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WEATHERING; PATINA, AND OTHER MEANS. REVEALING MATERIAL'S EXTERNAL CLIMATE ADAPTION PROCESSES

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Abstract: Materials used in building facade assembly are materials that have been man-processed into specific elements. All materials start as crude material, raw and sourced from our earth. A process of production demands crude material to change state - in wood for example - it is felled. Chopped down, killed and reprocessed under specific controlled processes. We assume control of all building materials through rigorous quality control specifications and regulations to ensure materials perform under specific constraints. Yet facade materials confront an external environment that is not controlled, and are susceptible to heat, to rain, to snow, to wind, to UV. All live forces undetermined, and of which materials naturally act and react through weathering, patination, discolouring promoting natural chemical reactions such as rusting.

The purpose of the paper is to present recent research that explores the after-life of specific material types and how understanding of materials' natural processes of transformation when exposed to the external climate can inform initial design decisions.

The research follows iterative prototyping processes where knowledge has been accumulated via explorations of specific material performances, from laboratory to construction mock-ups focusing on the architectural qualities embedded in control of production techniques, and facilitating longer term patinas of material surfaces to extend the aesthetic beyond common judgements. Experiments are therefore focused on how the inherent material qualities drive a design brief towards specific investigations to explore aesthetics induced through production and patinas obtained over time while exposed to external climate conditions.

Keywords: *Patina. Climate. Material Performances*

Introduction and background to building facades

A building's facade operates, both aesthetically and functional, on many different levels. As a functional part of a building, it serves as a climatic barrier and protects an inner environment from external weather conditions. It provides a robustness to protect a building throughout its lifespan. It is usually constructed as a waterproof membrane to ensure water does not penetrate and destroy the structure and internal materials. It guides rainwater away, allowing water to fall on a facade, but channels water safely away via guttering and piping. It is the first line of protection - and usually the only line of protection, to ensure a building doesn't deteriorate substantially when exposed to unreliable external weather conditions.

Aesthetically, a facade provides identity to a building. It communicates, for example, a corporate identity and provides evidence for what the building is used for. A factory's facade is normally different in its character than a facade of a one family home for example. Or an office. A facade communicates to the outside wealth, power, dominance - the status of the occupants in the society it finds itself in. Or a facade may consciously NOT communicate and act as a veil whereby it is difficult to get an insight into what a building contains. In Venturi, Scott Brown and Izenour's book Learning from Las Vegas[1], they write about the decorated shed as buildings with facades used as veils with applied symbols can also comminuícate the opposite[2], namely accentuate the value of what is behind and modulate a facade so that it goes beyond form based design application, to symbol based meanings. Facades therefore become signs, rather than a functional layer for weather protection alone.

> *"The sign is more important than the architecture. This is reflected in the proprietor's budget. The sign at the front is a vulgar extravaganza, the building at the back, a modest necessity. The*

[1]https://monoskop.org/images/archive/c/cd/20170506121429%21Venturi_Brown_Izenour_Learning_from_Las_Vegas_rev_ed_missing_pp_164-192.pdf
[2] https://www.architectmagazine.com/design/of-ducks-and-decorated-sheds-a-review-of-i-am-a-monument_o

architecture is what is cheap. Sometimes the building is the sign: The duck store in the shape of a duck, called "The Long Island Duckling," is a sculptural symbol and architectural shelter. Contradiction between outside and inside was common in architecture before the Modern movement, particularly in urban and monumental architecture. Baroque domes were symbols as well as spatial constructions, and they are bigger in scale and higher outside than inside in order to dominate their urban setting and communicate their symbolic message.

Western stores did the same thing: They were bigger and taller than the interiors they fronted to communicate the store's importance and to enhance the quality ánd unity of the street. But false fronts are of the order and scale of Main Street. From the desert town on the highway in the west of today, we can learn new and vivid lessons about an impure architecture of communication. The little low buildings, gray-brown like the desert, separate and recede from the street that is now the highway, their fronts disengaged and turned perpendicular to the highway as big high signs. If you take the signs away, there is no place. The desert town is intensified communication along the highway."[3]

As the authors write, contradiction between outside and inside is common in architecture. Often through choice, as described in Learning from Las Vegas, there are corporate driving ambitions. But there are also contradictions between outside and inside through a necessity of navigating between internal and external environmental setups. There are many driving factors that stimulate the way a facade is both designed, and how it performs. An external facade needs to navigate through changing weather conditions as a minimal requirement, and establish durability throughout a building's lifespan. The symbolic value of messaging corporate identities needs to come secondary to responding to climate. Responding to climate variations over substantial time. As Karsten Harries, Professor of Philosophy at Yale University, writes,

[3] P13-18 https://monoskop.org/images/archive/c/cd/20170506121429%21Venturi_Brown_Izenour_Learning_from_Las_Vegas_rev_ed_missing_pp_164-192.pdf

" Architecture is not only about domesticating space', 'It is also a deep defence against the terror of time."[4]

As a facade is continually exposed to the natural environment, materials that make up the facade will inevitably weather, meaning their appearance and performance will change over time. The aesthetic consequences of material change through weathering, today in new buildings, is often not substantially considered. The changing effects of material and a buildings facade, and through tenuous observations of newly constructed buildings in local neighbourhoods, it is evident weathering is not adversely considered as a conscious and a positive design tool. Far from it. Buildings stand out with facade coverings more conscious of symbolic values rather than barometers of time, meaning an architecture of today that is preferred as timeless, and therefore artificially removed from the reality of time. John Ruskin (1819-1900) in his book, The Seven Lamps of Architecture, writes that

"The greatest glory of a building is not in its stone, or in its gold. Its glory is in its Age (…) it is in that golden stain of time, that we are to look for the real light, and colour, and preciousness of architecture."[5]

Juhani Pallasmaa also focuses on how materials are able to trace time and offers a critique of modern architecture's neglect in embracing the passage of time for other architectural ambitions.

"Matter records time, whereas shape, particularly geometric form, emphasizes space and the world of ideas. Geometry and form speak of permanence, whereas materials – through the very laws of nature – trace the passing of time. Modernity has been obsessed with novelty and a perfectionist formal language that does not register this. As deterioration, erosion and entropy are the unavoidable fate of all material constructions, the ideal of perfect and unchanging form is bound to be a momentary illusion, and eventually a false ideal."[6]

[4] Karsten, Harries, 'Building and the Terror of Time', Perspecia: The Yale Architectural Journal, 19, New Haven, 1982, pp59-69.
[5] John Ruskin: The Seven Lamps of Architecture. London: Smith, Elder & Co., 1849, s. 162-84
[6] Juhani Pallasmaa, "Inhabiting Time", Architectural Design, 86/1 (2016), s. 50-59, 57

Christian Frederik Hansen (C. F. Hansen (1756-1845)) was a Danish classicist architect who was appointed as a royal court architect as well as a professor and director of the Academy of Arts in Copenhagen, Denmark. He is considered one of the most important architects in Danish history and was very prominent in Copenhagen in the early 19th century. His best-known works today are Domhuset, and Vor Frue Kirke in Copenhagen. Today these buildings are characterized by their marked weathering of the pink external rendering that gives an appearance of two building navigating well under years of changing weather conditions. At inception of course, the buildings did not appear as they do today. They have weathered and patinated. C F Hansen was an avid painter and he produced watercolour renderings of his buildings that seem to anticipate the buildings' weathering and patination.

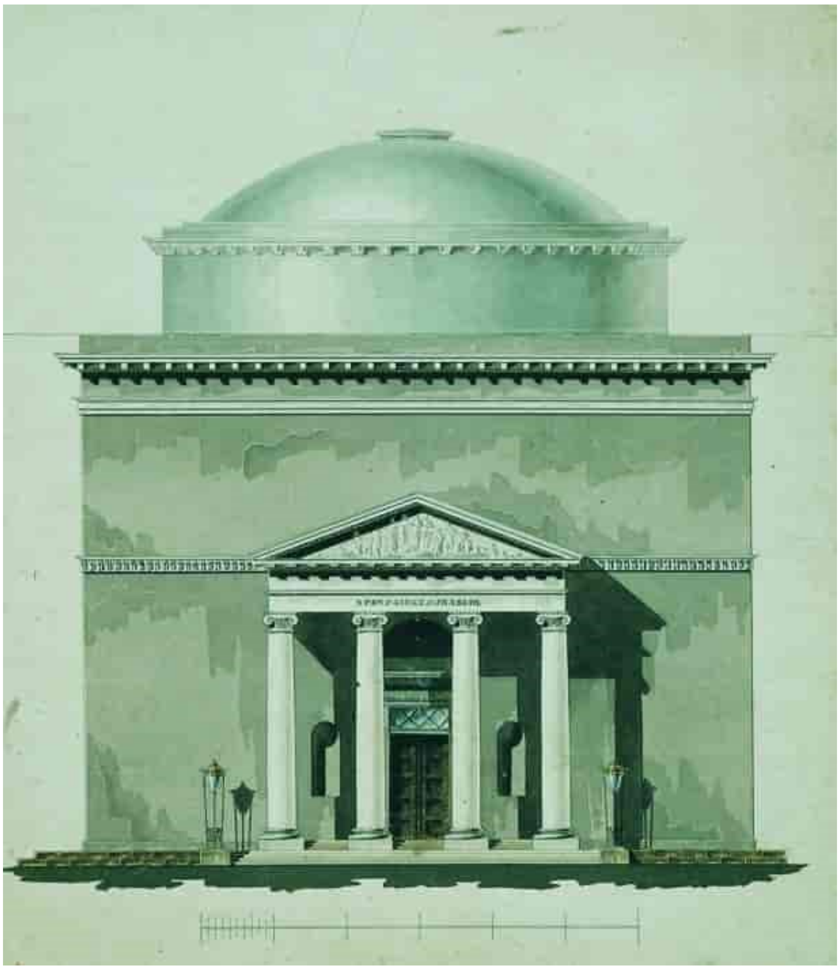

Illustration 1: Christiansborg Slot. C.F. Hansen. Kunstakademiets Bibliotek. Kunstakademiet

In Albert Algreen-Petersen ph.d ‘Patina. Architecture’s motive and informant’[7], he describes C F Hansen's approach to how a buildings facade can accommodate possible patina through his drawing methods, and how these inform the buildings design development.

” The large production of watercolor drawings he left behind testifies to an architect who was also a persistent and thorough draftsman. In several projects, numerous of C.F. Hansen's facade studies are made of the same facade with small adjustments and changes from drawing to drawing. They are done in line and with light watercolor or wash, as a drawing method to add color to the facade surfaces of the line drawing and a hint of materiality and texture as well as shading. However, it is also clear that C.F. Hansen also deals with the facade's possible ability to patina with his drawing method. Using the drawing method for the facade drawings, Hansen gives the impression of an architectural surface that is not newly constructed, but has been attempted to be projected with traces of the patina of time. Adjustments to the facade, where cornice bands are moved, the processing of materials is adjusted, or where the relief processing of the facade is changed, also changes the watercolor work's hints of patina. It means something for the structure when the smooth plastered facade is divided into squares. Not only for the pattern, but also for the facade's ability to patina. Such a study can be seen, for example, in the facade studies for an unbuilt carriage gate for a detention center. Here he shows how the processing of the plastered facade is important for its (presumed) patina.

It is not possible to say with certainty whether C.F. Hansen used the drawing method, where the building's patina was tried to be shown in the project drawing, as a carefully conceived and conscious design tool. In any case, I have not come across written sources that can neither confirm nor deny that hypothesis…….. I will pursue the hypothesis that C.F. Hansen worked with patina as an architectural informant in his drawings of not yet constructed buildings, ………. where a present

[7] https://kglakademi.dk/kalender/phd-forsvar-patina-arkitektonisk-motiv-og-informant

awareness of patina in the drawing led to decisions about weathering such as material selection, surface treatments and processing as well as building details."[8]

Illustration 2: Rådhusets Entrance Gate. Kattesundet. Tegning © Kunstakademiet

Although there is no conclusive evidence so far available, it is fair to assume C F Hansen used his knowledge and experience of how material changes through time as an architectural design informant that provoked design decisions and material choices. Public buildings at the time were predominantly constructed from stone, lime mortar and fired clay, with wood used for internal construction cladding and furniture. Today however timber is a well-resourced material for building in Scandinavia in particular, due to its availability and a pursuit for better sustainable building materials. Timber weathers in very different ways to stone and clay and is a result of a combination of light, moisture, heat, causing both physical and

[8] Patina: Arkitektonisk motiv og informant. Albert Algreen-Petersen. Institute of Architecture and Culture Publications: Book / Anthology / Thesis / Report › Ph.D. thesis

chemical changes to the appearance of the wood. A relatively rapid photochemical degradation of the surface occurs as a result of exposure to ultraviolet light. Wood begins to take on a brown tone, which then changes to grey. During this process, the UV rays damage the polymer bonds within the wood substrate (cellulose, hemicelluloses, and lignin). As a result, exposed wood in a Scandinavian environment can weather to a soft, silver grey colour. This colour change is due to the degraded lignin being washed out of the wood by moisture. The fibres that remain on the wood surface are high in cellulose content, grey in colour, and are more resistant to leaching and UV degradation.[9]

The resultant weathered appearance of wood is highly regarded and often compared to sealskin in both its appearance and texture. It is also relatively resilient to decay, providing the wood is allowed to dry after wet periods. More significantly however, patina and discolouring of wood over time communicates just that - that time has been embedded in the architecture (facade) and it is this that is well appreciated - the understanding that architecture becomes part of a wider ecosystem whereby the thresholds between nature and manmade become less defined. Time being a keeper of this phenomena.

Analysis and Inference

In building construction and its performance, today the industry amounts to up to 40% of CO2 emissions globally[10]. In urgent pursuits from the building industry to establish better environmentally conscious building practice there is now a focus on thinking of new constructions in a more circular manner, and investment into more bio-based material types. Biobased materials are a natural part of our environment, or biosphere. They typically have a low embodied carbon footprint and as they are organic, they tend to absorb carbon as they grow[11]. Significantly, they lock carbon sourced from our environment during their lifespan. When however, they are harvested for, for example building components, this carbon can be released. Limestone processed into cement being a typical example. Processing of raw material for building use therefore requires careful study and consideration to avoid negative impacts. The

[9] Silva Timber products https://www.silvatimber.co.uk/what-is-weathering/
[10] https://architecture2030.org/why-the-building-sector/
[11] A Review of the Environmental Impacts of Biobased Materials. Martin Weiss,Juliane Haufe,Michael Carus,Miguel Brandão,Stefan Bringezu,Barbara Hermann,Martin K. Patel

projectorary therefore is to think of material sourcing and application that promotes building materials that are NOT processed and 'artificialised', but as natural as possible, to be an embedded part of the biosphere.

Materials used today in building assembly are primarily materials that have been man-processed into specific elements. All materials start as crude material, raw and sourced from our earth. A process of production demands crude material to change state. This change of state is energy consuming, and often releases CO2 absorbed throughout the material's 'life'. We assume control of building materials through rigorous quality control specifications and regulations to ensure materials perform under specific constraints. Yet with facade materials for example, the material must confront an external environment that is not controlled, and is susceptible to heat, to rain, to snow, to wind, to ultra violet deterioration. All live forces as such, that are undetermined, and of which materials naturally act and react through weathering, patination, discolouring, and promoting natural chemical reactions such as rusting for example.

The development of a building practice thinking of new constructions in a more circular manner, and investment into more bio-based material types that are a natural part of our environment, or biosphere, gives designers opportunities to engage in how materials perform, change and patinate when exposed to external environments, and how an understanding of materials' natural processes of transformation when exposed to the external climate can inform initial design decisions. Facades for buildings should be considered not only shields from uncontrolled environmental conditions, but to be designed to navigate, contribute, enhance and mend our local and global environment.

The North Atlantic island of Bermuda has no fresh-water springs, rivers or lakes. It is therefore entirely dependent upon capturing rainwater and desalination plants.[12] Each house is required to collect rainwater from roofs and provide water storage equivalent to 8 gallons for every square foot of liveable space. The roofs themselves are constructed from limestone and painted every two years or so with a lime wash.

[12] https://www.enterbermuda.com/blog/how-bermuda-gets-its-water

Many houses also have lime-washed facades, resulting in a strong architectural expression often compared to wedding cakes. The use of limestone as the principle material that receives rainwater for collection however is not about an aesthetic, but has more practical reasons. In Bermuda, the architectural facades offer a way of ‘cleansing’ the rainwater for drinking. Firstly, the white colour is credited for reflecting rather than absorbing ultraviolet light. This means UV light helps to sanitize the water. The lime-based mortar also has an antibacterial quality helping to keep the rainwater clean. Rainwater has an acidic content due to, for example, acid-rain as a result of industrial pollution. Lime however is an alkaline, and so when mixed with the water can contribute to neutralize the acidic levels of rainwater thereby reducing negative pollution for drinking and further detrimental consequences for plant life as rainwater enters the earth.[13]

Illustration 3: Burmuda Roofs. Photo Samantha Clark https://blogs.lt.vt.edu/samclark95/2013/11/17/bermudas-architecture/

The Bermuda lime example describes how a community has found practical solutions through necessity and how the careful application of external material choices can contribute positively to our environment

[13] https://www.bbc.com/news/magazine-38222271

that goes beyond pure aesthetics. It promotes a mindset whereby facades are seen as navigating with our external environment so that they negotiate with external environmental conditions to not only provide shelter, but to respond in a manner that assists in repairing the detrimental damage done by mankind to our ecosystem. A kind of ecological engineering practice using external material whereby sustainable ecosystems become part of design development and implementation to establish synergies of new and existing needs of human society with its natural environment. But designing for mutual benefit.

“Ecological engineering uses ecology and engineering to predict, design, construct or restore, and manage ecosystems that integrate "human society with its natural environment for the benefit of both".[14]

Significantly however is the need for human kind to attempt to repair our ecosystem. New building practice and using designs of building fabrics, for example facades, can facilitate this.

“Ecological engineering, defined as the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both, has developed over the last 30 years, and rapidly over the last 10 years. Its goals include the restoration of ecosystems that have been substantially disturbed by human activities and the development of new sustainable ecosystems that have both human and ecological values.”[15]

The prospect of development of new sustainable ecosystems that have both human and ecological values in facade and building design is tantalizing, as the role of a buildings envelope goes beyond aesthetics and climatic protection, to establishing habitat for systems that contribute positively to our changing environment rather than resource consuming that produces a negative carbon footprint. This approach promotes thinking of facades as places for colonisation, that facades can be designed and constructed from building material that has the ability to be colonised by living organisms, known as bioreceptivity.

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[14] https://en.wikipedia.org/wiki/Ecological_engineering
[15] William J. Mitsch https://www.academia.edu/17933629/What_is_ecological_engineering

The term, bioreceptivity, first introduced by Olivier Guillitte in 1995, describes the ability of a building material to be colonised by living organisms.

"… the term 'bioreceptivity' as the aptitude of a material (or any other inanimate object) to be colonised by material (or any other inanimate object) to be colonised by one or several groups of living organisms without necessarily undergoing any biodeterioration. The word 'colonise' is important since it indicates that conditions for harbouring, development and multiplication have to be met and excludes the ability of a material to receive living organisms in a transient and fortuitous manner. It implies that there is an ecological relationship between the material and the colonising organisms."[16]

As a specific example, the Department of Construction Engineering, Universitat Politècnica de Catalunya, UPC, studies have been carried out in incorporating living organisms, such as photosynthetic organisms, on building envelopes to stimulate the development of patinas of biological origin on the surface of building materials.

"At UPC (Barcelona, Spain), we have developed a multi-layered concrete panel for the development of green facades. This patented material is composed of four layers (Manso et al., 2013). The first layer consists of conventional concrete and is responsible for the structural function of the panel. The main function of the second layer is to protect the first layer from ingress of water and noxious substances. Furthermore, it acts as a bond layer between the inner and outer layer. The function of the third layer is to stimulate the development of the biological patina. It represents an anchorage site for airborne microorganisms and a niche for microbial growth. Finally, the fourth and last layer is a discontinuous one in order to allow different designs of the surface. Exit of water is then

[16] https://typeset.io/papers/bioreceptivity-a-new-concept-for-building-ecology-studies-2gaaq6eo1u

redirected to the areas without this fourth layer, promoting better local conditions for colonising organisms."[17]

Research applications into bioreceptivity assumes building material (principle facades) to be receptacle to colonisation, that material has a porosity to colonising from airborne microorganisms, but is dependent upon airborne living organisms to attach themselves to a facade material for example. The most recent examples of material research and testing that I have carried out takes a more proactive stance in the sense that organic substance is embedded into material components to operate as a substrate and nutrient to and for organic growth. This work is an extension to previous research into recovered plastics as potential building material.

"…the outer skin of buildings are seen as a climatic barrier protecting the inner layers of moisture and temperature variations, like a skin protecting the building within. Traditionally (Denmark), the preferred material has been brick as clay can be locally sourced. Due to advancements in building demands – higher constructions, sustainable agendas, internal comfort, especially natural daylight – other materials are being adopted, normally using a dry assembly technique and promoting prefabrication. Panels. Our research development was to begin tests into using recovered plastic as a potential cladding, with a focus on the statement of intent,....... i.e. plastic to be understood as a species – that the composition of the material in question and its inherent DNA, metaphorically speaking, is a means to achieving a high level of architectural design articulation and detail."[18]

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[17] https://upcommons.upc.edu/bitstream/handle/2117/85045/STOTEN-D-14 04716R1.pdf;jsessionid=04CF965E96992468FB5B87BE8746C3D6?sequence=3

[18] IDRC 2020. Material and Advanced Techniques transforming recovered polymers into bespoke building components: Harvesting local plastic waste for building material. Architect Chris Thurlbourne

Illustration 4: Recovered Plastic facade. Photo. © Chris Thurlbourne

Plastic is probably one of the principle materials that is a long way from being termed organic. It is non-organic, and one of the materials principle challenges is that it does not biodegrade at a fast rate, if at all. It therefore is either burnt or ends in landfill. In Denmark however, infrastructure has been set in place to recycle as much plastic as possible giving scope for establishing new uses for recovered plastic.[19] This material has had a previous life, and is available for a new, after-life. In my research I suggest it can also be a host for new life - to be receptive to colonising living organisms, in particular organic plant species that will attract and promote wildlife such as insects that in turn attracts birdlife.

[19] https://danskretursystem.dk/en/about-deposits/where-return/

The examples tested use organic substance embedded into recovered plastic material components to operate as a substrate and nutrient to and for further organic growth. As recovered plastic is cleaned and shredded before becoming available for heating and remoulding, it creates an ideal opportunity to mix the material with other materials - organic materials that provide a substrate for plant growth. Shredded plastic is granular and can be readily mixed with additional materials.

After sourcing domestic plastic waste products, I shredded the plastic in a customised hand built shredding machine. This created rough shavings that I then mixed with sawdust as the first experiment. The mixture was placed in a metal form and put in a low heat oven for a couple of hours. Once the plastic was soft the form was put under pressure whilst cooling, thereby compacting the material composite, and containing the plastic ensuring it did not distort whilst cooling. The low temperature during firing also ensured the sawdust did not ignite, and the nutrients not burnt away. Examples have been left outside for some weeks (months), and it is clear colonisation occurred relatively quickly due principally to the sawdust's ability to absorb moisture. The plastic on the other hand, as an oil-based material is resilient to moisture and does not root.

Illustration 5_Plastic growth with sawdust. Photo © Chris Thurlbourne

The next exploration was following the same recipe, but using seaweed as the nutrient. Seaweed is being introduced into buildings as a building material. Eelgrass, a type of sea bound grass, has been developed as a raw material source for panelling. A Danish company, Søuld[20] has developed different types of panelling and have established themselves as experts in the field to convert the material into CO_2-storing building materials that combine a high degree of acoustic performance with quality aesthetics.

> *"Working together with local farmers, municipalities and ecologists, Søuld has optimized eelgrass collection based on environmental protection and the preservation of natural eelgrass meadows. The CO_2-binding sea plant is found washed ashore along Denmark's coastline as an abundant, renewable and overlooked local resource. The plant absorbs significant amounts of CO_2 while growing in the sea and therefore serves as a carbon sink when used in construction."*[21]

I sourced dried seaweed as it is more manageable for my process. Seaweed, when wet, can however regrow and when my experiments were placed outside the seaweed did in fact begin to expand putting pressure on the reformed plastic.

[20] https://www.sould.dk
[21] https://www.sould.dk/acoustic-mats

Illustration 6_Plastic with Seaweed. Photo © Chris Thurlbourne

Illustration 7_Plastic with Seaweed. Photo © Chris Thurlbourne

Another experiment is with horse manure. This is often used as fertilizer in agriculture so is well known for its ability to provide a source of nutrients to plants. This, to date, has not had sufficient time outside to test the potential for colonisation, but although all these experiments are at an early stage, it is clear with the results so far there are potentials in the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both. Both through sustainable, eco engineering as a framework, but also to develop a new aesthetic for building facade systems that embraces our ecosystem in new, exciting ways.

Conclusion

A building's facade operates, both aesthetically and functional, on many different levels. As a functional part of a building, it serves as a climatic barrier that protects an inner environment from external weather conditions. It provides robustness. Aesthetically, a facade provides identity to a building. It communicates, for example, a corporate identity and provides evidence for what the building is used for. But it can also be a membrane. Whilst engaging with our climate, facade materials confront an external environment that is not controlled, and are susceptible to heat, to rain, to snow, to wind, to UV. All live forces are undetermined, and of which materials naturally act and react. Materials will change. They will transform through patination. Significantly however, building facades join our climate and provide roles that go beyond corporate identity and communication, to be responsive and contribute in positive ways to establish habitat for systems for our changing environment rather than resource consuming alone.