Research Plan | aE Studio

Personal Information

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Studio

Name of studio: Architectural Engineering
Design tutor: Thomas Offermans
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Argumentations of choice of the studio: What architectural engineering offers is the integration of architecture and technology, in order to tackle the biggest architectural challenge of our time: a sustainable built environment. Thus the studio offers what I believe to be the ideal framework in which to prepare oneself to become an architect of the future. A future where social problems, climate change, scarce resources and energy do not frighten, but instead pave the way for a transition to a sustainable future where we can coexist with our living environment and planet harmoniously. The architect is well-positioned to take a coordinating role in this collaborative effort.

Title

Optimising the insulating capability of additively manufactured earthen facades

Graduation Project

Keywords
open building, infill, mass customization, additive manufacturing (AM), 3D printing, earth, thermal performance, heat transfer, thermal bridging, facade

Introduction

A substantial amount of the current Dutch housing stock was built in the wake of the second world war. The housing developments in the post-war period resulted in industrial products to house the then booming population. These mass-produced developments can be found throughout the country, often as urban expansions. Schalkwijk, located on the South-East of the historical centre of Haarlem and built in the 1960s, is an example of such an expansion (Gemeente Haarlem, 2019a). Schalkwijk was built on the principles as put forward by CIAM and the Athens Charter, which was a reaction to the problems associated with the historical city. Contrary to the organically grown city, a modern planned city was to offer all its residents affordable buildings with access to good air quality, sunlight and (green)space. Furthermore, different functions such as recreation, retail and work were to be separated by strict zoning. Thus, Schalkwijk has a distinct shopping centre centrally located between the residential neighbourhoods and is surrounded by the green belt of Haarlem: the Groene Zoom.

Schalkwijk includes four residential neighbourhoods: Europawijk, Boerhaavewijk, Meerwijk and Molenwijk. Boerhaavewijk is located in North-East Schalkwijk. It is bordered by the Schipholweg highway in the North, the Poelpolder-noord wetlands in the East, the Aziëweg in the South and the Amerikastraat in the West (Gemeente Haarlem, 2011). As such it is well located; nature, the city centre of Haarlem and the Schalkwijk shopping centre are all nearby. Lastly, it is well connected by public transport and car to both Amsterdam and Schiphol.

Each of the neighbourhoods was organised differently, with the intention to foster separate identities within Schalkwijk (Gemeente Haarlem, 2019a). Boerhaavewijk is characterised by its orthogonal grid and the repetition of building ensembles in ‘stamps’. The neighbourhood received its own ‘town centre’ with facilities concentrated along the Floris van Adrichemlaan. The appearance and location of these facilities were to be an urban highlight and strengthen the identity of the neighbourhood. Today, different facilities like elementary schools, community centres, a supermarket, a fire station and an all but abandoned, yet monumental (Vermeer & Eijkelboom, 2019) church are still located on this East-West axis.

There are many new building developments taking place in Schalkwijk, especially in the area known as Schalkwijk Midden (Gemeente Haarlem, 2013). Part of Schalkwijk Midden forms the entrance to Boerhaavewijk. Here the Poort van Boerhaave project is developed which will add 150 apartments (Wijkraad Boerhaavewijk, n.d.b). North of that development the demolition of the nursing home Boerhaave cleared space for Hof van Jacob, which will house 256 assisted care living units. The area north of Schalkwijk shopping centre is being heavily redeveloped too, with the addition of over 1.200 housing units and mixed-use facilities to the West of Europaweg (Mekking, 2020). Within Boerhaavewijk proper there have been small scale renovations and replacement of elderly housing with terraced family homes (MUST stedebouw, 2016), but no renovations yet on the scale expected of the energy transition.

Problem Statement

The previously mentioned densification of Boerhaavewijk’s surroundings is raising the number of residents considerably, which is a logical step towards meeting the national demand for housing (KAW, 2020, 2021). However the existing facilities, schools and community buildings, such as ‘Wijkcentrum de Ringvaart’ in Boerhaavewijk, even without the addition of new users, were already in need of renovation or replacement. Changes in demographics, be they age, ethnicity or socio-economic factors are unable to be absorbed by the existing built environment. For example, the population was ageing. But with the planned addition of new families, local primary schools are forced to change their long-term strategies for downscaling and instead have to figure out whether to demolish or renovate in favour of bigger and more modern school facilities (Gemeente Haarlem, 2019b, 2020). There is a shortage of future-proof facilities and community spaces in Boerhaavewijk.

When neighbourhoods like Boerhaavewijk were built there was an enormous demand for housing. This resulted in affordable and efficient industrial building systems. Today we claim that these buildings are unsustainable. They used materials like brick and concrete which have a big carbon footprint. The facades were energy-inefficient, because they were designed with little to no insulation. Often asbestos was used in construction, which makes renovation difficult. Finally, at the end of the building's life-cycle, there is no incentive to harvest demolition waste because of technical and economical limitations. Today, most new developments are still built in the same ‘traditional’ materials and construction methods. In 50 years time these buildings too will be outdated when confronted with new building standards. They won't adapt to changing demographics and won’t be harvested for materials. We still don’t use local renewable materials in construction that comply with today's building standards and also stand the test of time.

As a negative consequence of its urban planning, Boerhaavewijk became a self-centred (Gemeente Haarlem, 2019a) and unwelcoming neighbourhood. It is surrounded by wall-like apartment buildings, canals, busy roads and underutilised green space and there is a lack of activity on street level because of the separation of functions. The Floris van Adrichemlaan forms both a physical and social barrier splitting Boerhaavewijk in two, because of its width and how it separates social housing from privately owned housing (Gemeente Haarlem, 2017). Finally, the repetition of ‘stamps’ of mass produced buildings and the lack of qualitative architecture have a negative effect on the recognisability of the neighbourhood. The architecture and urban design of Boerhaavewijk promote anonymity, instead of social cohesion and a strong identity.

Objective

In order to foster social interaction, Boerhaavewijk needs new community spaces. This can manifest in a building such as a suggested ‘Commons College’ (Bolhuis, 2022). We propose for this building to become like a *metaphorical* Greek agora or Roman Forum: a public space in the centre of the ‘city’ of Boerhaavewijk where the commercial, political and recreational spaces find a common roof. As such it is a deliberate proposal to distance ourselves from the heavy handed separation of function as heralded by CIAM. Furthermore we want to prevent repeating the mistakes of industrial buildings by applying the concept of ‘Open Building’ as suggested by Habraken in the 60s and the concept of ‘Shearing Layers of Change’ by Stewart Brand (Open Building, 2021). Buildings should be designed with a separation between ‘support’ and ‘infill’, where different layers of a building have a specific technical lifecycle. While the ‘support’ will remain the area of expertise of the architect, the (re)design of the ‘infill’ should become more accessible to the end-user. This will require investigation in materials and construction methods that enable mass-customisation.

The intent is to locally harvest materials such as steel to create a circulatory constructed load-bearing ‘support’ for our proposed building, which will enable a long technical life-cycle. An interesting source for material is Schiphol, which recently started reusing its demolition waste in order to reach zero-waste in 2030 (Schiphol, 2021). A possible source could be the temporary department hall that will be used until 2023 (Schiphol, n.d.). For the creation of ‘infills’ the technique of 3D printing, either on-site or for prefabricated elements, with sustainable materials such as earth is promising. Earth is suitable for the shorter but more flexible life-spans in the ‘layers of change’ because it can be recycled over and over again in the printing process. 3D printing itself supports the goal of mass-customisation because it automates construction. The ‘support’ can then be filled with 3D printed ‘infills’ such as a ‘skin’ and ‘space plan’ made out of local materials. Sand and river clay for example can be found along the river Spaarne (Gemeente Haarlem, 2019c). Another source of material could be ‘bagger’ or dredge which renews at a rate of around one centimetre a year in this area and is a waste product from deepening waterways (Rijnland, n.d.). This mud-like material can undergo ripening processes to turn it into loam (Rijksoverheid, n.d.), which might prove suitable for 3D printing and construction.

As a public building exemplifying the transition to a sustainable and flexible built environment, the building should not just showcase that the building is technically feasible. It has to go a step further and fulfil an ambassador role. To do so the building will benefit from making a strong architectural statement and exploring the ways materials such as earth can contribute to that. By becoming an architectural icon in Boerhaavewijk it hopefully will strengthen the neighbourhood's identity and become a point of attraction, as was originally planned for the buildings along the Floris van Adrichemlaan.

Overall Design Question

Following the stated objectives, the overall design question is:

How to design an iconic and sustainable forum in Boerhaavewijk that can adapt to changing demographics?

Thematic Research Question

For the thematic research question we will develop a specific aspect of the overall design question in the architectural engineering 'make' theme. In this case research is needed on 3D printing earth for the creation of well insulated 'skin' 'infill' facade elements useful for a sustainable built environment. Thus the research paper will be more generic than specific to the context of Boerhaavewijk.

Earth has a long history as a building material. It is known under names and recipes such as loam, adobe or cob and can be found all over the world. Earth benefits from low embodied energy in its use because it needs no firing, nor cement, limiting its CO_2 footprint too. Furthermore earth is recyclable which allows it to be reused in future developments. Using additive manufacturing (AM) processes, a method of 3D printing, material usage can be reduced through optimisation while simultaneously form-freedom can be explored. Every element in AM can be unique without incurring additional cost to the manufacturing process, enabling mass-customisation. Since in AM the construction process is mostly automated, its potential cost-effectiveness in reducing labour shouldn't be discounted either.

Although the theoretical benefits towards sustainability of using both earth and additive manufacturing in modern construction are manifold, there remains the challenge of its implementation under contemporary building standards. It is necessary to understand the impact AM earth has on the function of a building envelope and in particular on reducing energy usage through effective insulative properties since earth itself has a very low R-value.

Following the stated objective of the research, the overall thematic question is:

How is the optimisation of an additive manufactured earthen facade for insulating capability reflected in its architectural morphology?

Furthermore the following sub-questions are formulated:

What are the advantages and disadvantages of additive manufacturing of earth?

What are the requirements for a functional facade?

How to measure heat transfer through a facade?

How to optimise the insulative capability of earthen facades?

Thematic Research Methodologies

In order to answer the overall thematic question we first need a firm grasp of different areas of knowledge. The sub-questions will help collect the necessary qualitative and quantitative information through state of the art literature research. The first sub-question will result in an understanding of in which cases AM can be considered a useful approach towards working with earth as a building material, discussing subjects such as infill patterns, compressive and tensile strengths, etc. The second sub-question aims to create a list of requirements and parameters influencing the effectiveness of the facade, such as vapour control, waterproofing, insulation values and wind loads. The third sub-question is formulated in order to list the principles and equations that are needed to evaluate the properties that affect heat transfer. It will also elaborate on the use of the software THERM to analyse heat transfer in horizontal sections. The fourth and last question will elaborate on the optimisation process of the AM earthen facades through generative design. Possible objectives and parameters will be discussed in the context of the visual programming interface Grasshopper.

Finally then, the main question can be attempted to be answered. This process is centred in the episteme of morphology, which is the study of the evolution of form in the built environment. Because the theme of 'make' was chosen for the research, this will be implemented through research by design. Different prototypes of AM earthen facade structures will be designed and their insulative capability evaluated through heat transfer simulations. Since it will be impossible in the time-span given of the research plan to do this in full scale mock-ups, we will simulate this using THERM, which can be integrated in Grasshopper in order to optimise the designs.

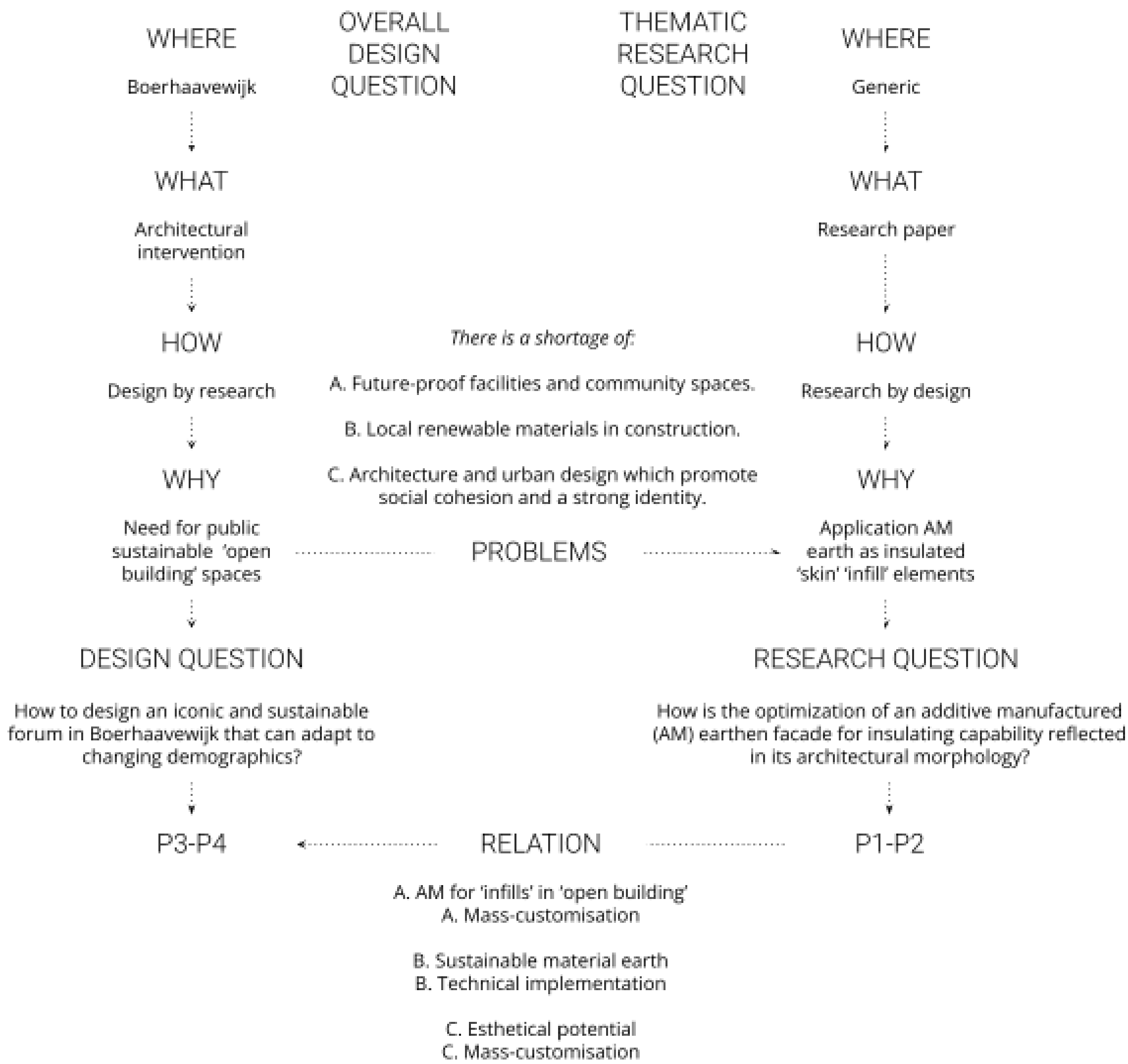
The results of the research plan will be presented in a matrix in which different AM earthen facade structures can be compared. Both on their respective quantitative parameters such as width, R-value, etc., but also on qualitative information such as appearance.

Relevance

The graduation design project touches upon problems that are specific to Boerhaavewijk. However, at the same time this location is a microcosm of post-war neighbourhoods found all over the Netherlands. That is because of the CIAM guidelines the post-war neighbourhoods followed when designed and built, resulting in an incredibly high rate of similarity throughout the country because of standardised building systems and repeated 'stamps'. Thus, the problems tackled during the design research concern not just Boerhaavewijk, but potentially similar sites undergoing technical ageing of the building stock and changing demographics.

The thematic research into additive manufacturing of earthen building envelopes is relevant in contemporary scientific research. In recent years there can be a major uptick observed in the number of published papers concerning the additive manufacturing of earth, as well as a great progress in the actual application of it in structures and buildings. However there is still more research needed on its application in modern housing. Being able to understand the thermal performance of AM earthen facades is of great relevance to its application under real world conditions. Although understanding such technical properties of earth are essential to pivot towards a sustainable built environment, a better understanding of its appearance and esthetical design potential as a result of the AM process will be crucial to get the material, nowadays not even considered for modern building, socially accepted and approved by both designers and users.

Research Plan Diagram



Planning

CALENDAR WEEK	TEACHING WEEK	DEADLINES & ACTIVITIES	DESIGN	RESEARCH
45	1.10	P1 + RP Presentation	Prepare P1 slides	Submit Research Plan
46	2.1	Boerhaavewijk excursion	2nd Location visit	Literature study
47	2.2	Table meeting		Scripting
48	2.3		Site analysis	Literature study
49	2.4			Scripting & scale models
50	2.5		Site analysis	Literature study
51	2.6	Table meeting		Scripting & scale models
52	Christmas			
1	Christmas			
2	2.7	open building excursion	Draw conclusions	Prototype 1:1 fragment
3	2.8		Finalise program of requirements	Finish Research Paper
4	2.9	P2 Presentation	Prepare P2 slides	Submit Research Paper
5	2.10	P2		
6	St Nicholas'			
7	3.1	Excursion 3D printing?	Establish design concept	Apply knowledge Paper
8	3.2		Investigate material flows	" "
9	3.3		Research 'support' structure	" "
10	3.4		Research 'infill' structure	" "
11	3.5		Sketch design mass model & climate concept	" "
12	3.6	Table meeting?	Sketch design floor plans & sections	" "

13	3.7		Sketch design fragments & details	" "
14	3.8	P3 Presentation	Prepare P3 slides	
15	3.9	Excursion 'bagger' use?	Construction planning	Apply knowledge Paper
16	3.10	Table meeting?	Finalise design	" "
17	4.1		Finalise technical drawings	" "
18	4.2		Finalise concept drawings	" "
19	4.3		Finalise impressions	" "
20	4.4	P4 Go / no-go assessment	Prepare P4 slides	
21	4.5	P4		
22	4.6	P4		
23	4.7		Finalise products & additional models	
24	4.8		" "	
25	4.9	P5 Final public presentation	Prepare P5 slides	
26	4.10	P5		
27	4.11	P5		

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