a good example of how reed thatch is improvised and reinforced structurally to clad a 6-storey high office block.

To conclude, the preliminary studies give a positive prospect to justify the relevance of further exploration on the subject of applying reeds onto feasible façade modules. With proper documentation and improvisation, we see that reed is equally competent to meet the general functional requirements demanded in contemporary architecture.

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