Bioreceptive Urban Facades:
Integration of Bryophytes Into Facades and Their Impact on Exterior Building Temperatures

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P4 Reflection

Throughout the report series of steps were taken to explore how bioreceptive materials be integrated into urban facades. The present state of bioreceptive research focuses on the development of the material and small prototypes and have yet to be implemented on a building scale. Due to this, literature relevant to the topics were distilled to a series of factors that can be implemented towards the generation of a bioreceptive facade. These guiding principles were used to drive the design and generate one which is focused on the successful implementation of a bioreceptive facade. Once created, the facade can be evaluated to determine what influence this new facade can have on external surface temperatures.

Answering the main research question of this report; the evaluation analyzes the potential to reduce external facade surface temperatures. Based on the calculations conducted in the report the use of bryophytes on the exterior of the facade can reduce surface temperatures by up to 3.7 °C and an additional 6.6 °C when under forced convection (theoretically). The largest contributor to the result is forced convection and the conductive heat transfer of moss. However, this effect is highly connected to wind velocity (forced convection) and the evaporation of water via latent heat. Given the transient nature of wind and the variable amounts of moisture the potential cooling effect will also be a constantly changing variable in a real world application. Building size and form is also an influential factor given the turbulence that can be created along the surface of the building.

Sub Questions:
What materials can be used that meet the requirements of a building facade as well as meeting the required properties of a bioreceptive material?

Currently only a few materials have been observed for their potential inherent bioreceptive properties, of these materials MPC has been documented to achieve the necessary material properties to achieve bioreceptivity. The report outlines how this material can be further improved to achieve the desired level of porosity and water retention to increase the bioreceptivity. However, this is only one potential material. Due to the fact that bioreceptivity is a material property and not a material type, there are many more potential materials that can be researched and developed in the future.

Which bryophytes (mosses, liverworts and hornworts) are suitable for vertical urban facades in the given site conditions?

The selection of the bryophytes are highly dependent on the material acting as the substrate and the environmental conditions present on site. The pH level of the material is a key determinant for the selection and the moss should be within the range of acidity of the material. In the instance of the foamed MPC, the pH range is about 8 (although some modifications may be able to reduce this even further). Based on these conditions, a series of potential specimens where selected to be further refined (shown in table: xxxx).

What are the additional required systems to be integrated into the facade in order to successfully maintain facade growth (i.e. irrigation, sensors)?

Based on the development of the facade design and the existing research on bryophytes an irrigations system is strongly recommended. However, this may change depending on the environmental conditions and the height of the building. As discussed in the irrigation section of this thesis, the irrigation system provides many more benefits than just maintaining the health of the moss; such as maintaining the cooling potential of the surface through latent heat and as delivery method for nutrients.

Other systems that should be added to the facade can also include humidity sensors and a micro weather station. These are also necessary for optimizing the activation of the irrigation system. As discussed in the thesis, these are important for the longevity of the bryophytes and monitoring the moisture on the surface to improve upon the cooling potential of the surface.

What influence will this facade have on the external temperature of a building?

The performance of this bioreceptive facade is highly dependent on the speed of wind making contact with the facade. This an unpredictable variable that can change in direction or velocity at a moments notice. Evaluating the facade with both a static and transient scenarios shows how the cooling effect can either be more prominent or reduced at different points on the facade. This makes the result much more unpredictable. However, by taking some averages for the environmental conditions that are present on site a generalized reduction of about 2 - 4 °C can be estimated. Additionally, the result is dependent on how much of this material is being used in the design and the window to wall ratio can influence the overall impact of the building.

Reflection

As stated previously, this concept of integrating bioreceptive materials still needs to be expanded upon and further evalutated.It is also important to note that there is a considerable amount of overlap between different fields. Some of these are obvious fields within the realm of construction such as Architecture, Engineering, Building Physics and Facade fabrication. However, other fields uncommon in the realm of Architecture or building construction such as, Bryology, Horticulture and Irrigation systems that make the thesis concept unique. Merging these different fields together is necessary to create a successful bioreceptive facade. However, this also requires a wide ranging body of knowledge to support the development of the concept.

The concept of bioreceptive materials are still in their infancy but further exploration into this up and coming material can help push the concept of bioreceptivity into reality. The aim of the thesis was to improve upon the material research and further develop it into a facade system for urban environments. Only then can the facade be evaluated for the thermal impact that this could have on building surface temperatures. There are promising results to support the idea that integrating these bioreceptive materials into urban areas will have an impact on the surface of the facade. Based on calculations conducted in the report the use of bryophytes on the exterior of the facade can reduce surface temperatures by up to 3.7 °C and an additional 6.6 °C when under forced convection (theoretically). The largest contributor to the result is forced convection and the conductive heat transfer of moss. However, this effect is highly connected to wind velocity (forced convection) and the evaporation of water via latent heat.

The thermal performance results of this paper falls into line with similar research conducted on moss green roofs in Japan (Katoh, Katsurayama, Koganei & Mizunuma, 2018). Similar to their findings, the thermal performance was affected by the wind velocity in combination with the moisture of the moss. However, these variables change throughout the facade as shown by the

CFD building wind analysis. By sampling different locations of the facade for different velocities it can be observed where the effect of forced convection changes. Unlike solar irradiation which can be calculated with a degree of accuracy, wind is a transient, and wind velocities can fluctuate causing the result to fluctuate as well. However based on the research outlined in the report, speeds above 2 m/s differ only slightly. So long as the minimum speeds of 2 m/s are meet there should be an adequate amount of forced convection.

Additionally, given the highly unpredictable nature of urban environments, there are many more factors that can impact the actual result. Thus, further validation is needed to support the initial claims of this report. More intensive CFD transient simulations can be used to optimize the effects of forced convection on moss at a micro and macro scale. It is also recommended that material prototypes be developed and monitored over time in both laboratory and real world environments to further validate the result.

Just as important as understanding the benefits it is also important to investigate the limitations of bioreceptive facades. This paper outlines some of those limitations based on the environmental conditions of the species of bryophytes being used for the material. These limitations are set based on the regional conditions of Europe and assumes the solar conditions, relative humidity, ambient temperature and wind speeds of The Netherlands for the purposes of simulations. The results of this paper may vary based on the climatic conditions of a different geographical location. Additionally, bryophytes and the concept as a whole may not be suitable in other regions of the world. Thus, climatic conditions and existing flora should therefore be carefully investigated before implementing any bioreceptive materials. Additionally, there are no guidelines for the climatic and regional limits of the concept and further development of these limitations are needed in order to better define its application.

The underlying literature research conducted in this thesis and the current development of the concept by research groups are still in their early stages. The limited body of work has created some issues when it comes to sourcing the correct supporting research. This can impact the success of the concept, with many aspects still being investigated (at the time of this writing) and needs to be reevaluated once a large body of work has been developed. The field of bioreceptive materials for construction remains in uncharted territory and allows plenty of room for the development of ideas around the concept. Bioreceptive facades are a challenging feat to accomplish, however the potential to pave the way for a new green facade typology makes this a worthwhile endeavor.

Further Exploration:

This report highlights the impact that bioreceptive materials can have on the surface temperature of the building however, yet this is only one potential benefits of this material. It is important to note that there are many more aspects to be explored and tested when it comes to bioreceptive materials. Some potential aspects to be further explored include but are not limited to: CO_2 sequestration, particulate matter & air purification, rainwater absorption, urban biodiversity, moss as an insulator, among others.

This new category of green facades still has room for further development and exploration. Building upon the research generated in this report there are opportunities to further expand the body of work. The report outlines a series of principals that should be followed however, some aspects are open ended and leave room to develop different design variants. In the case of wind and geometry, different forms can be investigated for their influence on wind along the facade's surface. Another aspect to be further investigated is the application of the irrigation system. This report developed a misting system as a way to provide supplemental water and nutrients to the surface, however this should be properly investigated to determine how a misting system may function on an urban facade and how moisture can be evenly distributed on the surface.

In order to properly measure the impact, a prototype should be developed that can meet the requirements of bioreceptive materials. This requires developing a system dimensioned to the appropriate sizes, selecting suitable materials and integrating the correct systems. The thesis provides the proper foundation for the development of the concept however, based on the underlying research, further steps can be taken to improve the facade to increase the chances of success. The steps explored in the report include wind optimization and creating geometric grooves on the surface, both of which can increase the colonization of the surface with bryophytes. A prototype of these techniques can be further developed and evaluated for their performance over time.

Furthermore, the thesis is not set up to be a comparative study of green facades systems or living wall products.The existing green systems were taken into account when designing the facade components and with the intention of simplifying the systems. However, it was not intended to make definitive comparisons between the bioreceptive facade and other vertical green systems. Further LCA, product cost, production cost and maintenance costs are needed in order to compare this green facade with others. This will ultimately determine the economic incentives to implement this new green facade typology.