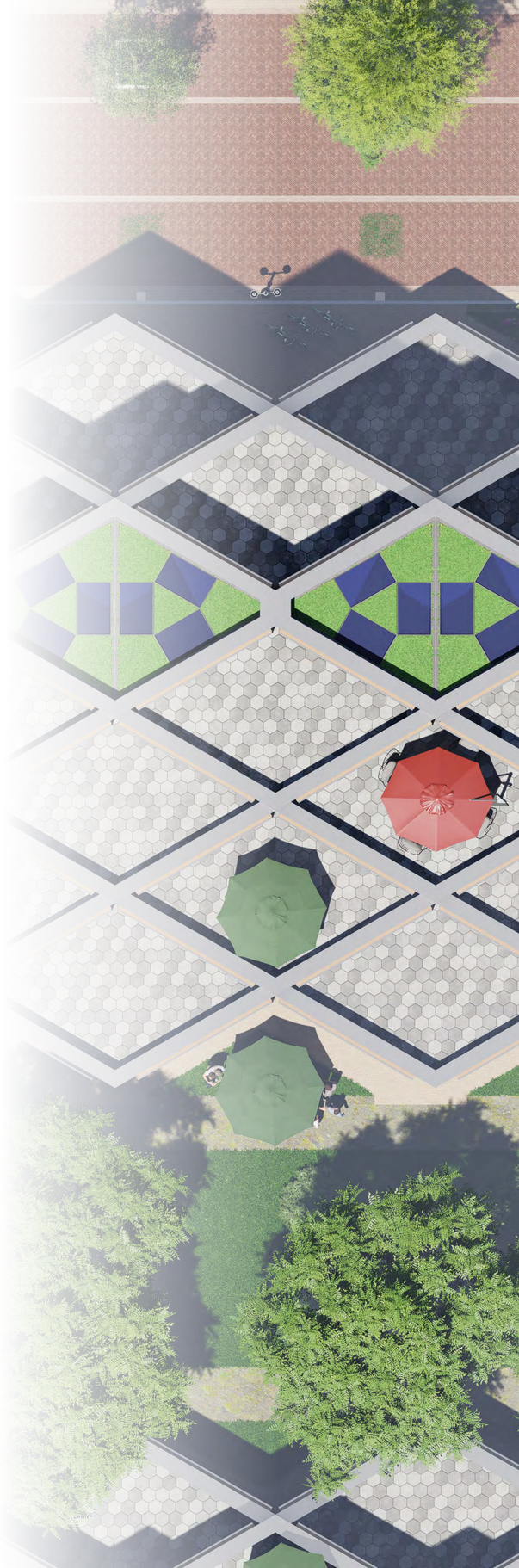
Architectural Engineering Graduation Report A3

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The capacity of the built environment to respond to change is increasingly important as housing demand, land-use pressures and societal needs continue to evolve. Dutch post World War 2 ‘stamped’ neighborhoods demonstrate both the advantages of systematic construction and the limitations of urban structures designed around fixed uses. Urban and structural repetition enabled rapid, affordable construction, but often produced stagnant environments with limited capacity for change.

By revisiting the logic of the architectural ‘stamp’ and combining it with adatability as fundamental building principle, the research investigates how repetition might support diversity rather than monotony. Through a multitude of design philosophies, such as: stamping, open building, shearing layers and metabolism, a tool was developed able to insert an adaptable urban structure capable of adjustments in size, division, function and appearance.

The proposed approach does not attempt to anticipate every future requirement. Instead, it seeks to establish a framework pr re-imagining of large scale urban developments in which urban spaces can continue to serve society and avoid a recurring cycle of obsolescence, demolition and replacement

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Introduction

Current situation

The Netherlands is currently facing significant challenges in its real estate market. An increase of 10% of the total housing stock is expected to be necessary for adequately housing the population (Rijksoverheid, 2025). Increased pressure on land use, combined with long-term projections of growing inequalities and ongoing population growth, could result in drastic further suburbanization and a continued loss of unbuilt landscapes (Dellar et al., 2024). These trends raise concerns about sustainability with the current approach to realise the built environment.

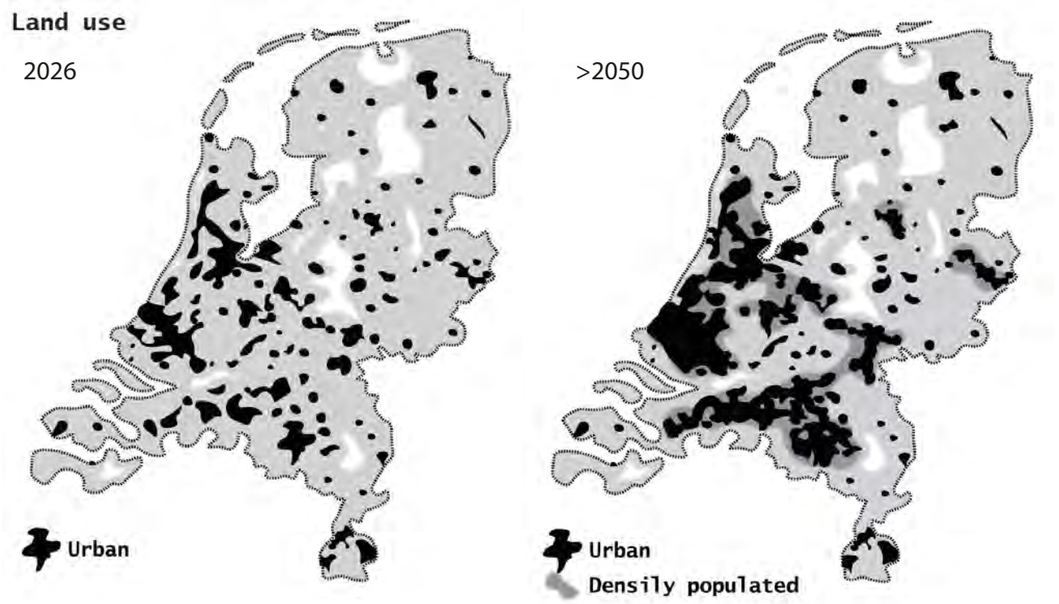


Figure 1, Visualisation expanding urban areas and strain land use.

Urban areas developed after World War 2 have faced similar challenges in great housing needs on a tight budget. The approach taken commonly followed the “stempels”, stamps, ideology. These consist of small communities which would each function distinctly, akin to a small village but unite for general amenities and leisure in the urban core (Ibelings, 1999).

The stamps fit together and tile to fill the plane. Larger arrangements of stamp combinations form these communities and are surrounded by large arterial roads or green spaces. The potentially unlimited repetition had two sides. It formed the basis of an interesting spatial rhythm, but it became the foundation of monotony as well. This development was caused by the fact that, from 1960 onward, urban development increasingly came under the influence of construction economics. Concepts such as upscaling, cost-efficient construction, continuous building processes, and the use of construction cranes imposed new requirements on the design of the city (Blom et al., 2004).



Figure 2, Urban Design Pendrecht (1949- 1953) by Lotte Stam-Beese, april 2, 2019, https://www.metalocus.es/en/news/lotte-stam-beese-urban-planner-bauhaus

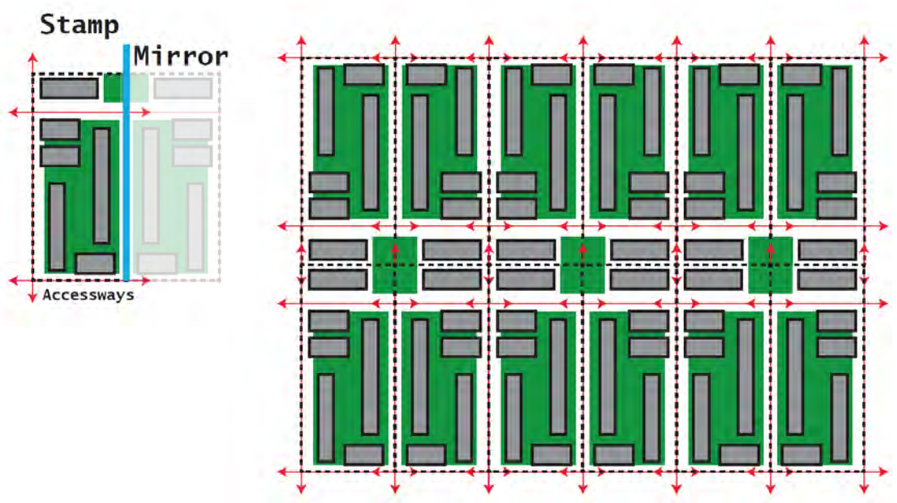


Figure 3, Repeated tesselation stamp, with mirrored pattern.

Introduction

Post 65 neighborhoods and flexibility

On an urban scale, monofunctional areas, developed into the urban fabric after World War 2, are underperforming. Single use districts often experience significantly higher vacancy rates and weaker social cohesion (Remoy & De Jonge, 2009). In the 1960s, a grim prediction to these areas was already given by Jane Jacobs in *"The death and life of great American cities"* (1961), she describes that both district and city as a whole must be made from a mixture of uses, to be able to adapt.

Many of these post-war monofunctional areas have become the focus of large-scale redevelopment initiatives, including well-known examples such as the Bijlmermeer. However, adapting the existing built environment remains a complex and costly process. Many buildings are poorly suited to functional change due to their monofunctional position, and misalignment with contemporary building regulations. Therefore renovation costs can approach or overtake total redevelopment costs (Remoy, 2009). This lack of adaptability complicates sustainable renovation efforts, as inflexible structures hinder transformation.

Moreover, the real estate market demonstrates a limited capacity to respond swiftly to changing societal demands. Misalignments between supply and demand persist, causing housing shortages, increasing prices and making 1.8 million households experience a mismatch in dwelling typology (Van Dijk, Van Rooij, 2023). A lack of flexibility remains present in the built environment on various scales. Where monofunctional environments cannot adapt to either the change of an individual or to broader changes in society.

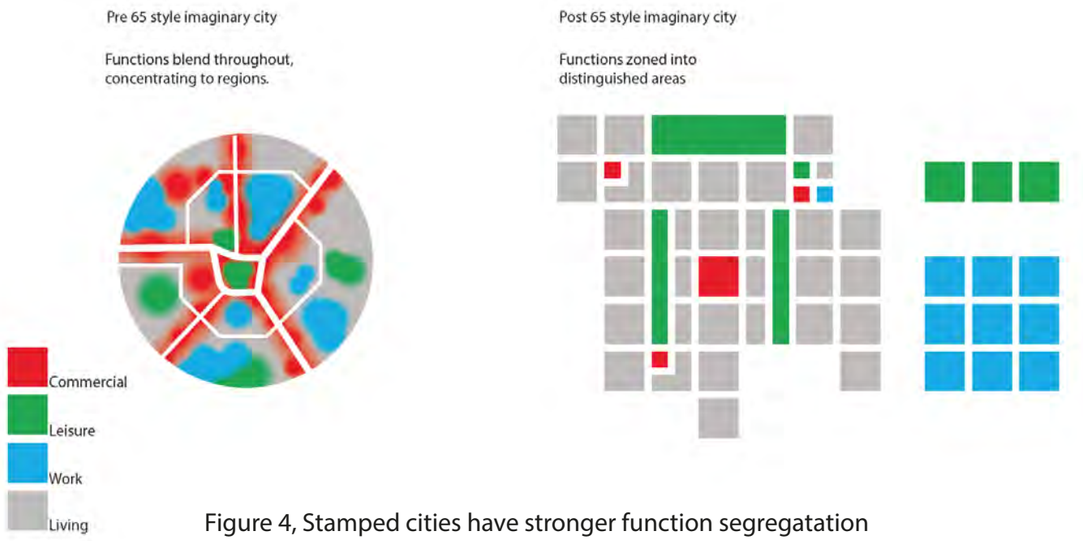


Figure 4, Stamped cities have stronger function segregatation

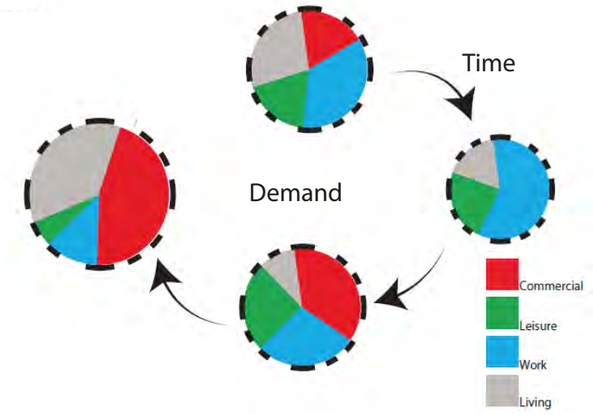


Figure 5, As societal demands change, local building stock has to adapt

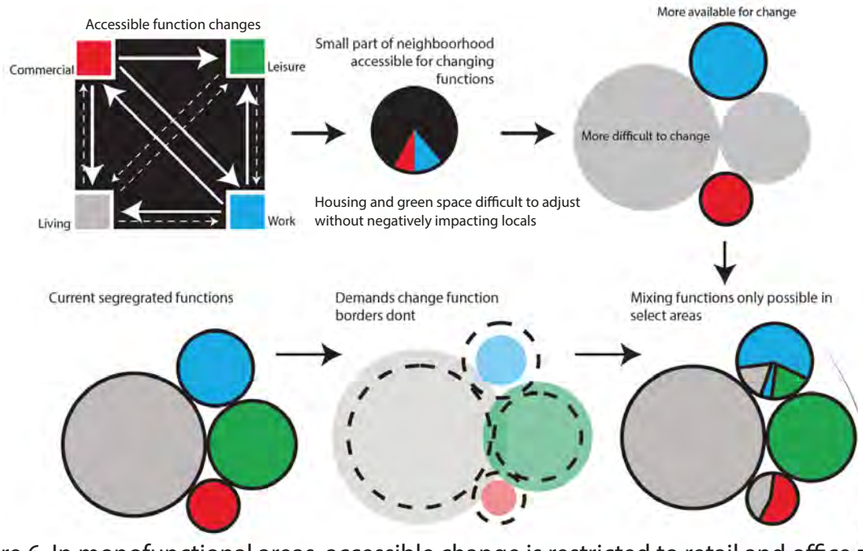


Figure 6, In monofunctional areas, accessible change is restricted to retail and office zones. These remain accessible to change without the displacement of locals.

Motivation

Well-documented cases of unsuccessful large-scale post-1965 housing developments have raised my interest in the past. The Bijlmermeer in Amsterdam was conceived as a comprehensive solution to the challenges of the built environment, and was presented as the pinnacle of modern living at the time of its construction (Wassenberg, 2011). The plan featured a doubling of the average dwelling size, an abundance of publicly accessible green space, and a strong integration of public transport and amenities. Using hexagonal stamps, a few well designed elements could generate an entire city. Despite these seemingly well-founded principles, the development ultimately failed.

As societal conditions and housing demands evolved, and amenities, transport and third spaces were executed late or more soberly than planned, the rigid spatial and structural framework of the Bijlmermeer proved incapable of accommodating change. This inflexibility contributed to social decline and eventually led to large-scale demolition, resulting in significant emotional, financial, and environmental costs (Wassenberg, 2011). The project aimed to solve past problems yet after completion was unable to face future problems due to a lack of adaptability.

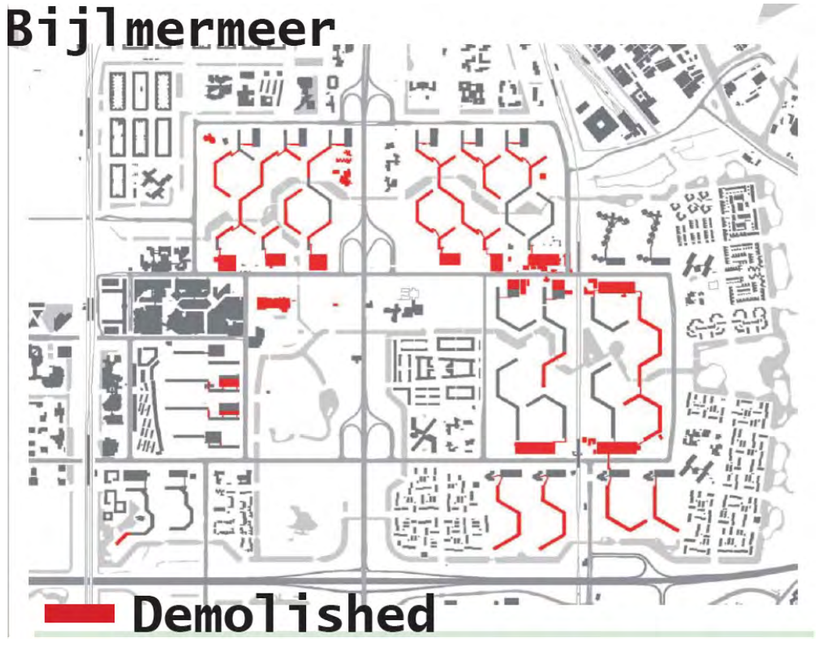


Figure 8, Large scale redevelopment has taken place in the Bijlmermeer, edited, from Wassenberg, 2011.

Relevance

While the role of the architect is not to alter and aim to solve policy directly, they can alter the course of the built environment through materializing activism. Addressing and examining the challenges at stake. .... , to finally consider the spatial and social impact of particular developments on society (OASE 116l, Journal for architecture, 2023). In this context it is the duty of the architect to respond to issues in the built environment, as present buildings will still form >50% of the built environment in 2065 (Wilkinson & Remoy, 2018). Yet many inflexible buildings and districts face great challenges reaching the theoretical end of their structural lifecycle before redevelopment.

The unadaptive nature of past developments strengthens the strain on land use. A more sustainable approach to land use could be found within higher levels of flexibility. Embedding mass flexibility in future design approaches may offer pathways to prolonging the lifespan and use of these urban districts, buildings, and materials. Moreover, such strategies could enable the real estate system to respond to and support societal change rather than hinder it, thereby contributing to improved quality of life and enhanced sustainability in these often troubled neighborhoods.

Stamped neighborhoods are surrounded by a negative stigma in the media (Blom et al., 2004), perhaps it is not the principle of the stamp but rather the shape and filling that have resulted in unwanted outcomes. Rethinking stamp philosophy could improve both design and construction.



Figure 9, Structures in the Bijlmermeer have difficulty adapting, edited, from Wassenberg, 2011.

Site and history

Post 65 neighborhood Woensel

Woensel developed rapidly after World War 2. The new stamped neighborhood took little consideration for the predating built environment and older structures were either lost or severed. Woensel rose to be the largest neighborhood of Eindhoven with a population of >100.000 (CBS, 2026). Currently, Woensel faces similar issues as other monofunctional post World War 2 neighborhoods lacking adaptability. Woensel offers little space for change, as the majority of land spent on stamps has a heavy focus on low rise dwellings. The stamps used in Woensel are designed with some room for later adjustments, however most of this remaining leftover space was promptly used for high density housing (Kadaster, 2026). And as such little space remains available for new development or later adjustments to the structure. Changes either involve sacrificing green space or replacing occupied structures. Later areas of Woensel discontinued 'stempels' for 'Bloemkoolwijken', aimed to tackle issues such as the repetitional flaws of square tessellations. These areas continue to have similar spatial challenges regarding redevelopment (De Graaf, 2012).

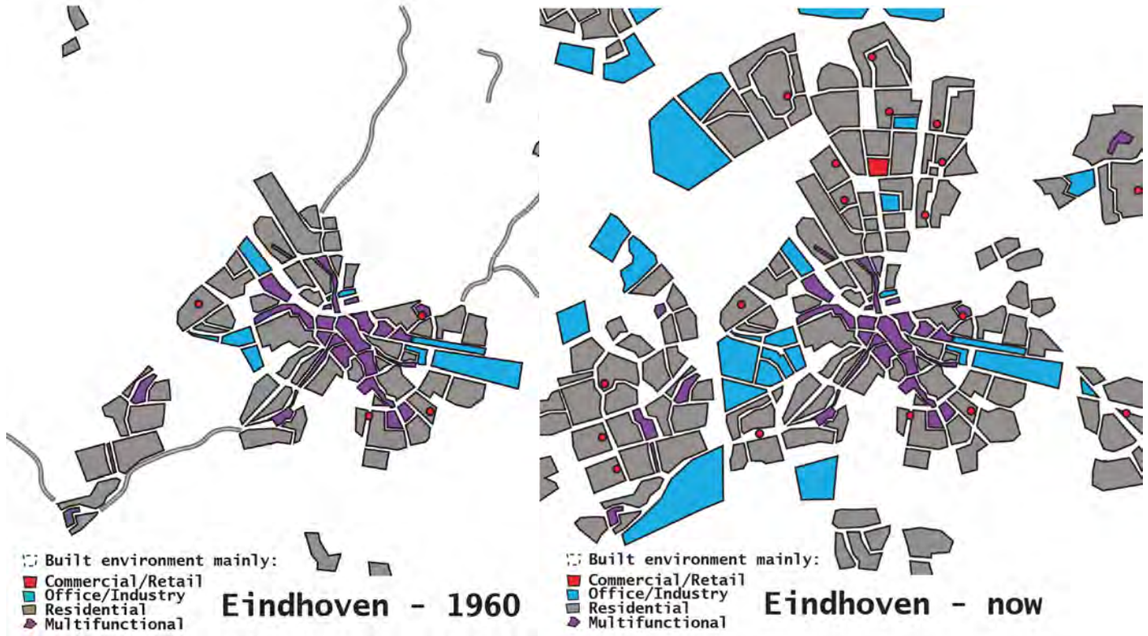


Figure 11, Post 65 developments have fewer multifunctional areas.

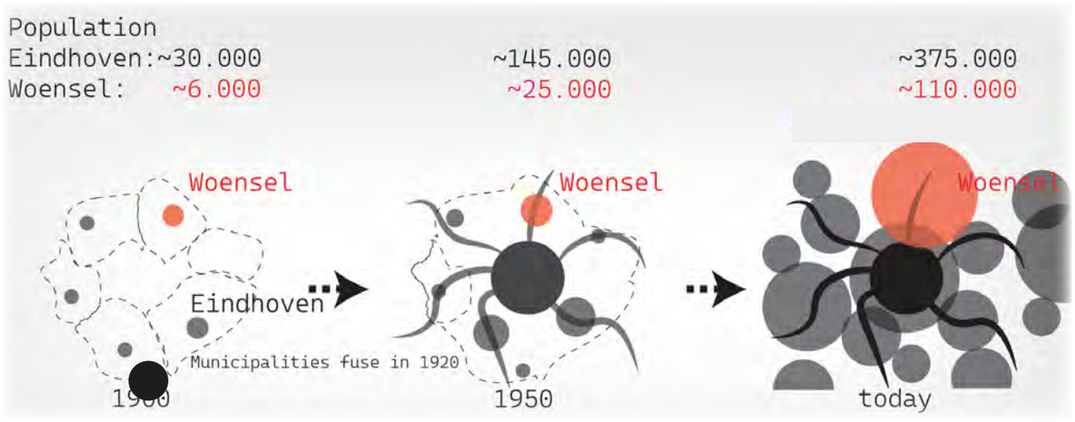


Figure 10, Growth of Eindhoven and neighboring villages.

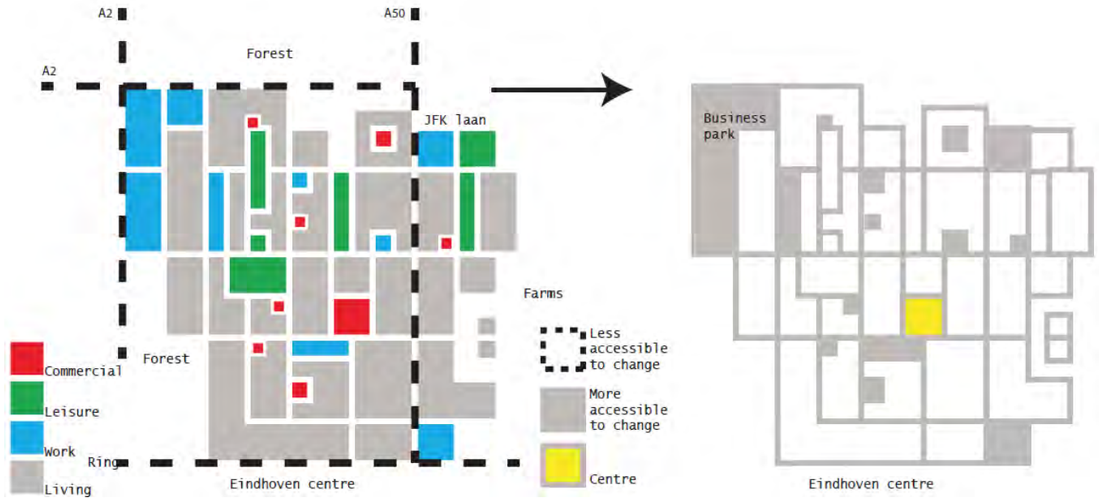


Figure 12, Woensel has little space left accessible to adapt.

Site and history

Woensel urban core

In Woensel a large centrally located territory spanning 400 by 400 meters, mostly surrounded by large arterial roads, forms the intended urban centre of Woensel. The central meeting place for all stamped ‘villages’. The multifunctional plan by Broek & Bakema from the 60’s was ambitious. At the time it would have been the largest planned centre in the Netherlands, with access to shops, work and third spaces (Crimson Architectural Historians & Urbanists, 2024). Eventually the plan was executed in a vastly reduced scale, Mainly public functions, mixed use and amenities were scrapped. Losing various elements such as cinemas, office towers, public centres and squares. What remained was an American-inspired outdoor shopping mall, too importing the transport philosophy. Arrive by car, and walk within the premises. Resulting in surface parking covering more than half of the site's area.

By the turn of the century WKC Woensel experienced greater financial difficulties and lower social cohesion, initiating redevelopment. The redevelopment took place from 2003-2006 (Crimson Architectural Historians & Urbanists, 2024). Covering the original concrete structure in black brick, narrowing entrances, adding cover and rebranding to WoensXL. Furthermore, improvement of social cohesion was attempted by introducing new residents directly in the area through 3 new apartment buildings, the tallest of which, Portos, being over a 100 meters tall. 20 years later similar issues persist and the municipality of Eindhoven is drawing plans for redevelopment of the area once more, with the ambition to resolve ongoing issues, from site specific to regional. These include low social cohesion, economic struggles of both the neighborhood and site, plus the ongoing housing crisis. (Gemeente Eindhoven, 2026). The municipality plans to add over 3000 homes, decrease retail space and increase third spaces to solve the local issues of the present time.



Figure 15, Modern day approach to WoensXL, from the west,
from Crimson Architectural Historians & Urbanists, 2024

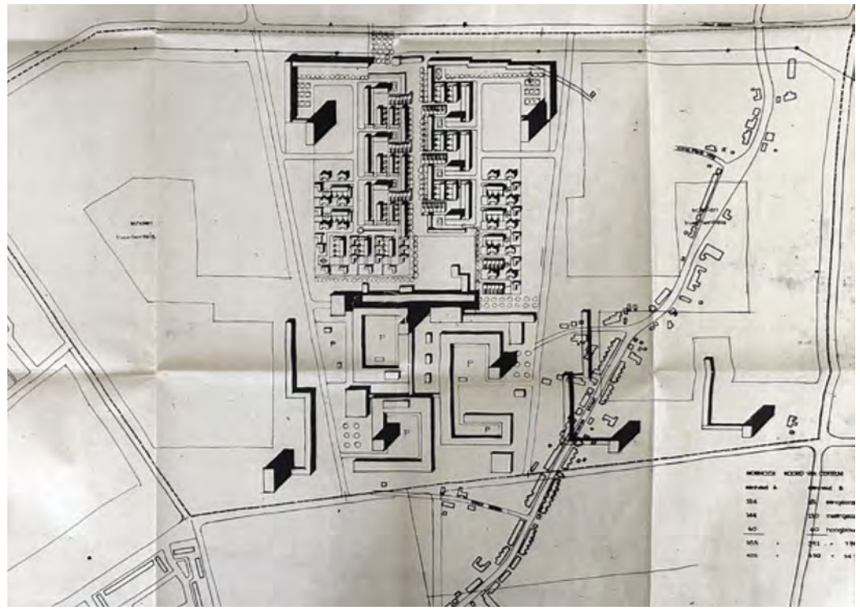


Figure 13, The original plan by Broek & Bakema, 1962 (RAE), edited from Crimson Architectural Historians & Urbanists, 2024, The plan neglects former structures. Ambitions for the centre were turned down and the structure went from from 3 ‘G’ to 4 ‘J’ shapes



Figure 14, 70’s Aerial image of WKC Woensel from the north, foreground ‘t Hooi,
a stamped neighborhood, also designed by Broek & Bakema,
rom Crimson Architectural Historians & Urbanists, 2024

Objective

WoensXL provides the largest centrally located plot of land in Woensel in ability to be reconsidered. Improving the currently unsuccessful urban core can provide benefits to all residents in Woensel and the general Eindhoven metropolitan area. An attractive urban core in Woensel could relieve Eindhoven's centre, and could share Eindhoven's ongoing rapid growth in both visits and investment (Hoekstra, 2026).

There should be careful considerations in the approach of solving these issues surrounding WoensXL. Since the stamps have been locked in monofunctionality little space is available in the neighborhood for redevelopment, kept to the fringes of wide roads, outskirt business parks, hospitals and shopping centres. The built environment that is currently present, once too, was constructed in a way which would tackle issues of their time. However an unadaptable built environment will be stressed over time as it will be unable to adjust to change in society. New developments in locked monofunctional areas should maximise adaptability as a measure to not further restrain space for future unknown matters and allow future adaptation and sustainability of these areas.

This research aims to introduce mass adaptability through combining multiple strategies of architectural flexibility, with a focus on application in vulnerable monofunctional post-war neighborhoods in the Netherlands. The tool offers a revision of underperforming monofunctional areas absent of housing, aiming to aid without the displacement of local residents. The tool will be applied on Woensel creating an alternative to the urban core that will be providing an adaptive and sustainable design. Strong adaptability in the urban core will feedback throughout the neighborhoods stamped 'villages'. The development of a design tool capable of combining various ways of flexibility is central to the project.

The flexibilities included are scalable, refitable, adjustable and convertible. These tools will be tested, through prototyping, and be combined into a single adaptable structural model. The centre of Woensel experiences adaptability issues on 4 different levels. Creating the main project goal: a design that will consist of a space filling structure, providing a multifunctional role as urban core, that responds to changes in society through future adjustments in size, division, function and appearance.

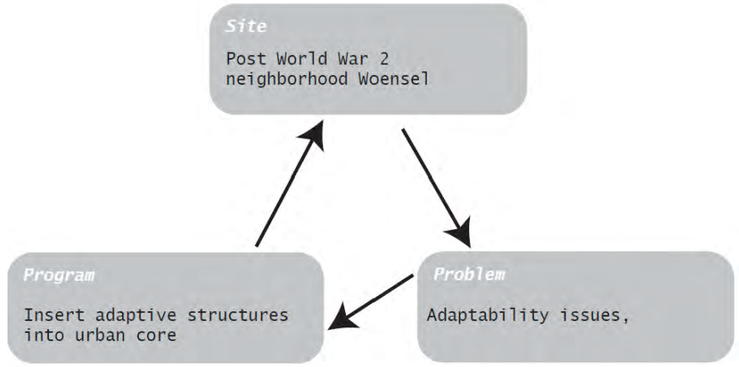


Figure 16, Relationship between problem, program and site.

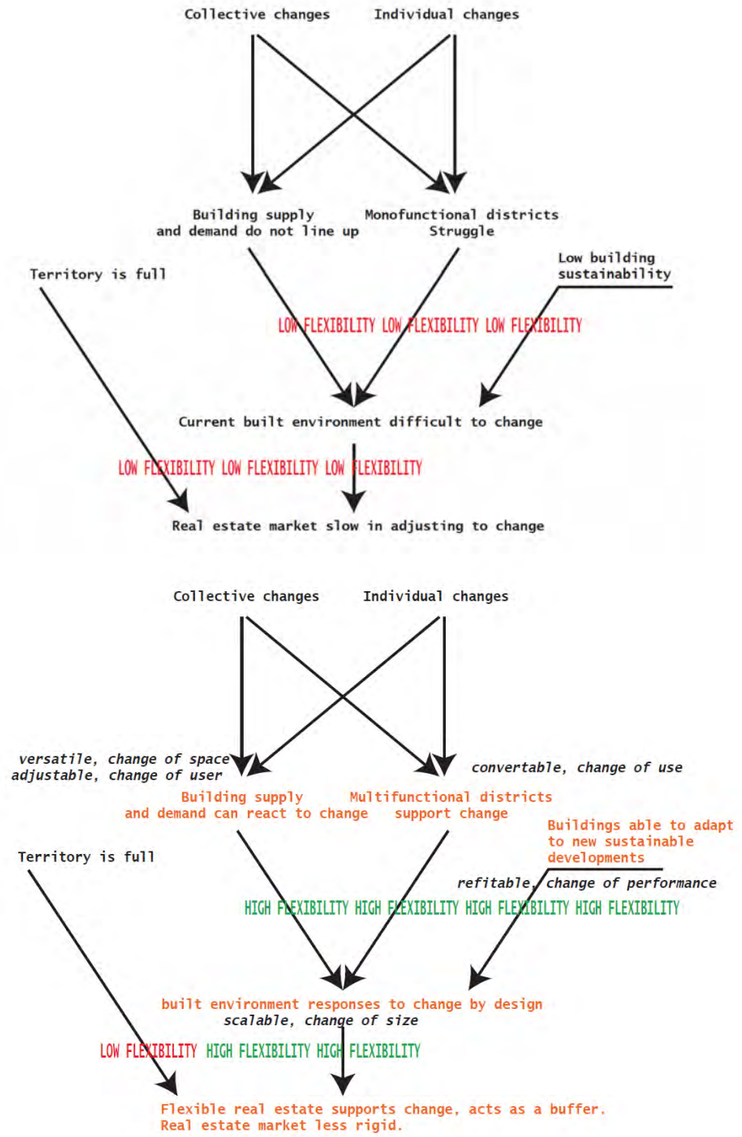


Figure 17, Insertion of flexibilities may improve adaptability in urban environments.

Research and design questions

The main question *"How can the town center of Woensel provide the adaptability needed for Woensel to adapt to changes in society?"* will be supported through subquestions.
Previously discussed shortcomings in the design of Woensel have briefly touched on the first subquestion about site context and philosophy, *"How have philosophy and design methodology applied in Woensel affected flexibility?"*. Understanding previous shortcomings might give new insights in future solutions, aiding to create adaptive space filling models. Other subquestions relate to the 4 flexibilities that require exploration in the development of the tool.

"What generative approach to a space filling structure guarantees liveability, avoids monotony and encourages adjustments in size?" targets the 'stamp' structure and aims to discover a repeating structure able to generate large liveable urban plans without falling into monotony.

Where scalable flexibility materializes on a large urban scale, other flexibilities take place either in or attached to the structure itself. Refitable, adjustable and convertible flexibilities are dealt with through open building design approaches, building upon shearing layers and metabolic growth. Resulting in the subquestions: *"How can a building system provide for future adjustments in division to accommodate changes in society?"*, *"How can a building system provide for future adjustments in function to accommodate changes in society?"* and *"How can a building system provide for future adjustments in appearance to accommodate changes in society?"*.

The subquestions relate into 4 different design approaches achieving, sometimes overlapping, flexibility goals. These design approaches are open building, shearing layers, metabolism and stamping. Through prototyping these 4 different flexibilities will be combined into a design tool, and used on the site of WoensXL.

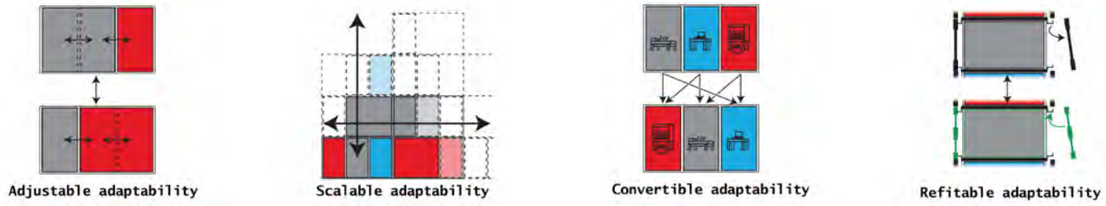


Figure 18, different kinds of adaptabilities.

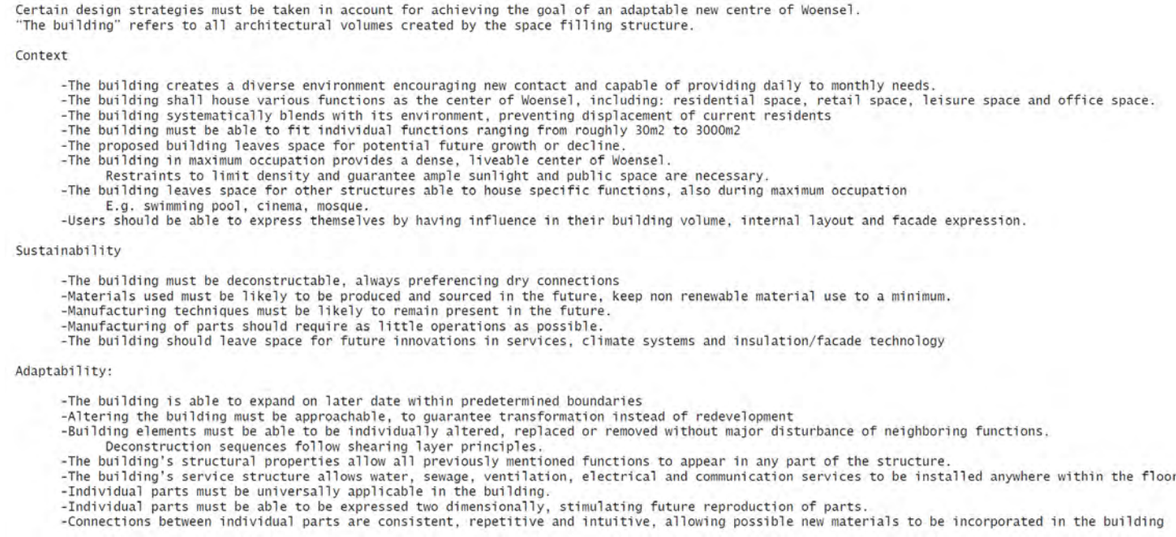


Figure 19, Insertion of flexibilities may improve adaptability in urban environments.

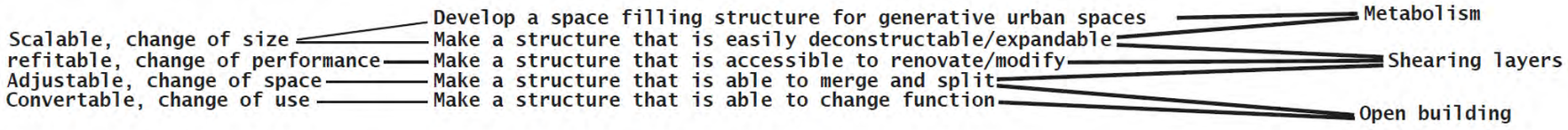


Figure 20 , Relationship between flexibilities, adaptabilities and building methodologies.

Scope

The selected plot of WoensXL is roughly a square with sidelengths of 400 meters. The developed tool will be applied on all areas free of housing, generating a new multifunctional adaptive urban core. Since total redevelopment will amount to >100.000m2, a spatial suggestion of functions rather than exact floorplans will be established. The urban plan will consist of various property shapes and multiple exemplary plans will be explored for each lot to test the effectiveness of the tool. Structures will follow open building adaptable floorplans, have the ability to alter in size and materialization, and be able to be manufactured at scale with sustainable manners. Manufacturing processes must remain accessible in the future, encouraging continued alterations to the proposed structure. Woensel paid little attention to the historic fabric. After application the stamped tiles will replace most of the structure of the current site. Present buildings and a fragment of old the shopping centre will be integrated to challenge the ability of the tool to wrap around current urban fabrics.

Sophisticated structures of transport systems will not be applicable on the scale of WoensXL. Further research has to be conducted into developing this tool into a holistic 'city builder' complete with long distance infrastructure such as rail, tram or car travel. The public transport hub of Woensel, on the southern side of the site, will remain unchanged and deemed sufficient. The wide roads surrounding the site will too remain unchanged. The tool will attempt to insert maximum adaptability in the neighborhood, while being bound to its site and integrating with local bike- and footpaths, enabling a low-car urban core. Altering large scale transport networks requires a complete and costly revision of neighborhood structures and could lower potential future applications of the developed tool, which aims to transform accessible space into dense adaptive neighborhoods.

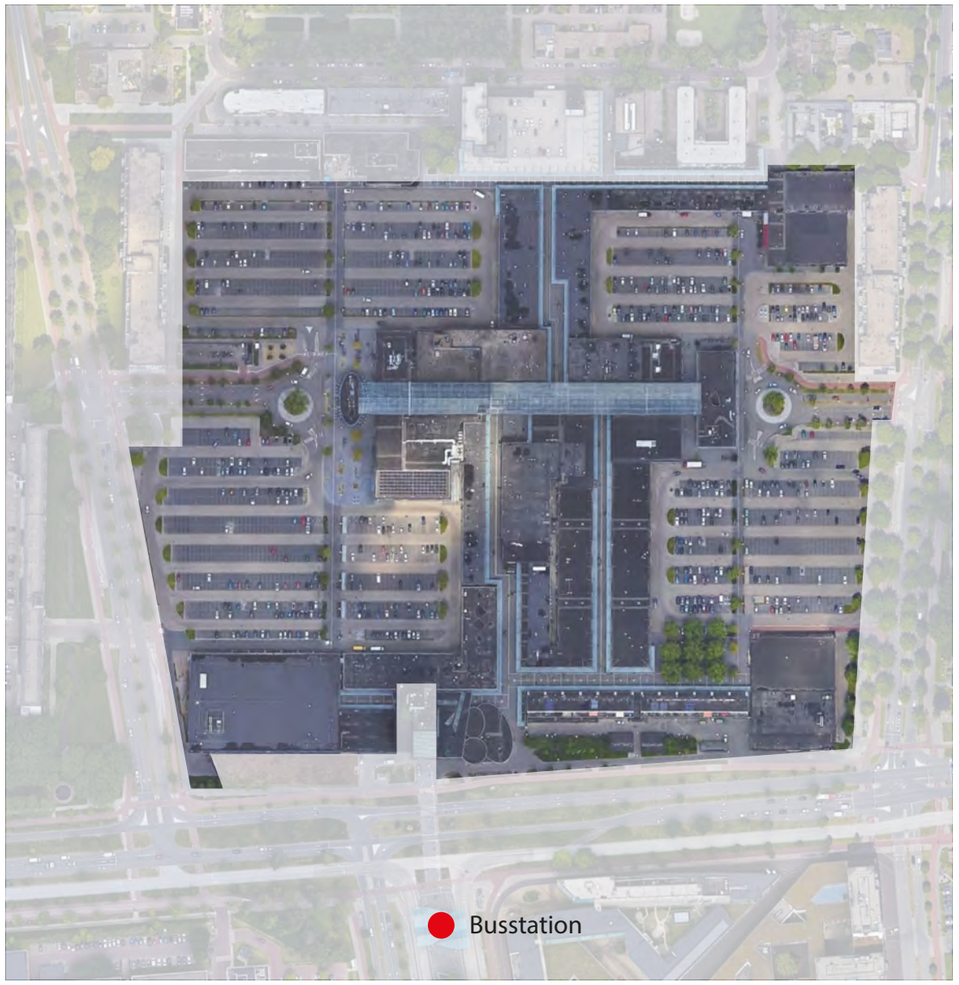


Figure 21, Total site, WoensXL witih the exclusion of residential areas, data from Google Earth, Woensel, Eindhoven, Netherlands [Satellite imagery]. Retrieved October 15, 2026, from https://earth.google.com/

Theoretical framework

Site analysis and stamped neighborhoods have been discussed prior.
More topics require a proper introduction as they determine many foundations for prototypes, analysis and design.

Flexibility, adaptability and 10R's

Robert Schmidt and Simon Austin have developed categories for kinds of flexibility to increase the adaptability of the building. With adaptability being defined as "the capacity for a building to accommodate effectively the evolving demands of its context, thus maximizing its value through life" (Schmidt & Austin, 2016).
The categories: adjustable change of user, versatile change of space, refitable change of performance, convertible change of use, scalable change of size, can be inserted in the previous diagram. The following diagram highlights the opportunity in system change when including these flexibilities. Providing opportunities in the built environment for the individual, region and planet.
Reframing the categories of Schmidt & Austin from the previous diagram, into design requirements for a structure of utmost flexibility, the objective, their benefits can be related to the 10R's of circularity developed by Jacqueline Cramer (2017), when considering the building as a product itself.

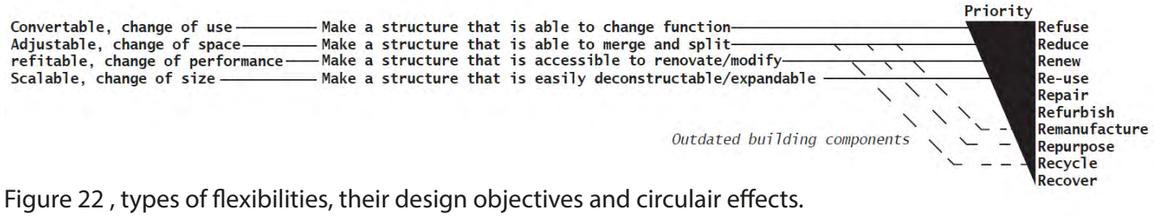


Figure 22 , types of flexibilities, their design objectives and circulair effects.

Metabolism and Structuralism

Metabolism began at Tokyo's 1960 World Design Conference . It conceived cities as organisms, combining lasting infrastructure with replaceable units, as in Kurokawa's Nakagin Capsule Tower (Schalk, 2014). The Dutch parallel is structuralism. Links between metabolism include repeated elements and provision for growth and change (Ioannidou, 2011). Van Eyck's Burgerweeshuis in Amsterdam (1960; Figure 23). Habraken's support/infill approach adds a Dutch model for independent change in housing (Habraken, 1961/1972).
Intended benefits encompass efficient modular construction, legible spaces and adaptability.. Future designs should be supported through adaptable structures with shared spaces, affordable replacement and realistic maintenance: Nakagin's capsules were never replaced during occupation (Ishida, 2017).

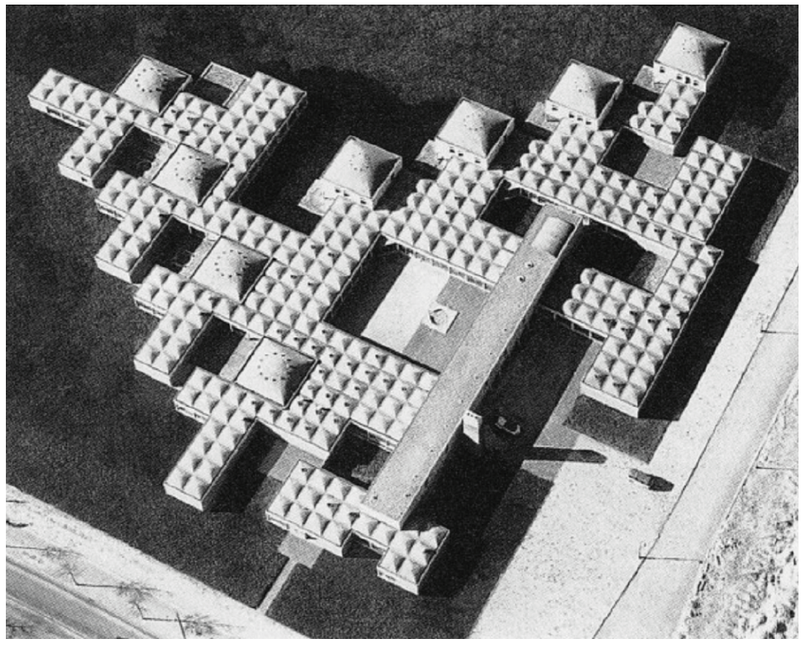


Figure 23. Burgerweeshuis. 24 February 1960, Aviodrome Lelystad - Luchtfoto archief

Theoretical framework

Open building separates durable shared supports from adaptable infill, while distributing design decisions among professionals and occupants. Dutch architect Habraken initiated its theoretical basis in 1961 through Supports: An Alternative to Mass Housing (Habraken, 1961/1972); the SAR research foundation subsequently developed the approach.
Applications include housing where architects design shared structures and residents influence partitions, kitchens, bathrooms, and later alterations.
As levels of control can accomodate independent change (Habraken, 2002).

Coordinated dimensions and interfaces support components with different lifespans. Benefits include resident autonomy, easier adaptation, and reduced disruption during refurbishment (Cuperus, 2001).
These principles suggest that architecture should combine frameworks, accessible services, and replaceable interiors, enabling buildings to evolve with their occupants.

Shearing layers describes a building as layers of components that age at different rates. Frank Duffy developed the layered view; Stewart Brand expanded it in 1994 into six layers: site, structure, skin, services, space plan and stuff (Brand, 2018; Figure 8). In architecture, this means distinguishing foundations and load bearing structures from façades, installations, internal division and furniture. Design considerations include accessible service routes, removable facade cladding and adjustable partitions, allowing refurbishment while retaining durable elements. Research identifies independence between components and reversible interfaces as important enablers of adaptation (Askar et al., 2021). Geraedts (2016) applies different component lifespans to assessing flexibility in offices and schools. Benefits can include longer building use, easier maintenance with less disruption and reduced material waste. Future designs should maintain access to frequently changing elements without hinderance of lasting ones,

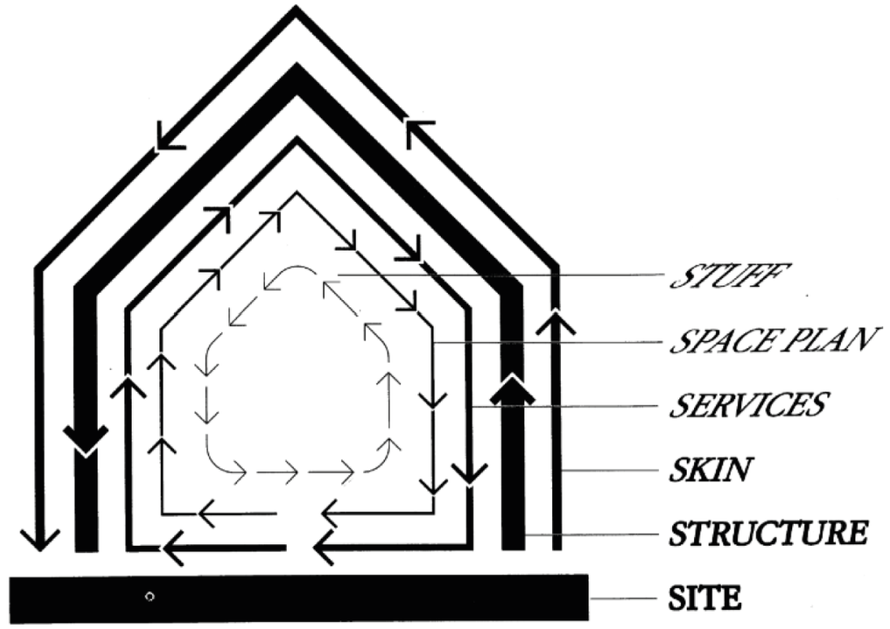


Figure 24. Diagram of shearing layers, Brand, 2018

Methods

The design tool that has been applied on WoensXL had to be extracted into various components. These components divided into scales are all bound by rules. These rules set up the basis for a generative metabolic structure.
A method of space filling structure for these rules to apply to is crucial. The chosen method must combat past downsides of stamping. Rules must be found in how stamps are tiled and modified. Zooming in, restrictions must be determined how the urban landscape can fill the stamp: from maximum density to sunlight access and building depth to street width. Finally rules must be established about the make-up of the urban volumes, from property lots and structure, to personalization and modification. Rules of these different scales influence each other. Scales rotate throughout the design process to intercept influences from rules in other scales. As such building elements combine in great numbers to organize themselves into structures. Structures are formed through a combination of rules from the space filling structure and the wishes of the user, these structures are subsequently organized into neighborhoods. Due to the repetition and interaction of parts found in these space filling structures, most spatial experiments have been conducted digitally. Physical models were unfavorable since prototypes require many duplicates in studying structures and relations. The definitions of the rules have been established through a compromise of case studies, literature and other influencing rules. Culminating in a minimum to maximum volume for the repeating stamp, and the building system for the space filling structure. Finally the tool was inserted into the site of WoensXL. Following a set list of integration points with the existing urban fabric the generative tool inserts a space filling blueprint into the site, with a suggestive urban volume. In practice it would be up to local government and demand to determine the exact functions, divisions and densities of the building volumes on the generated blueprint.

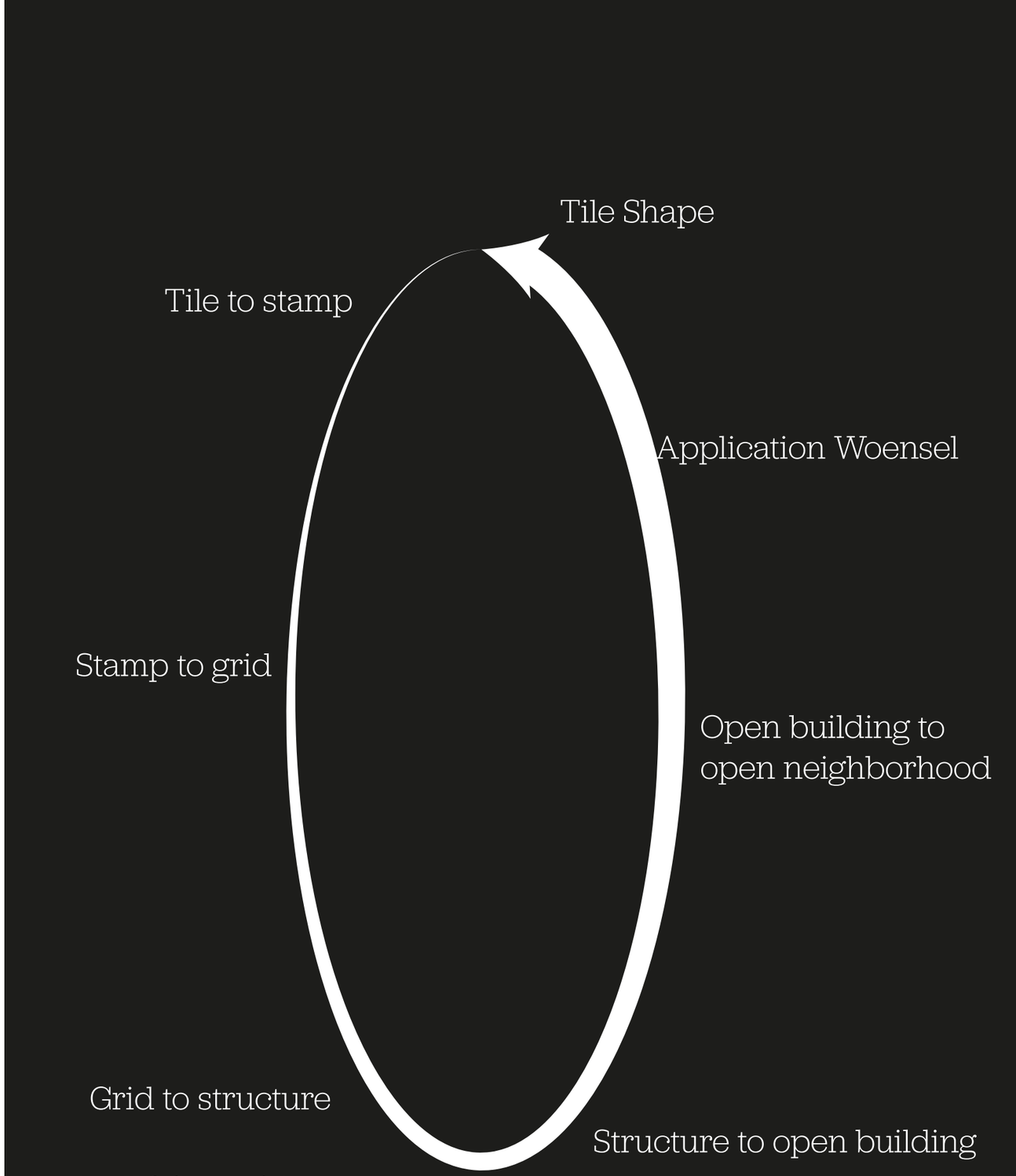


Figure 25. Cyclic process design.

"A design that will consist of a space filling structure, providing a multifunctional role as urban core, that responds to changes in society through future adjustments in size, division, function and appearance" is a multifaceted complex goal. Most design processes track a winding path, turning back on itself and readjusting, branching or converging, transcending disciplines and scales. Therefore the report may at times refer to information from later parts that influenced decisions in other parts of the design process.

Results

Tile Shape

Stamped neighborhood criticisms are an interesting paradox. Areas are both predictable and disorienting, with a low sense of place. Tessellations of squares, rectangles or hexagons are predictable. Many other methods for space filling systems exist. Such as crystal growth, cellular systems and fractals. These systems, however, showed in prototyping to require a large footprint before highlighting their structure and continue to remain predictable through symmetry. One repeated unit, that completely tiles the plane, while remaining unpredictable and varied throughout, is needed. In mathematics such a unit is called an aperiodic monotile. Various aperiodic tiles have been found by mathematicians. Such as the penrose tilings, Taylor-socola tile and Einstein tiling (Bruneau & Whittaker, 2023), named after the German ‘one stone’ not Albert Einstein. The Einstein tiling is based on a hexagonal structure, and does not require markings on the tile for achieving aperiodic properties. Arranging Einstein tiling following a precise hierarchical algorithm no specific tiling combinations can have translational symmetry and will even result in uncountably many tilings (Smith et al., 2024).

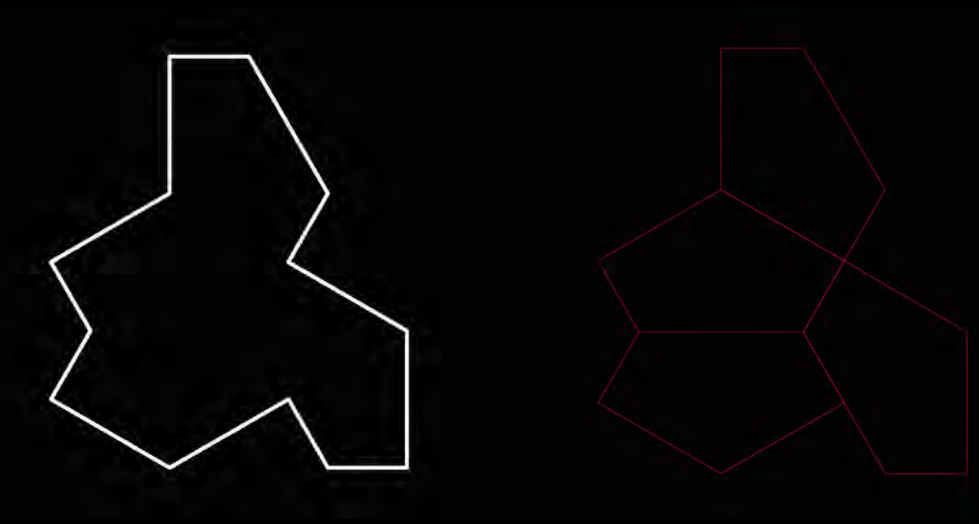
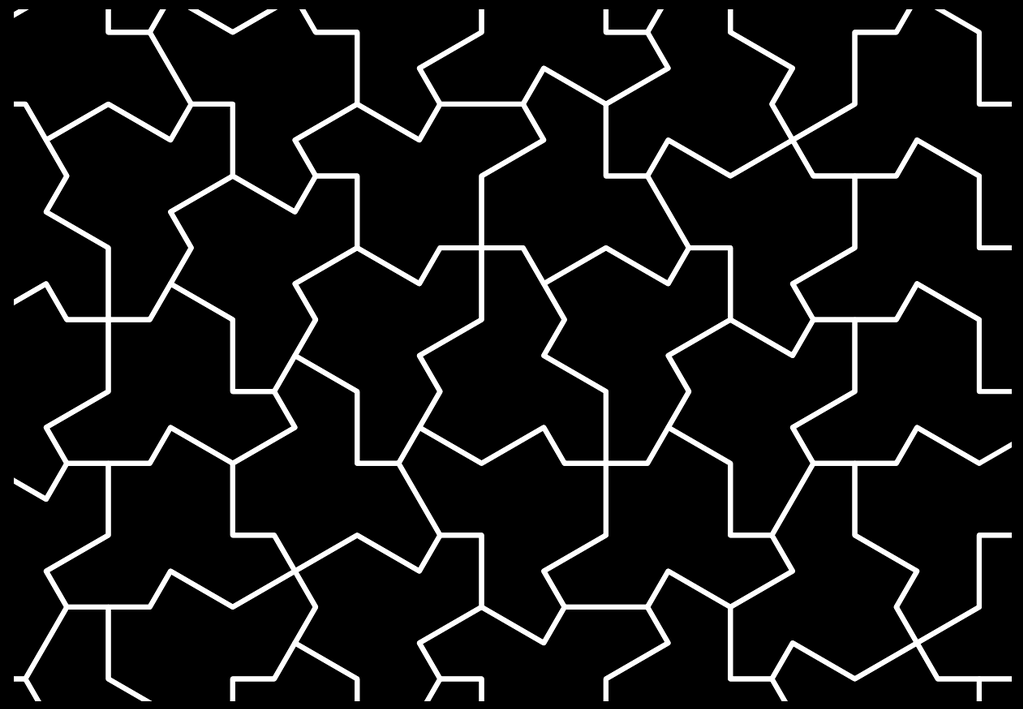


Figure 26. Einstein shape, and Einstein shape subdivided into 1/3rd parts of a hexagon



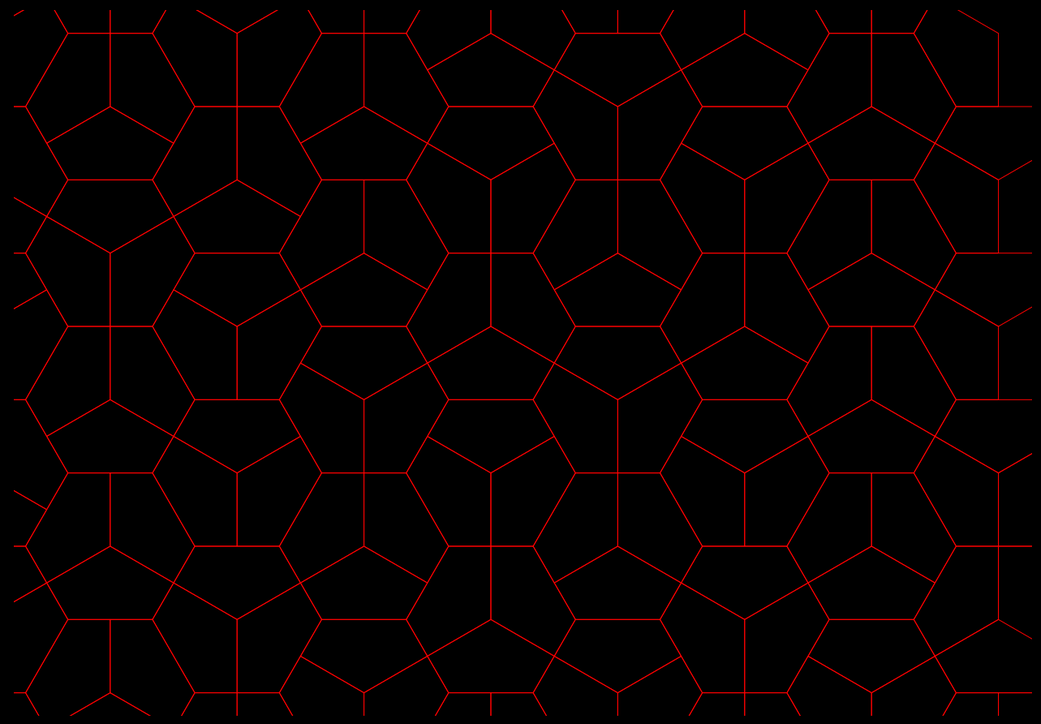


Figure 27. Tiled Einstein shape, and Einstein shape subdivided into 1/3rd parts of a hexagon

Figure 28. Experiments in fractal structures for generative volumes were unsuccesful.

Results

Tile to stamp

Building profiles are uniform to account for the rotation of the Einstein tile. Widespread sun coverage is necessary to guarantee proper sunlight in high density, rotated stamps. Studies inspired by staggered building profiles in Manhattan set boundaries to maximum volume, benefitting natural light access in high densities. Settling on a compromise of >49% of sun hours receiving direct sun to at least one area of each roof terrace. Later defined parameters such as maximum building depth (18-24m) and floor-to-floor height (4m, the legal maximum for a flight of singular stairs, (Rijksoverheid, 2026) and load bearing structure geometry determined precise sizing of building profiles. Due to sun restrictions the resulting stepped-pyramidal profiles cannot reach very tall without resulting in a deep base. Taller ceilings allow a greater room depth, since tall windows allow the same angled light further into the space.

Profiles can be converted into volumes and placed on the tile to make stamps. Prototyping showed that extruding profiles along roads create building blocks with courtyards. With a clear private public division in space. An element lacking in regular stamped neighborhoods and not appearing in other methods of volume placement. By slightly skewing the triangular cross section to be steeper towards the public streets, a gentler angle, and subsequently better sun coverage appears within the private core of the building block. Consequently increased density in building profiles steepen angles towards public streets compromising sun coverage, but communicate the urban density. Distinction between public and private is communicated through this building volume.

Various prototype road placements on the tile result in vastly different stamped structures. Tiles can connect with each other in multiple ways. Prototypes of all possible tile connections have been considered. Tilings that connect in the middle of long edges connect to split the Einstein tile into 6 building volumes. These 6 differently shaped zones connect to zones in other tiles to create unique building zones. Since the way tiles connect varies, many kinds of building zones emerge from 1 repeating tile. The selected divisions create a varied mix of building blocks, and road connections. Centrally located squares of various shapes can be added within the tile. The final kite-shaped square resulted from other influences such as maintaining a low count of unique structural components and simplifying the property lot and street profile systems. The square will repeat throughout the urban fabric and guarantee public meeting spaces and relieve the high density of the development. Stamps organise into building blocks in ‘dots’ and ‘bones’ shapes, while building block shapes repeat and appear on 6 angles, interactions with other building blocks generate unique urban structures using only one stamp, challenging structural monotony issues in stamping.

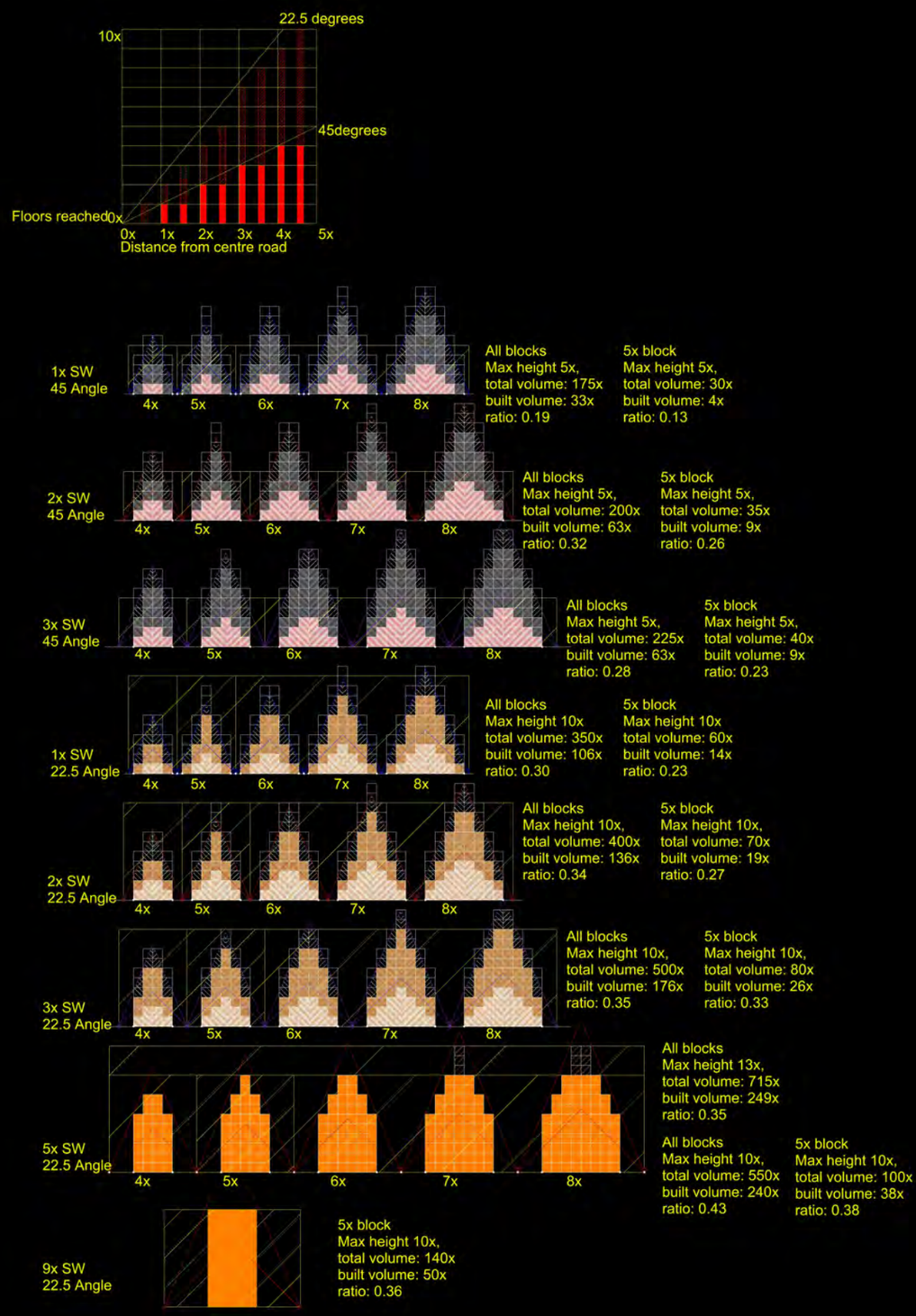


Figure 29. Study in relationship street width, natural light access and urban density.

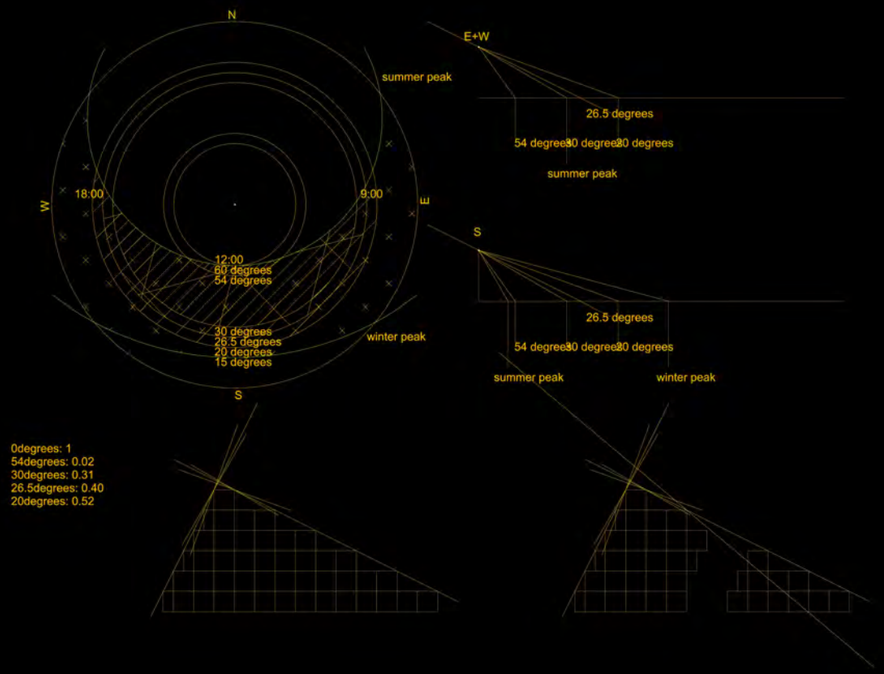


Figure 30. Calculation in sunlight angles, for Eindhoven, for deriving ample natural sunlight

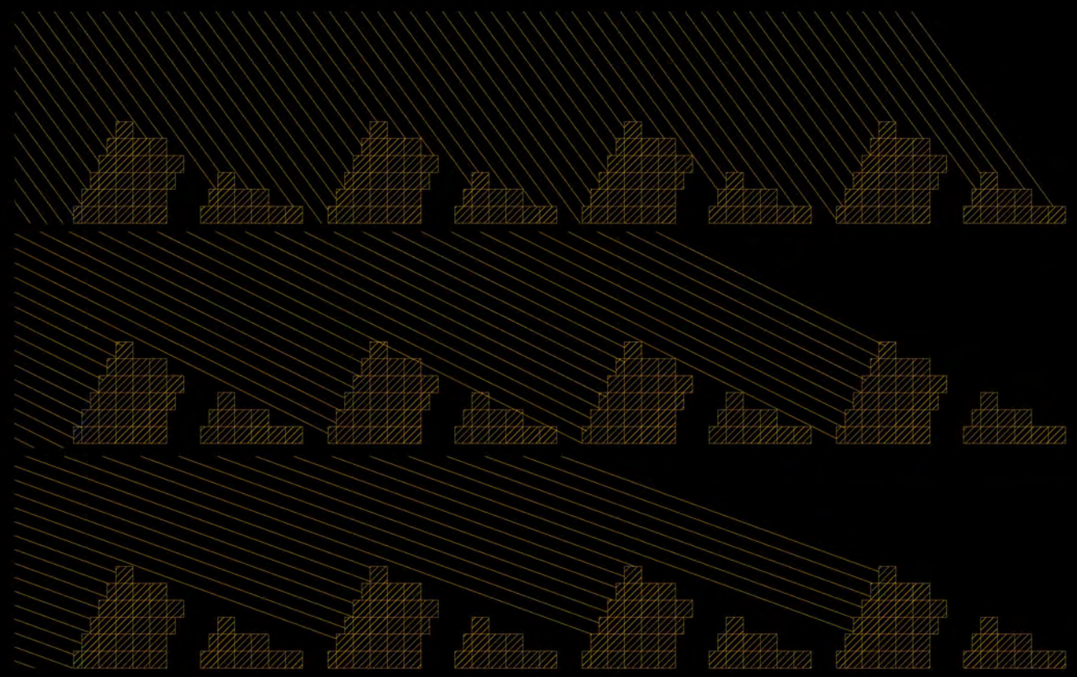


Figure 31. Prototyping building block cross sections.

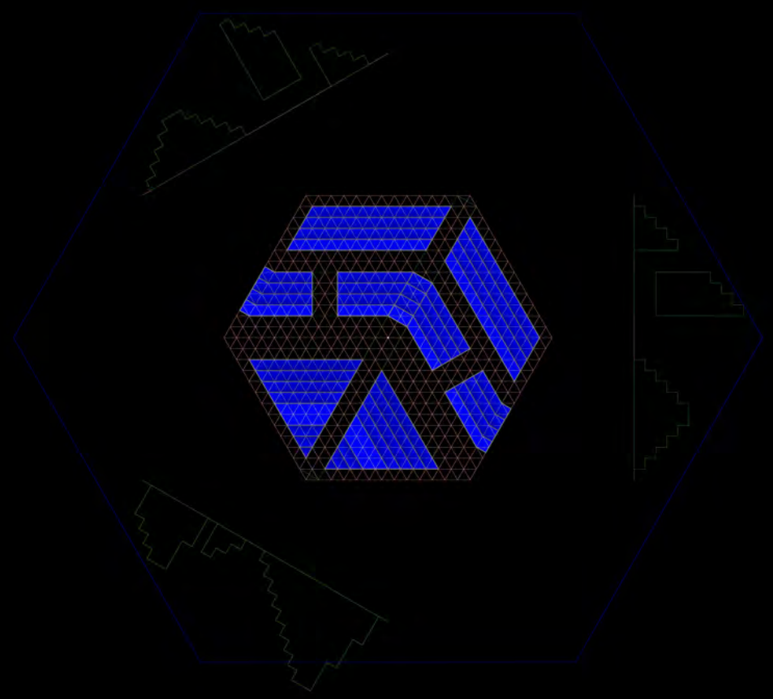
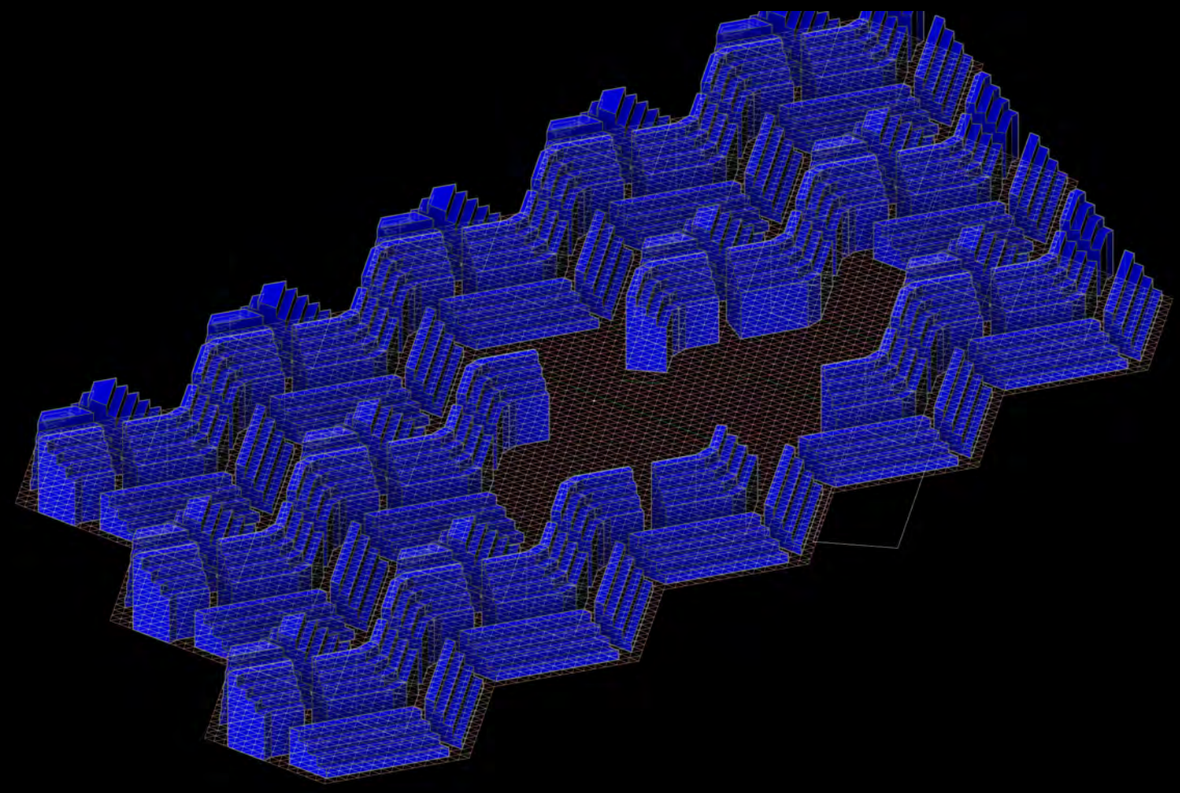


Figure 32. Prototyping hexagonal stamp following sun-optimized cross sections.



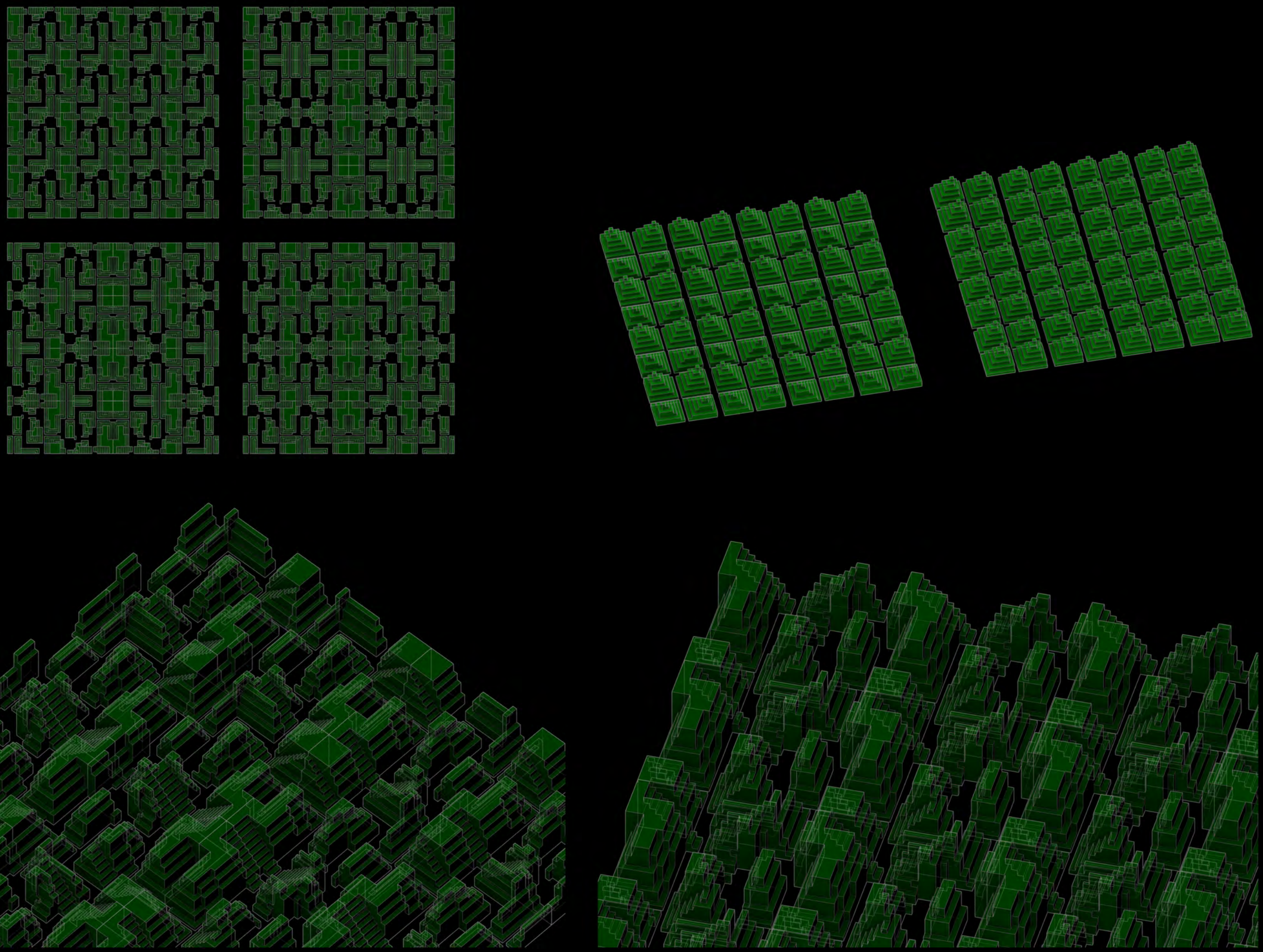
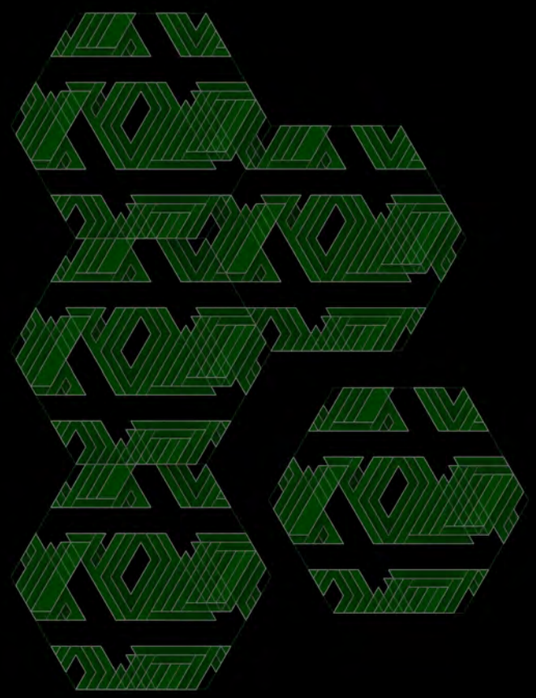
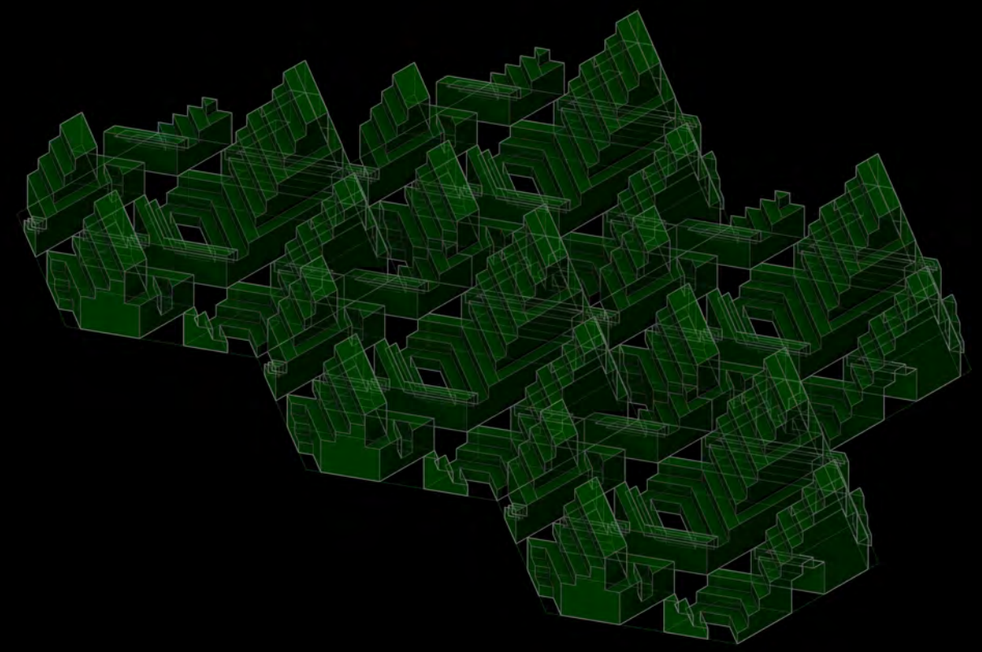
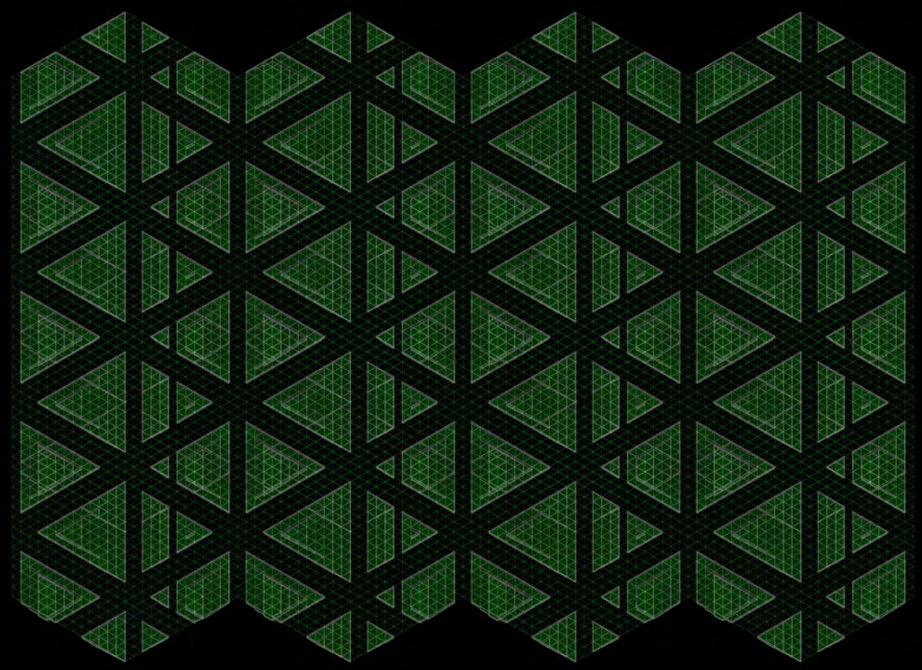


Figure 32. Experiments in developinig high density stamps, while preserving natural light access, square grid. Unable to beat monotony.







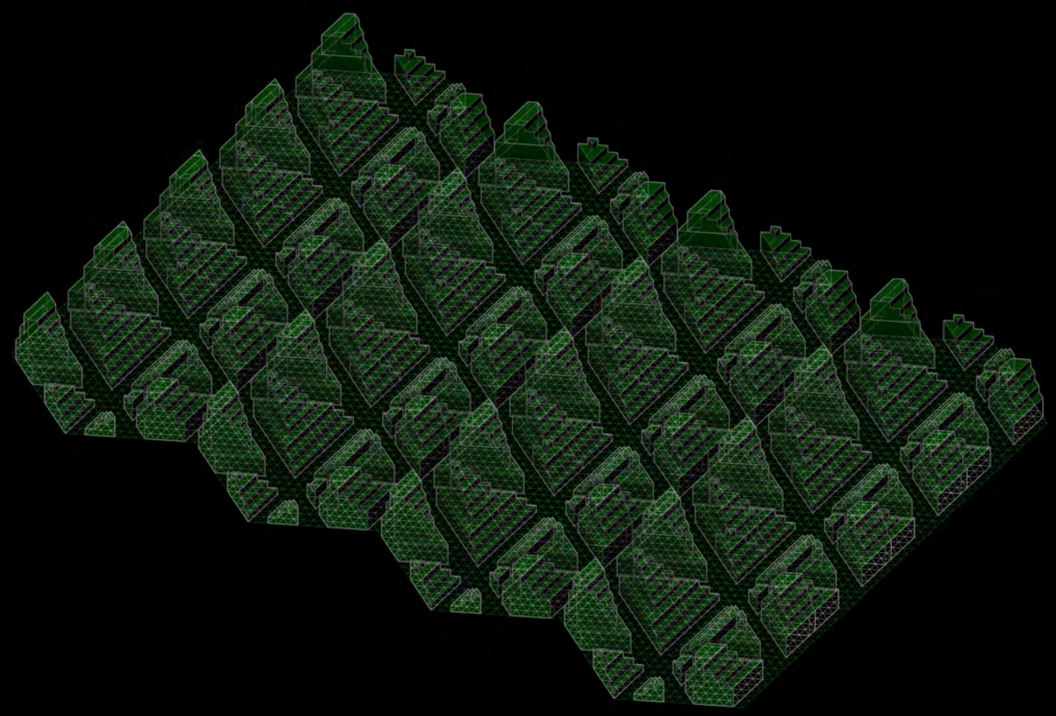


Figure 33. Experiments in developinig high density stamps, while preserving daylight access, hexagonal grid. Unable to beat monotony.

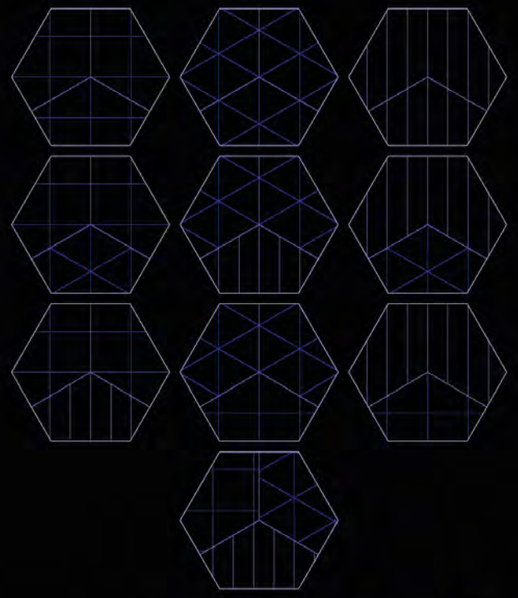




Figure 36. Einstein-tile filled with square grid, results in tiles not being able to connect and thereby reducing variety

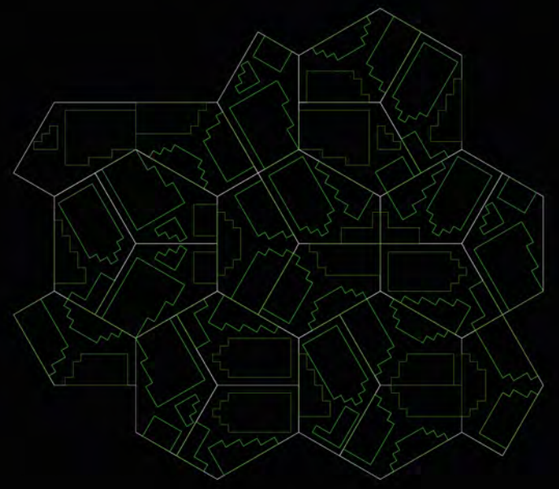
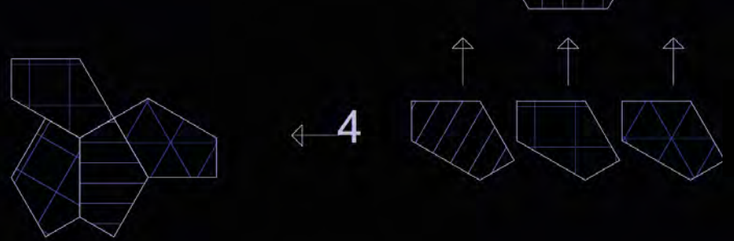


Figure 37. Rectangular grids do not aline with Einstein-tile fragments



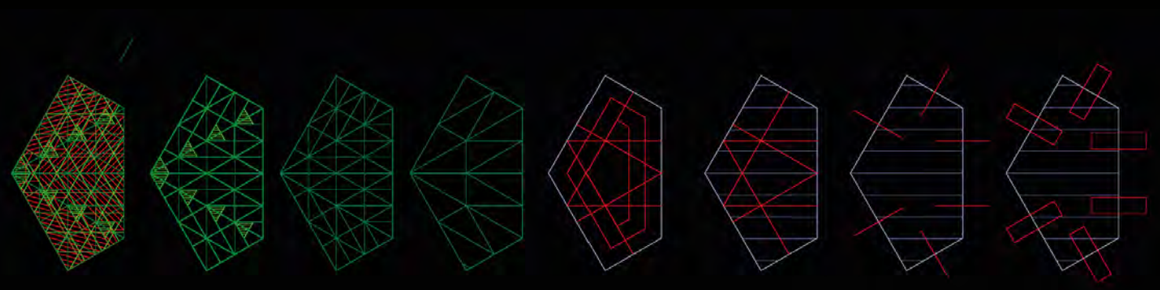


Figure 34. Extracting the Einstein-tile into components of 1/3rd of a hexagon, simplifying the geometry.

Figure 35. Exploratory work in determining a basis for a grid, and connection points between tile fragments.

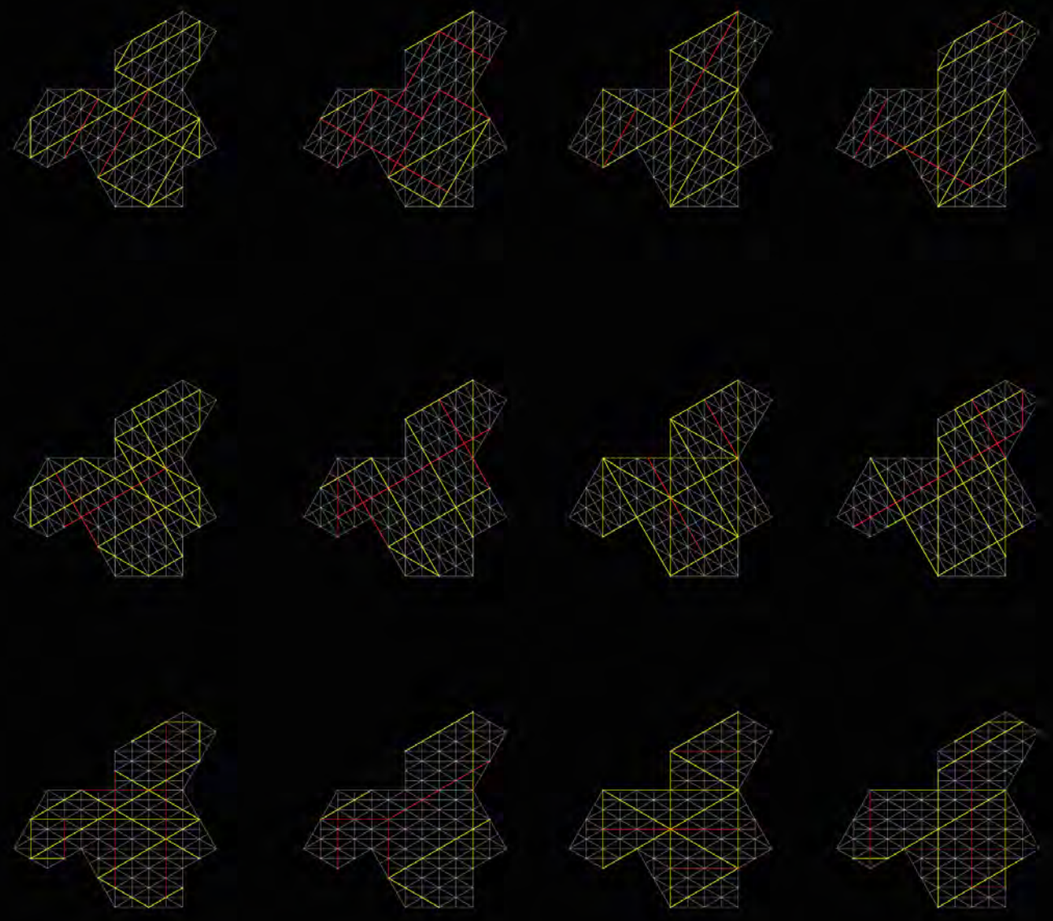


Figure 38. Einstein-tile filled with triangular grid, different straight line connections between seamless tile connection point.

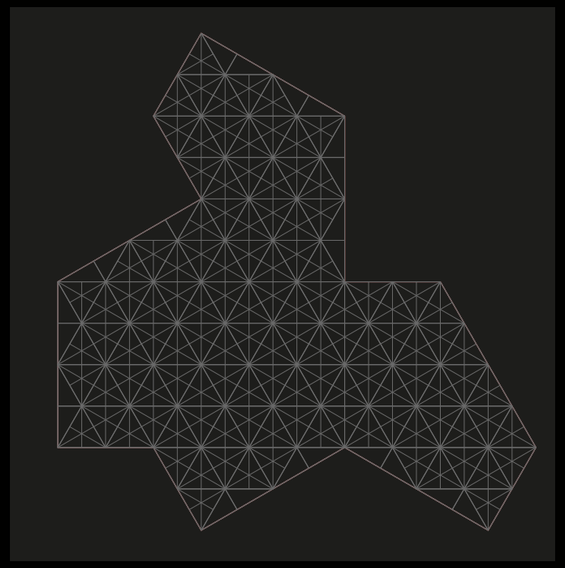


Figure 39. Triangular division einstein tile.

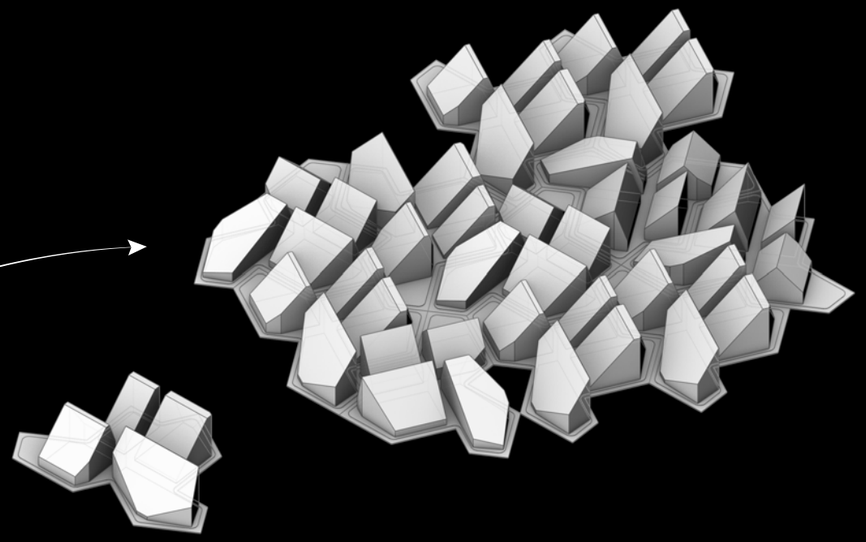


Figure 41. Sun-optimized building blocks on prototype-stamp.
Only 4 different building blocks produced reducing variety.

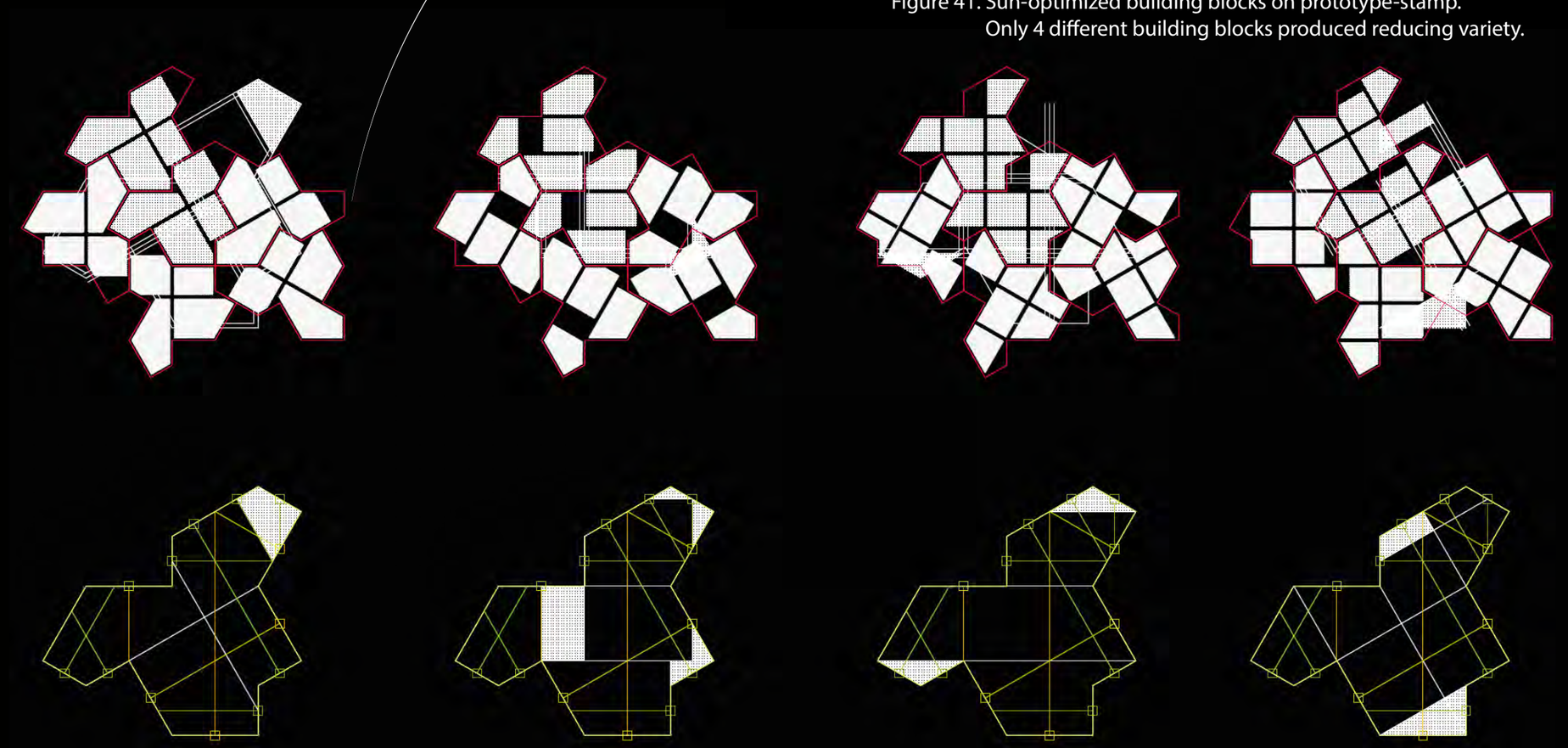


Figure 40. Experiments in various tile connections and the subsequent urban building blocks.

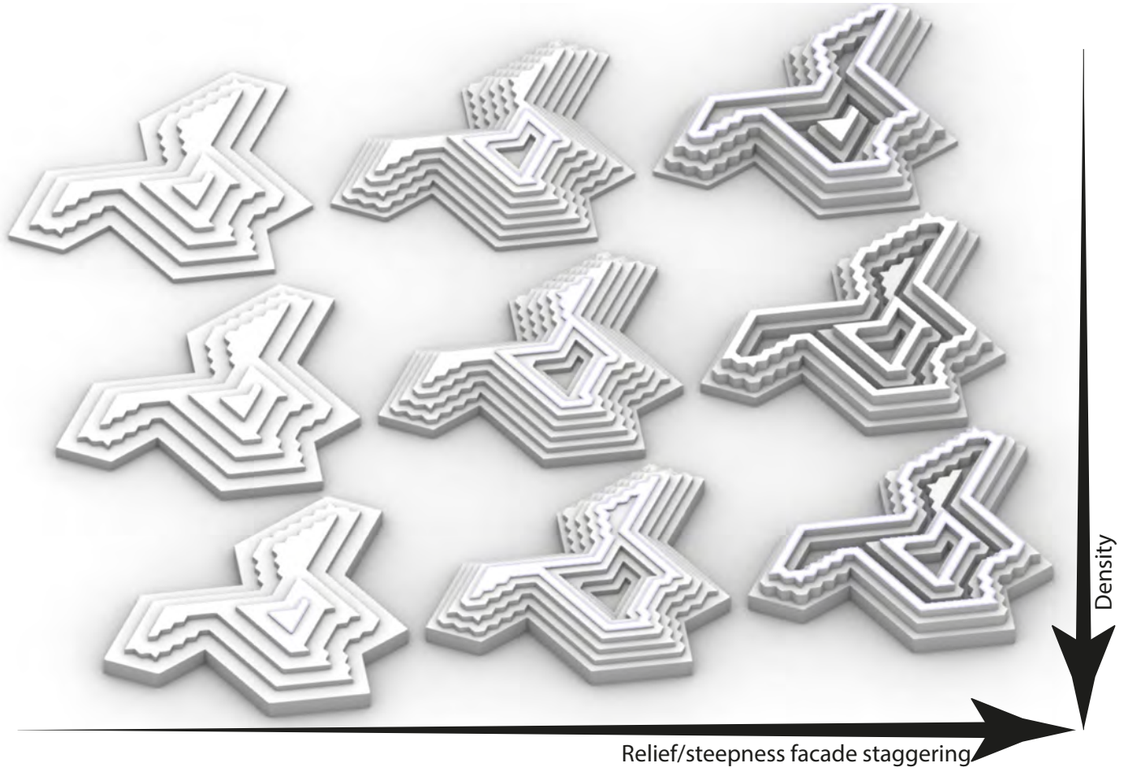


Figure 42. Einstein-tile as 1 individual volume.

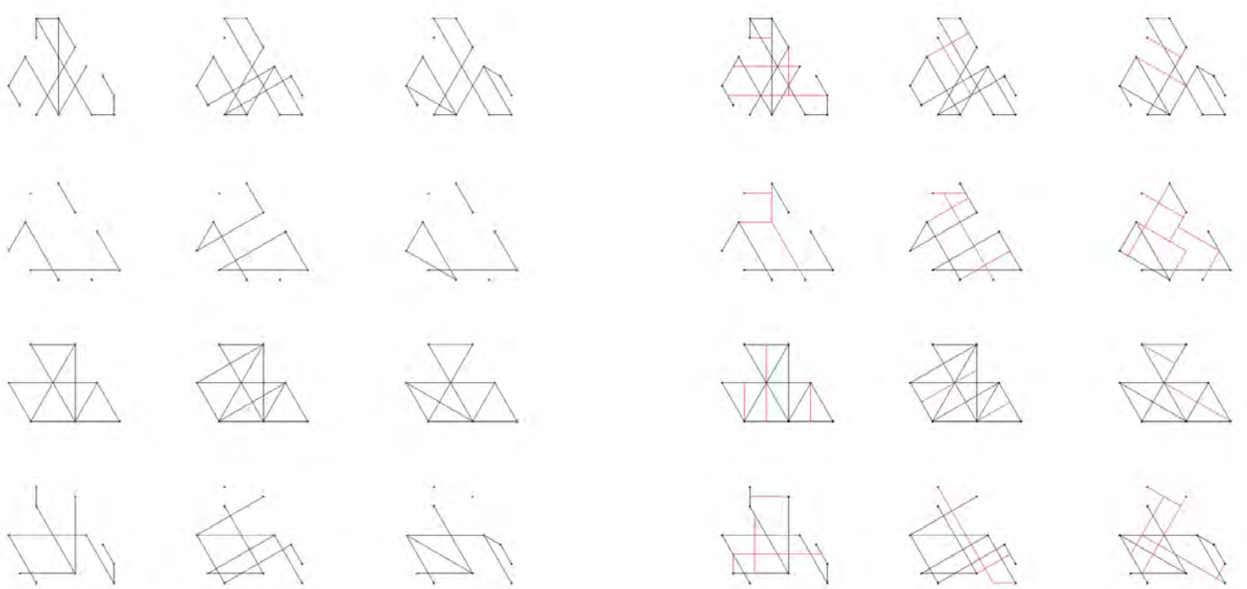


Figure 43. Experiments in straight seemless connections with other tiles, within a triangular grid on the Einstein-tile.



Figure 43. Building blocks of higher densities should include a courtyard. for adequare natural light access

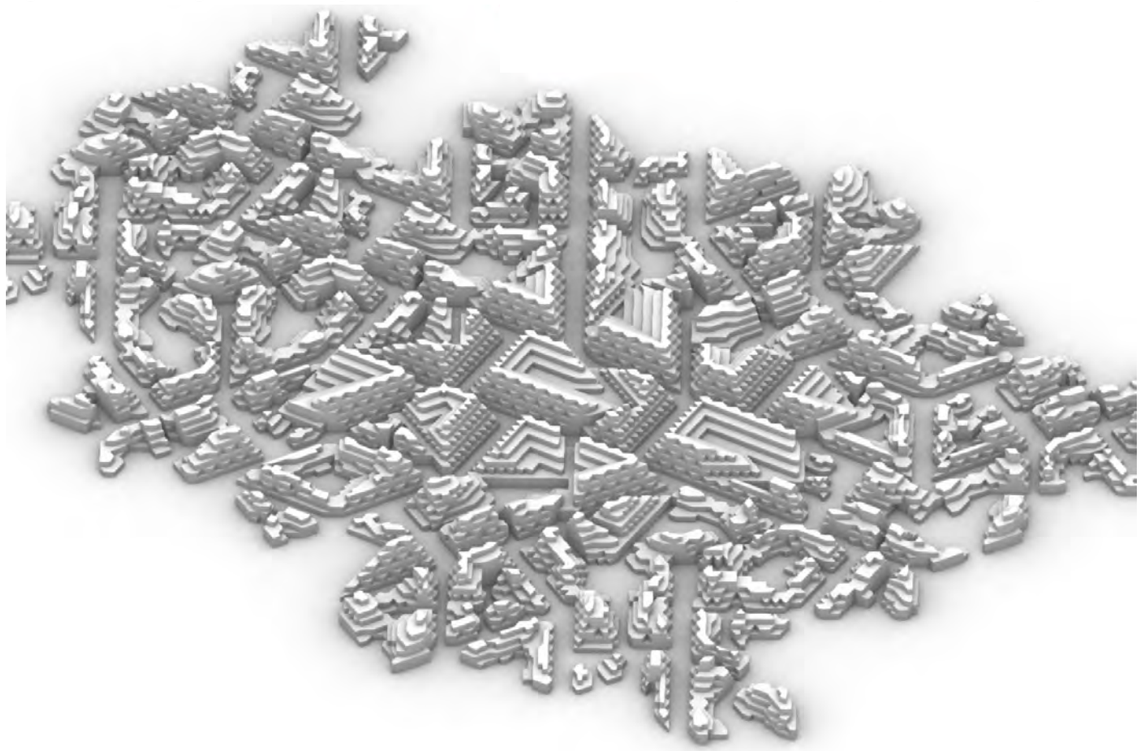


Figure 44. Organic volume development on Einstein-tile, resulted in a fragmented appearance

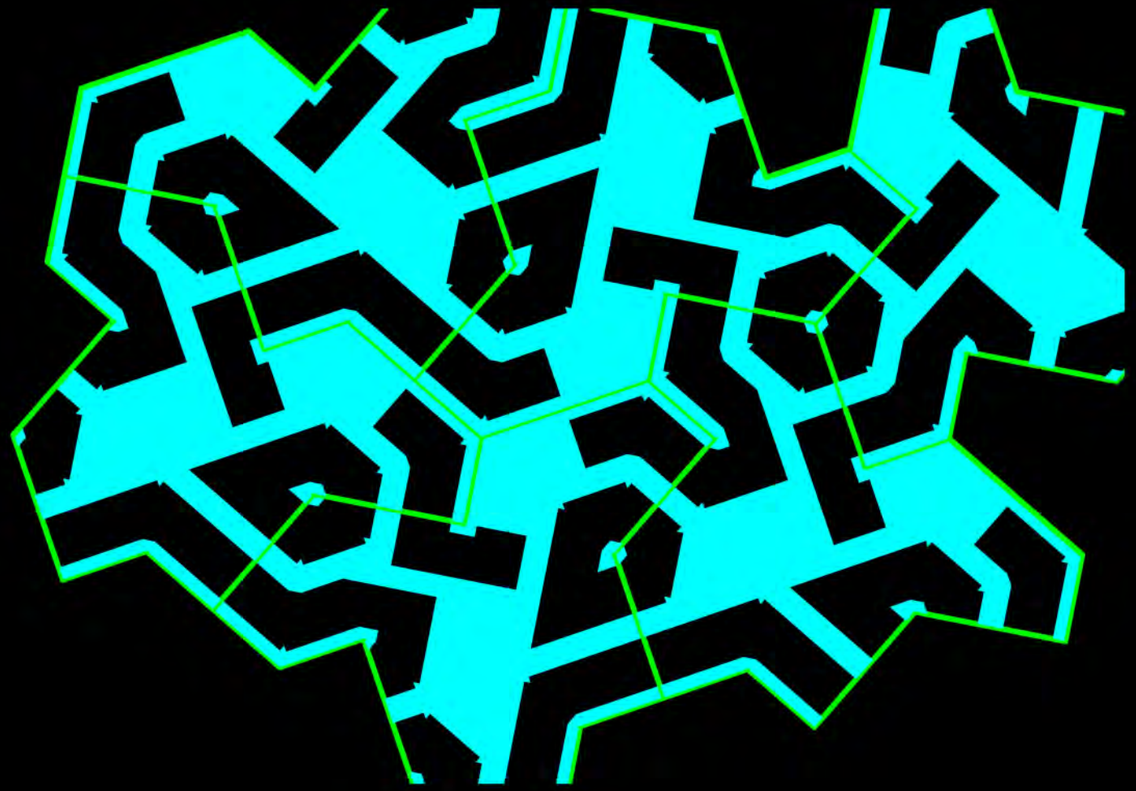


Figure 45. Stamp shape that connects building blocks with different stamps, significantly increasing variety.

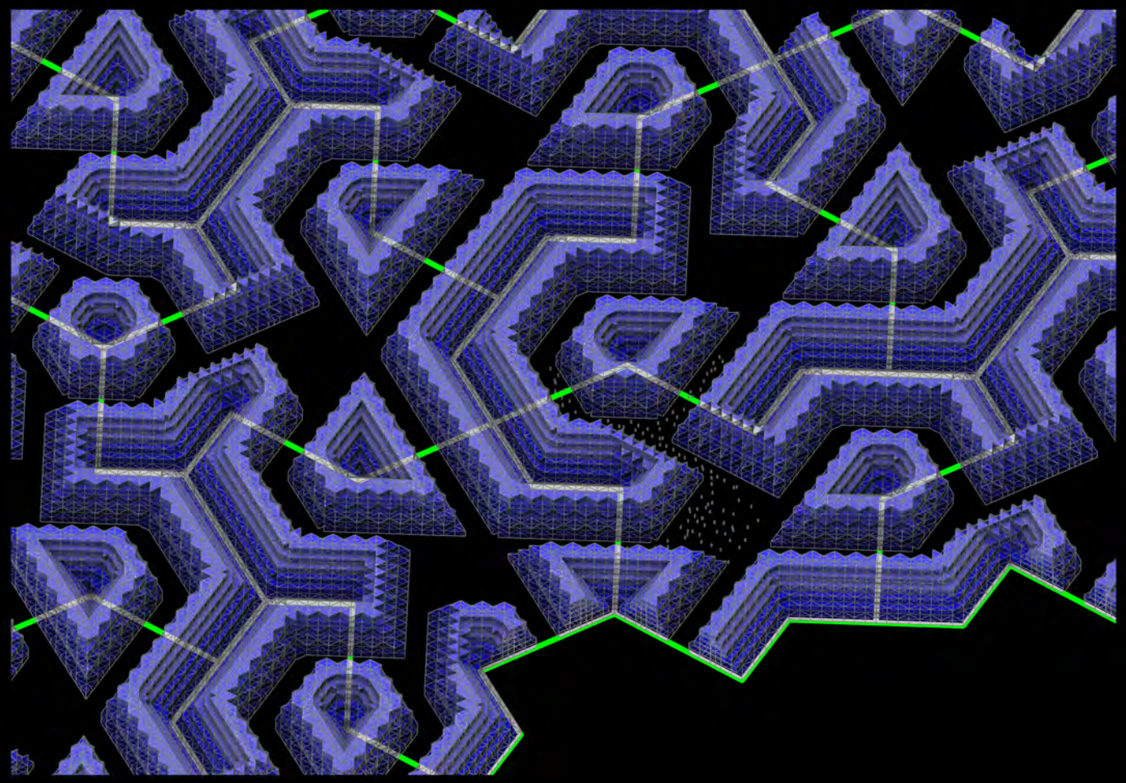


Figure 46. Building blocks enclosed, creating distinct seperation between public and private outdoor space.

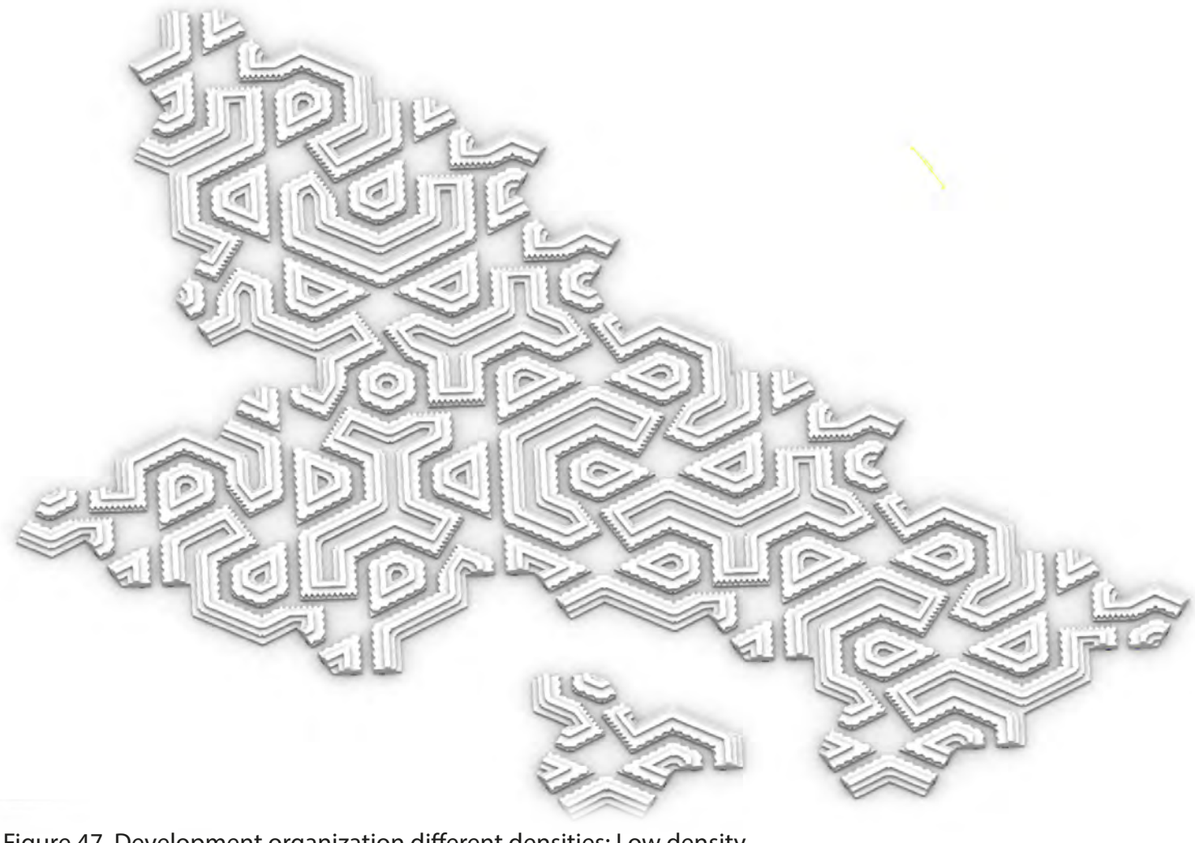


Figure 47. Development organization different densities: Low density.

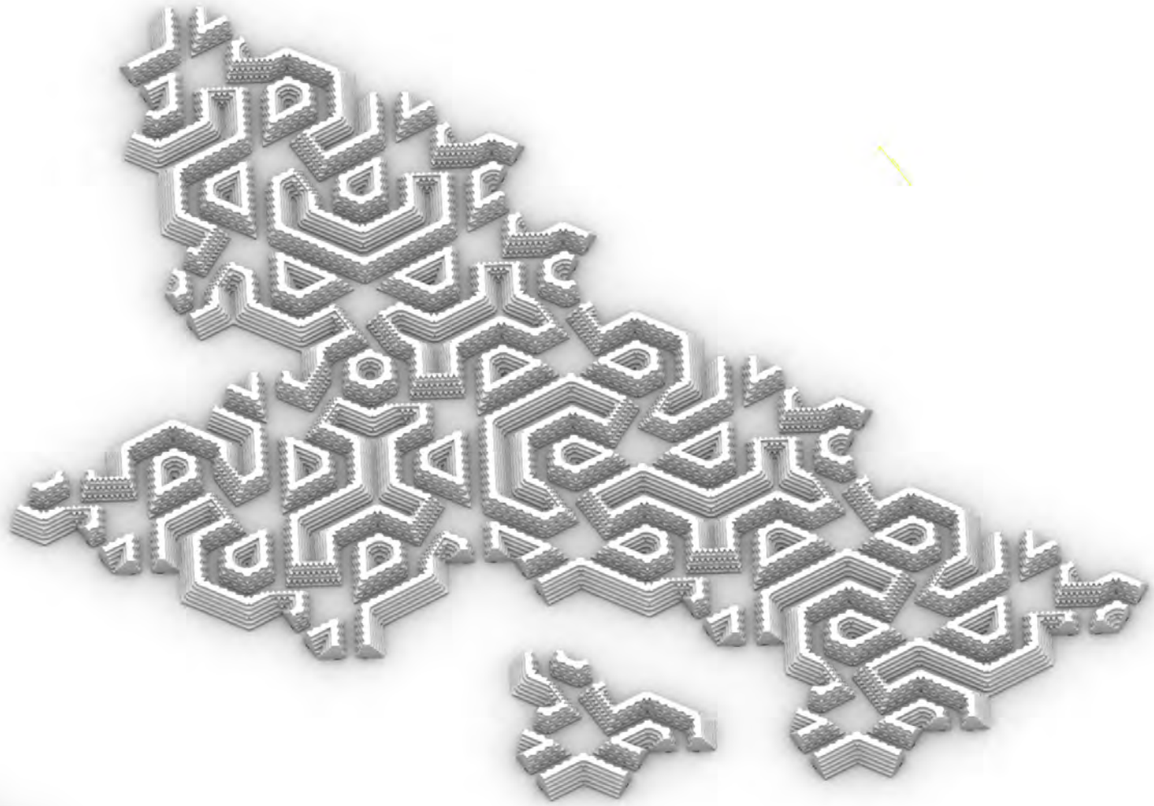
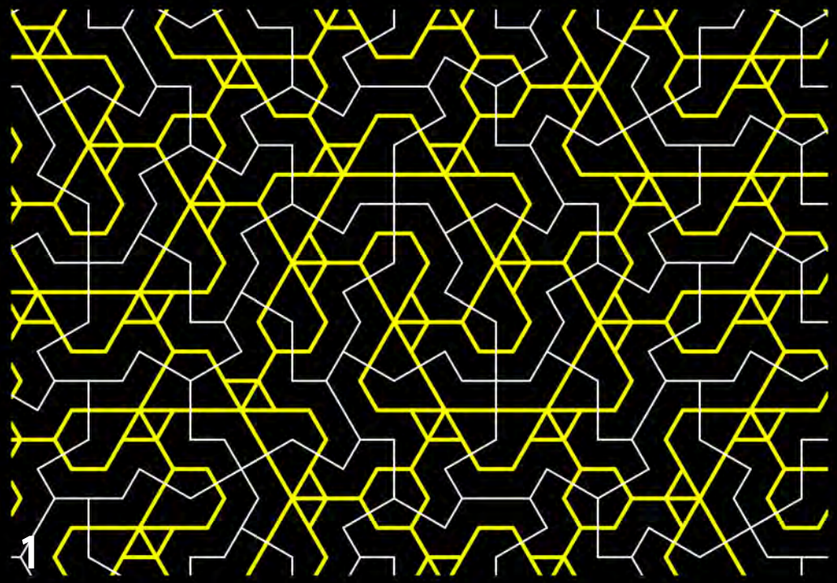
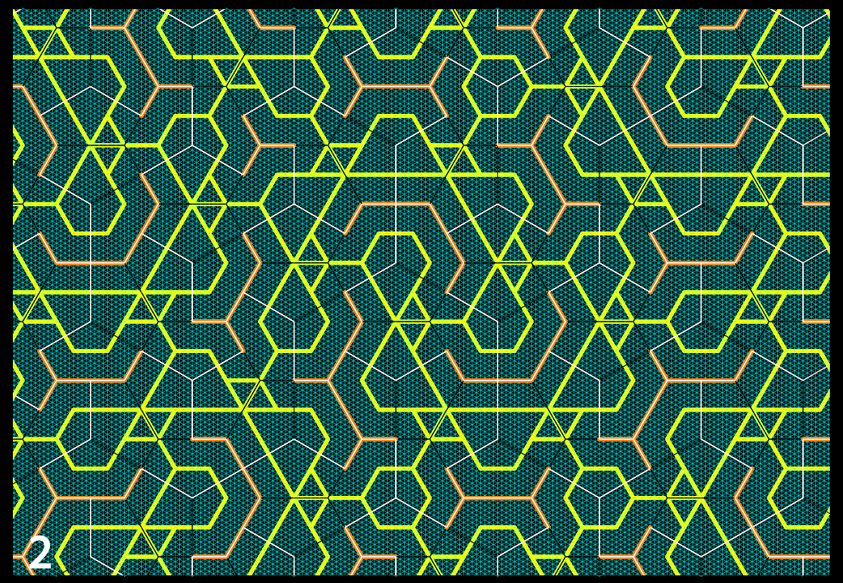
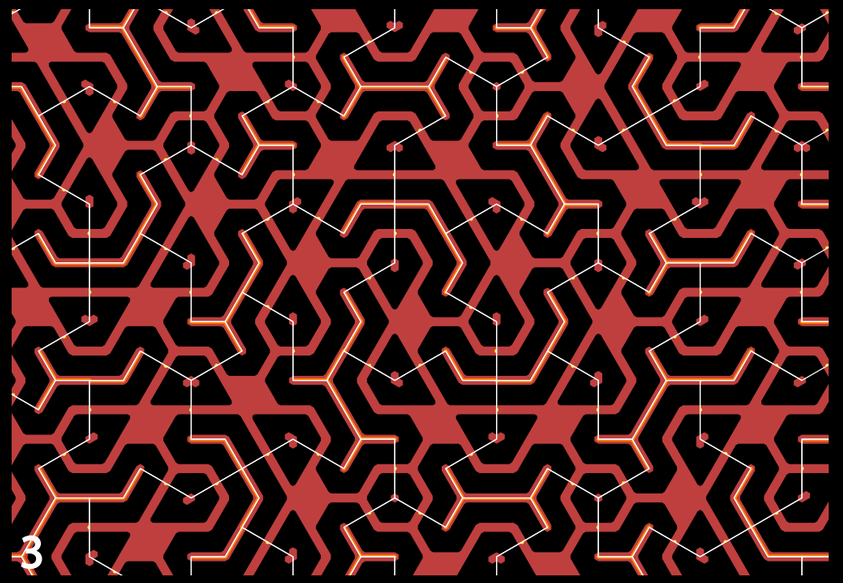
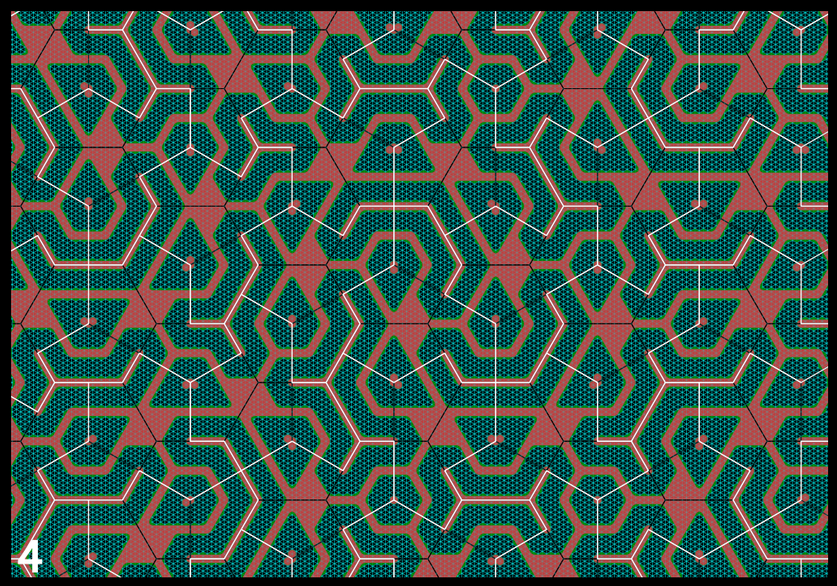


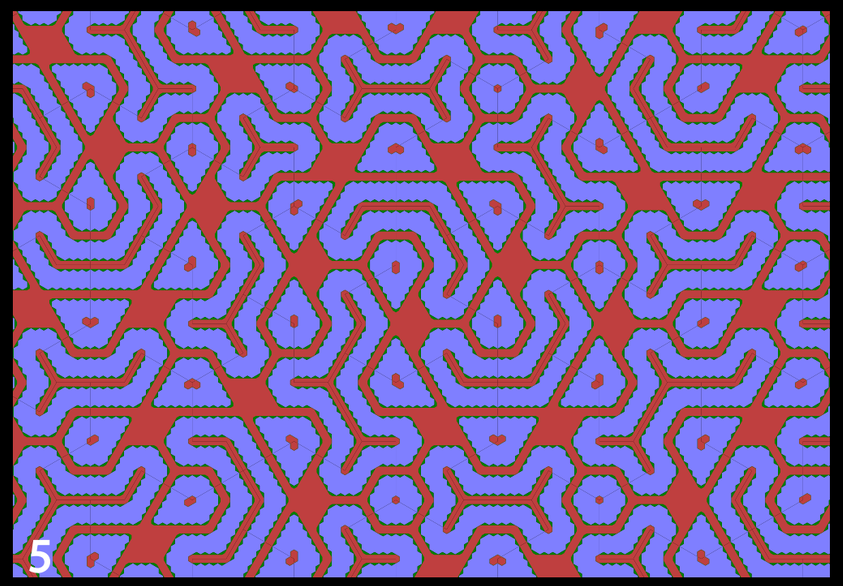
Figure 48. Development organization different densities: High density.

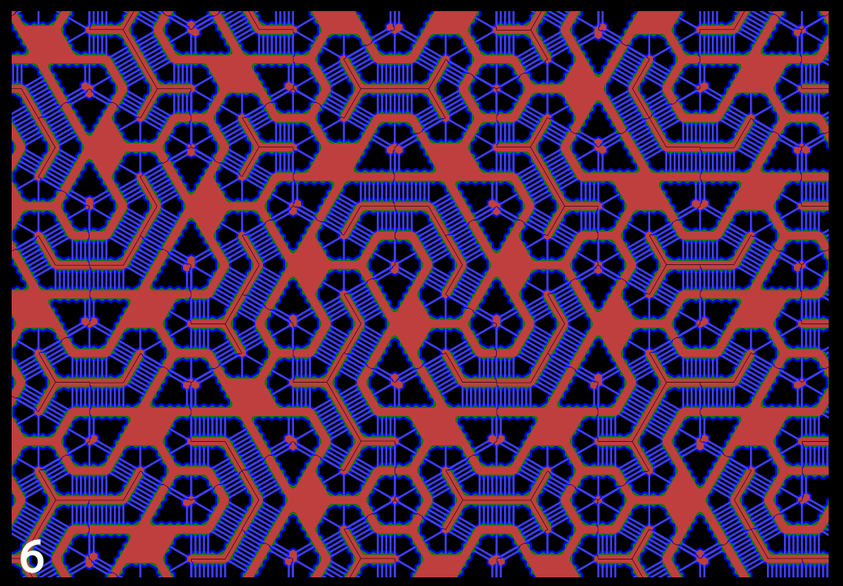


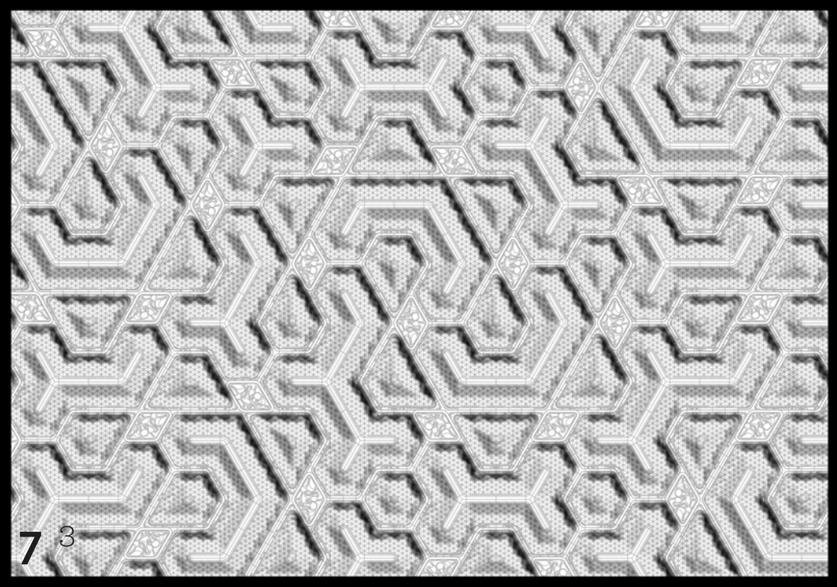


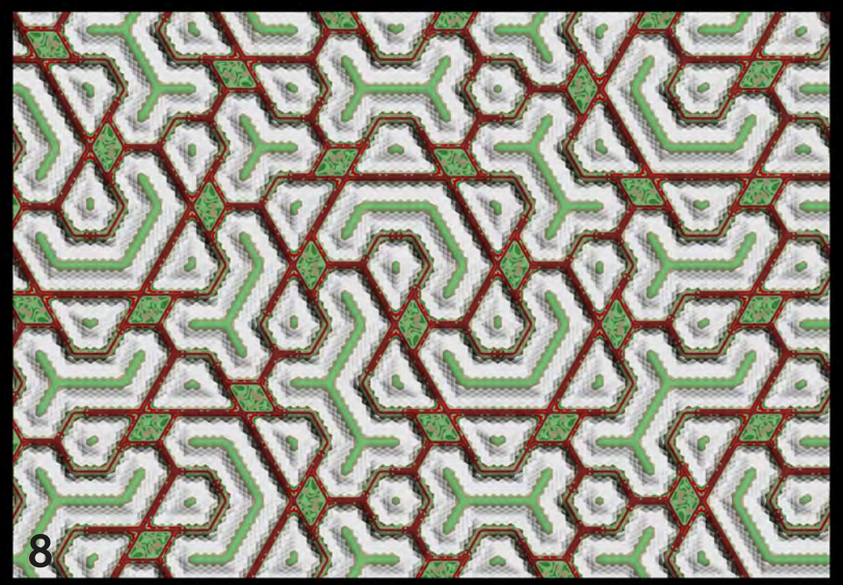




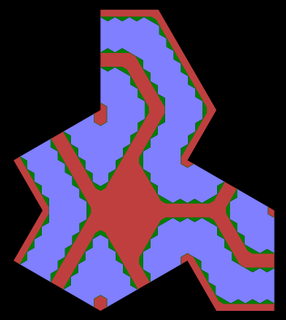








Final sequence of urban stamp design on Einstein-tile
1, Internal seemless road connection
2, Courtyard area within building block
3, Open space stamp
4, Back and front gardens, on stamp
5, Building block volume stamp
6, Property lots stamp
7, Relief, natural light stamp
8, Infill street profiles stamp



Einstein-tile stamp

Figure 49, Design sequence urban stamp geometry.

Results

Stamp to grid

The Einstein tile is rooted in a hexagon. Corners and other tile connections require the building system to accommodate variations of 60 degrees. Extracting building systems from the determined profiles produced 6 prototypes for structural frameworks. Solutions with rectangles, and 30-60-90 degrees triangles showed great ability to express a wide range of volumes compatible with the desired profiles, However, this building system required more than twice the amount of unique parts in assembly compared to a single individual unit, such as triangles and hexagons, preventing accessible adaptation from structure modification. Using only rectangles eliminated the structure from bending around the tile and diminished the strength of previously established urban split of public and private space. The selected structure uses triangles supported by columns on its vertices. Multiple triangles can be combined to form a hexagon, allowing a larger column free space. A construction sequence can be found in the appendix under the name 'Load bearing system sequence'

Distance between vertices, floor structure height, floor to floor height and column dimensions were a complex consideration determined by many clashing parameters. Table 1, 'grid size spreadsheet', in the appendix enabled dynamic adjustments to values, colored by performance. Core values of the building system were determined, such as 6000mm between vertices, 3000mm floor to ceiling height, and 1000 ceiling thickness. These values are an equilibrium from various metrics, with some being; sunlight exposure (for all arrangements of staggered terraces), adequate service floor space (taking into account gradients for plumbing and distances to service spaces) and load per square meter (ensuring the structure is adaptable to function changes of a public gathering space).

The grid of the load bearing structure, allowed volumes to be better explored on the Einstein-tile. Volumes of 4 different densities are produced, allowing smooth transitions between urban densities, lowering the boundary of modification.

Further collection of sections, 1:5 details and 1:20 details, can be found in the appendix under 'Details'.

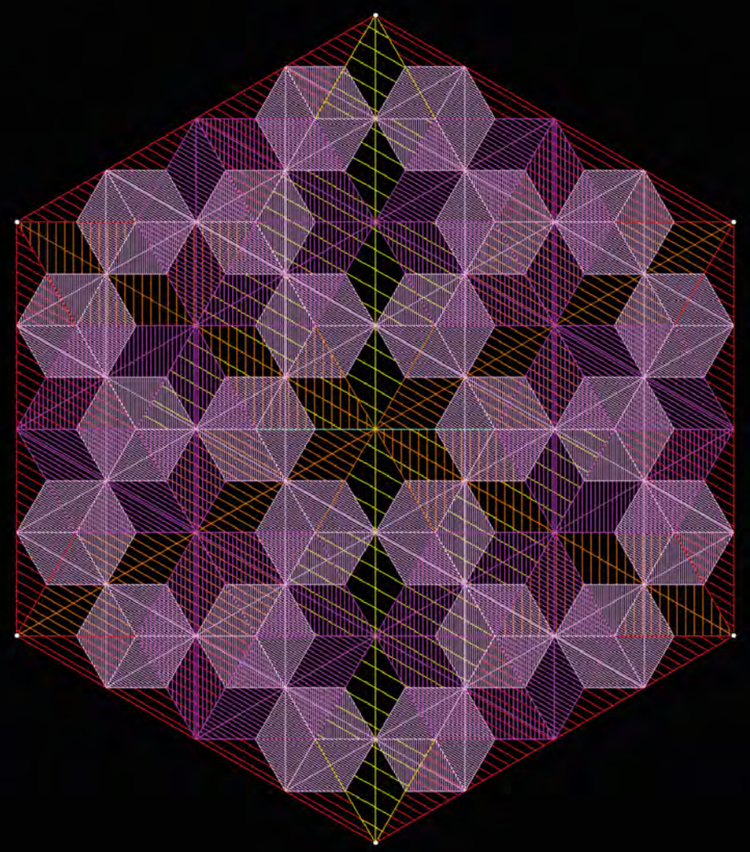


Figure 50, Surface area of load bearing beams when dividing into a triangular waffle structures. From longest spans to shortest; yellow, orange, red, purple, pink.

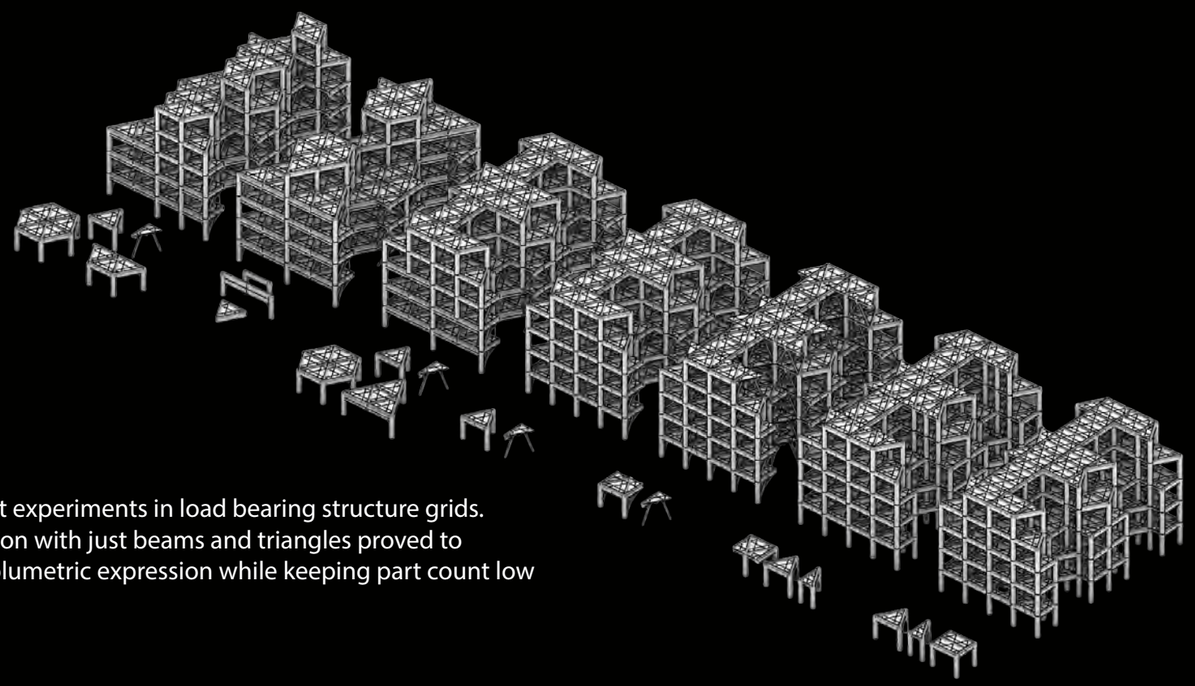


Figure 51, Different experiments in load bearing structure grids. The option with just beams and triangles proved to allow volumetric expression while keeping part count low

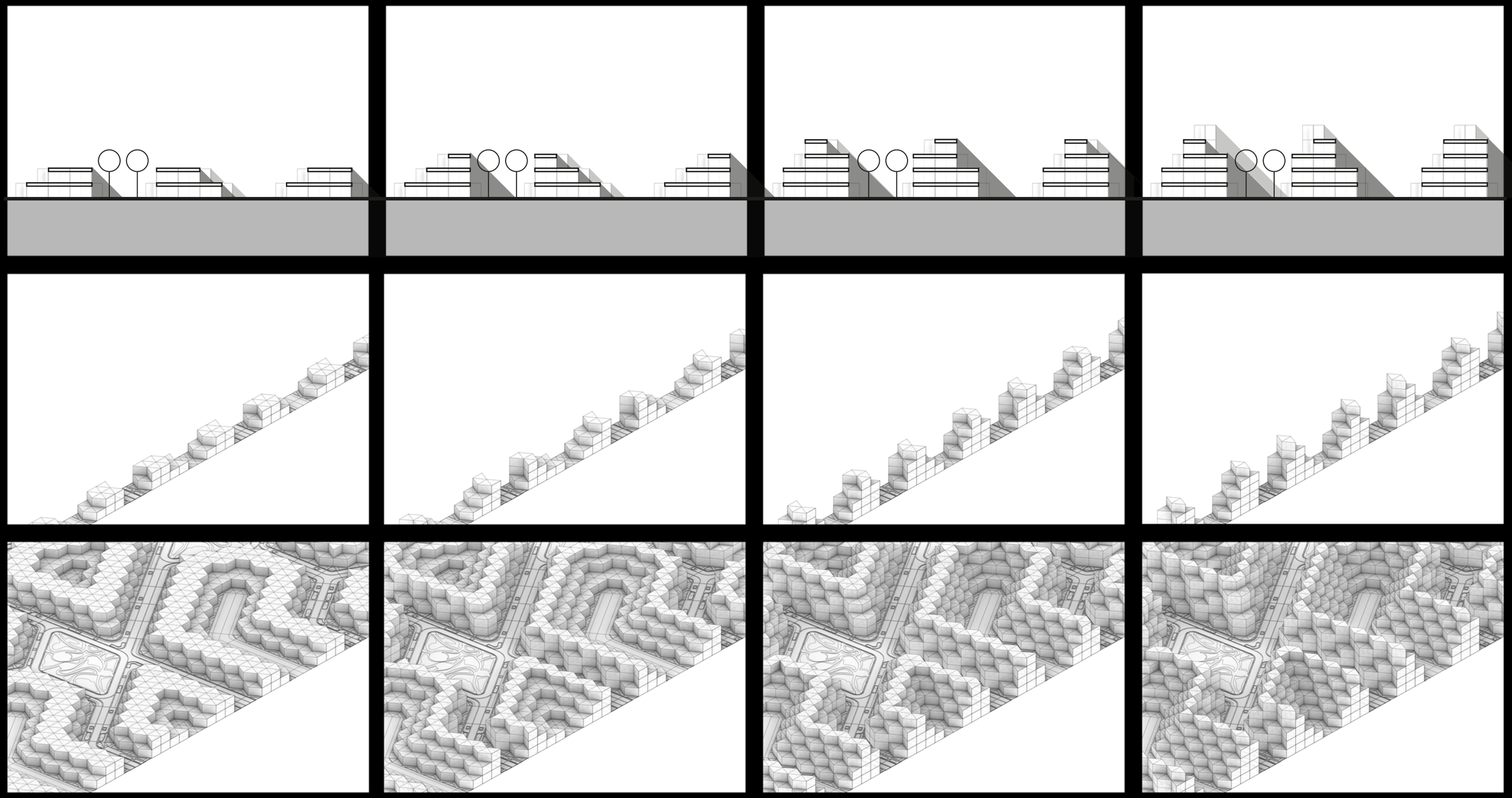


Figure 52. 4 different densities, cross section, and integration on the stamp.

Results

Grid to structure

Columns in the current structure contain a conflict between sustainability and flexibility to expand. Planning for potential additional floors, uses material in the present for a hypothetical scenario. Previous prototypes of multiple columns each sharing a determined set of own floors were unsuccessful as multiple, slightly staggered building systems caused problems in facade connections, vertical translations and stability. Rotating the problem from the vertical plane into the horizontal plane each vertice of a triangle could be split in 6 individual columns only transferring load from their direction. This way, column combinations located near the facade of the building, will be constructed with fewer materials, while retaining the possibility of adapting through changing size. Cross bracing, for stability, can be installed within each plane of 2 columns and 2 beams.

The current load bearing structure can be defined to be made from parts of 3 natures: points (connections), lines (columns and beams) and planes (walls and trusses). The load bearing structure has to be fully dismantable into its components, and allow later manufacturing of additional components. Parts should be expressed in only 2 dimensions so few machining steps are needed, and all parts could be machined in a cnc machine or lasercutter. Parts attach through dry connections. Bolts are used instead of dowels or timber joinery. Dowels are limited in reuse and timber joinery results in 3-dimensional part geometry, negatively influencing production. Columns and beams use GLT, while trusses and walls use CLT, due to differences in their wood grain orientations. Connections are made through bolts and steel plates. These steel plates interlock, but are not welded together, such welds hinder future adjustment to the structure. Offcuts of parts are reused in the design, for example: the triangular holes in the trusses of the roof structure are reused as flooring.

The triangular frame of the loadbearing system is subdivided into 4 triangles twice, creating a rigid hollow waffle structure leaving ample space for services to pass through. All load bearing parts are produced with accessible dimensions of materials and can be manufactured with a limited number of steps and machines. A schematic view of construction is in the appendix under the name of 'Load bearing system sequence'.

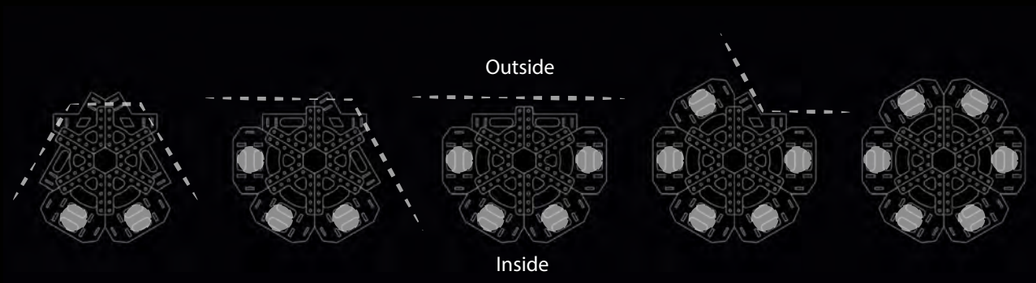


Figure 54. Column split in 6, being able to change positions for facades, growing whenever the building expands.

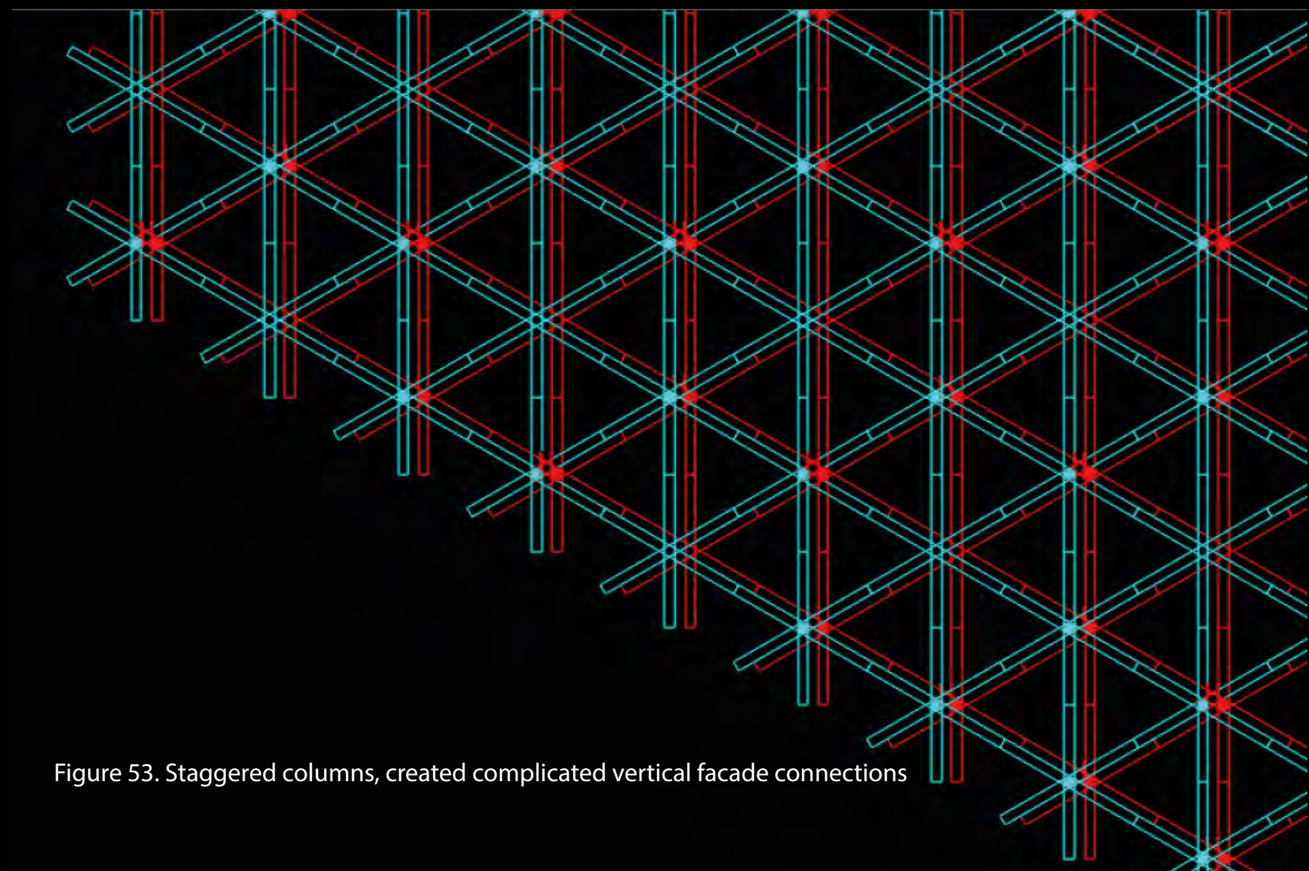


Figure 53. Staggered columns, created complicated vertical facade connections

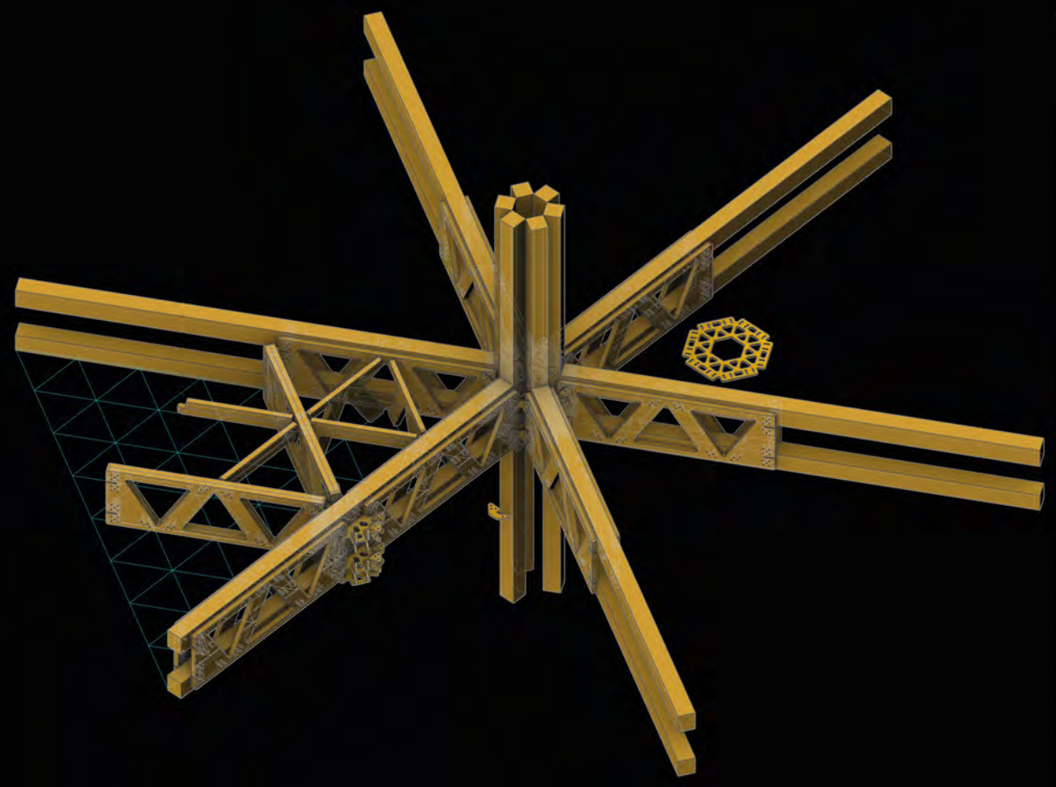
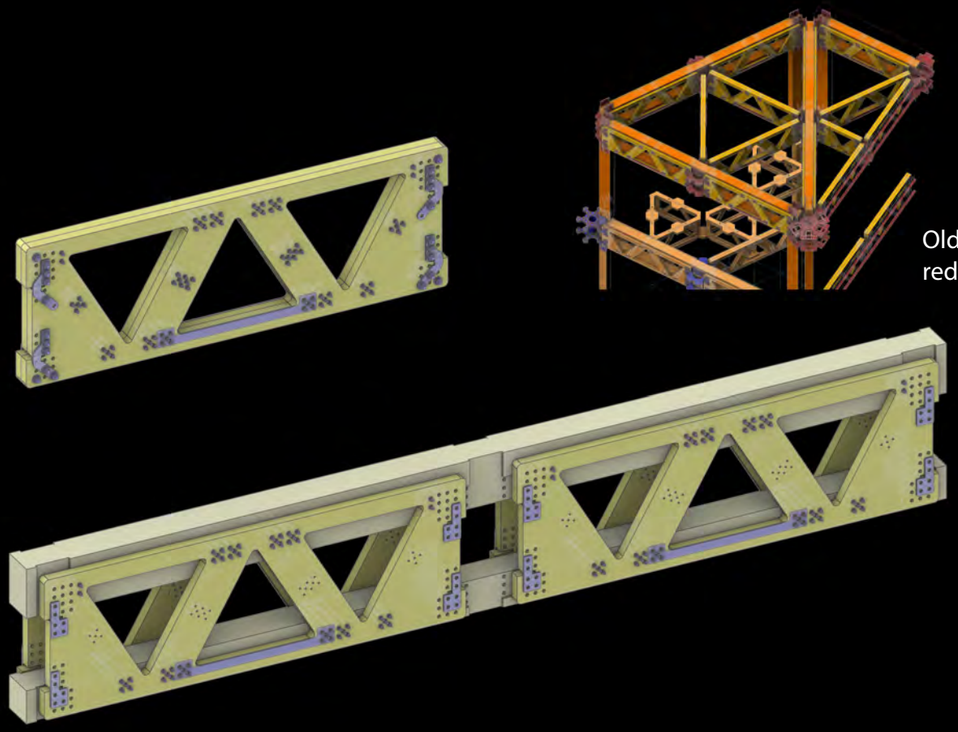


Figure 55. Column split in 6, all carrying their direction but sharing stability.



Old system had 4 different trusses,
reduced to 2 by adopting triangular frame

Figure 56. Truss construction, uses few parts, Long spans are reinforced with GLT-Beams, triangular cutouts, reused as floor/ceiling panels.

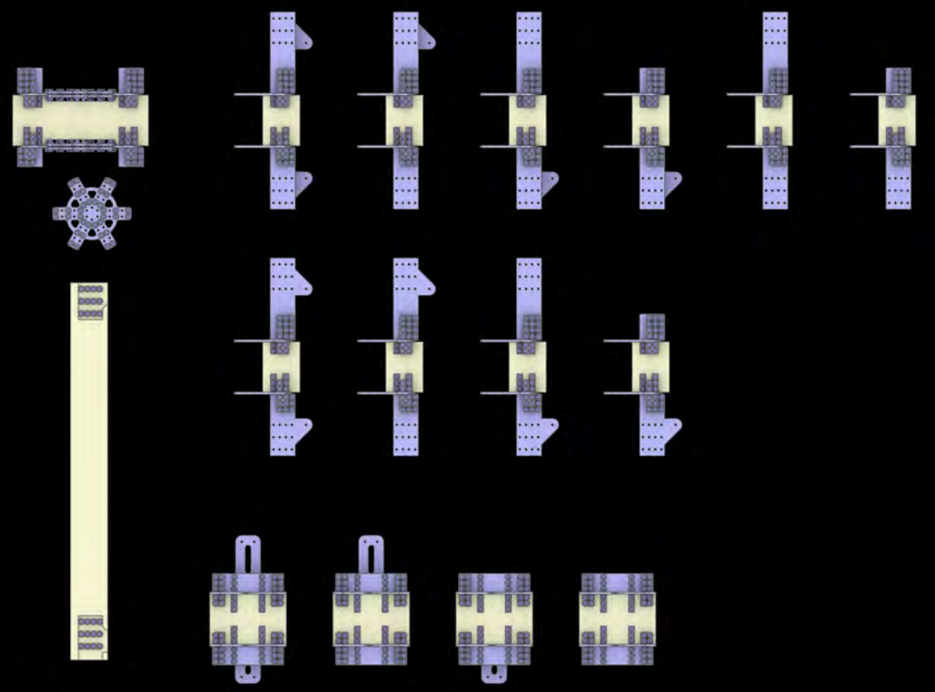


Figure 57. Part configurations, middle + end truss connections.

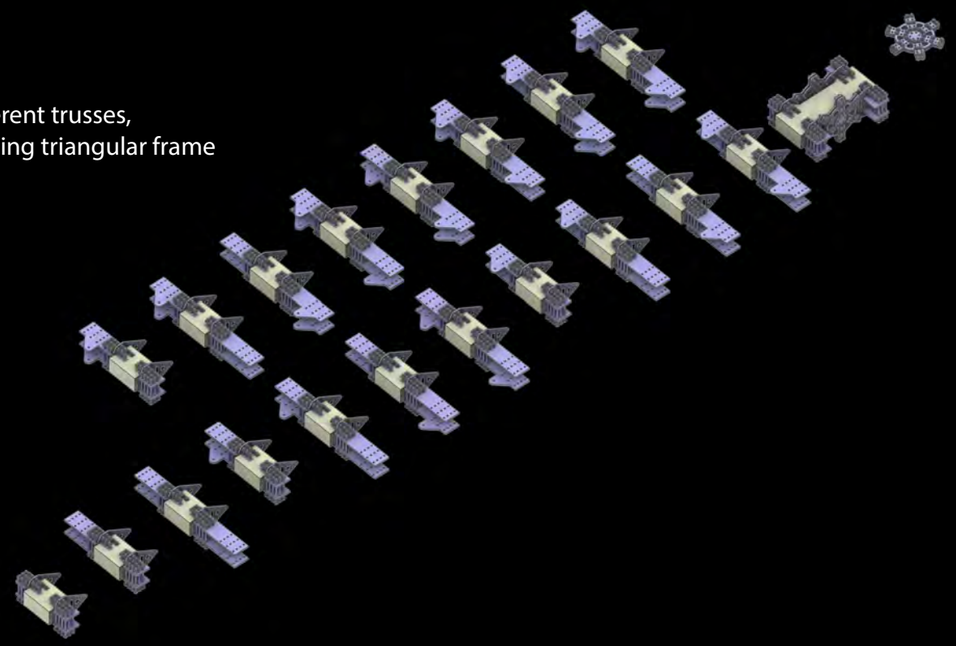


Figure 58. All possible end of truss connections, made from the modular building system

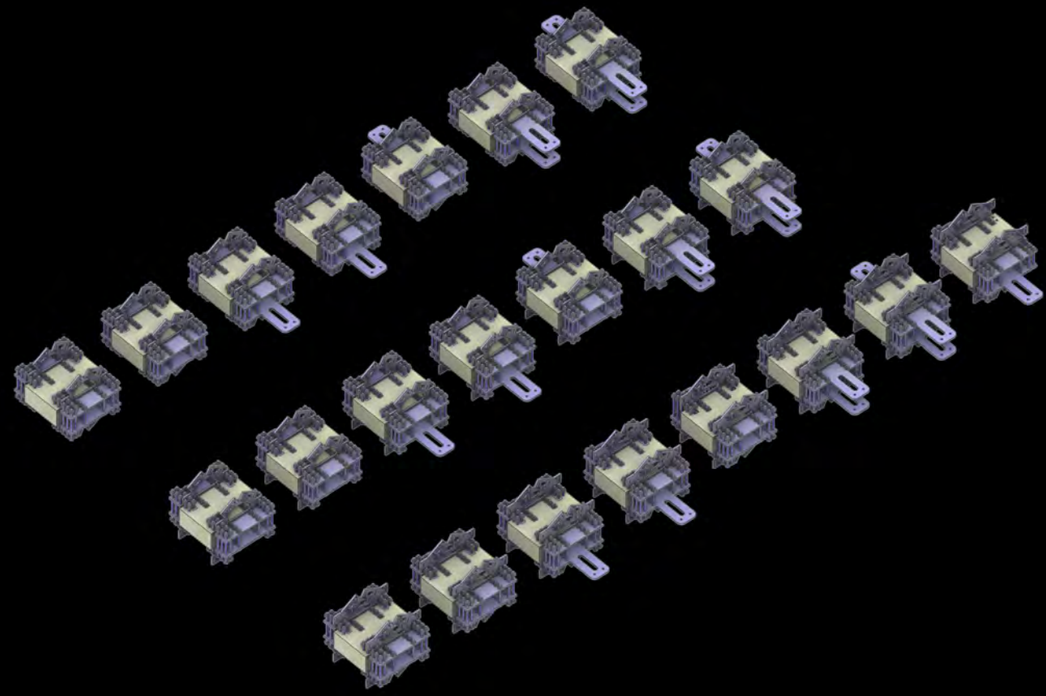


Figure 59. All possible middle of truss connections, made from the modular building system

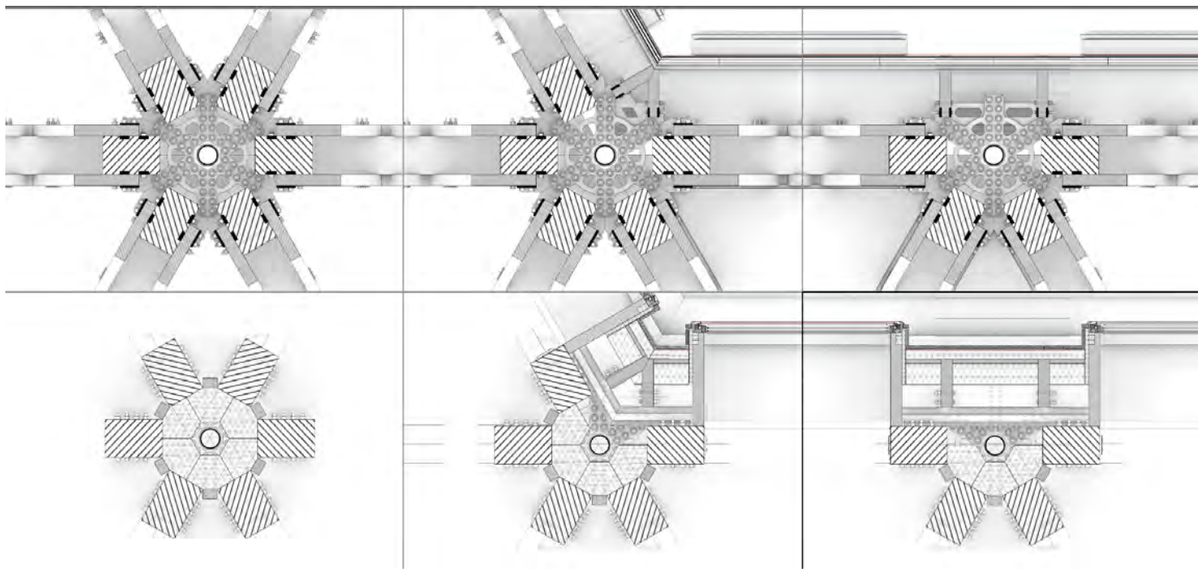


Figure 60. Horizontal details, top row, open floor height, bottom row, living space height
More details in appendix: 'Details'.

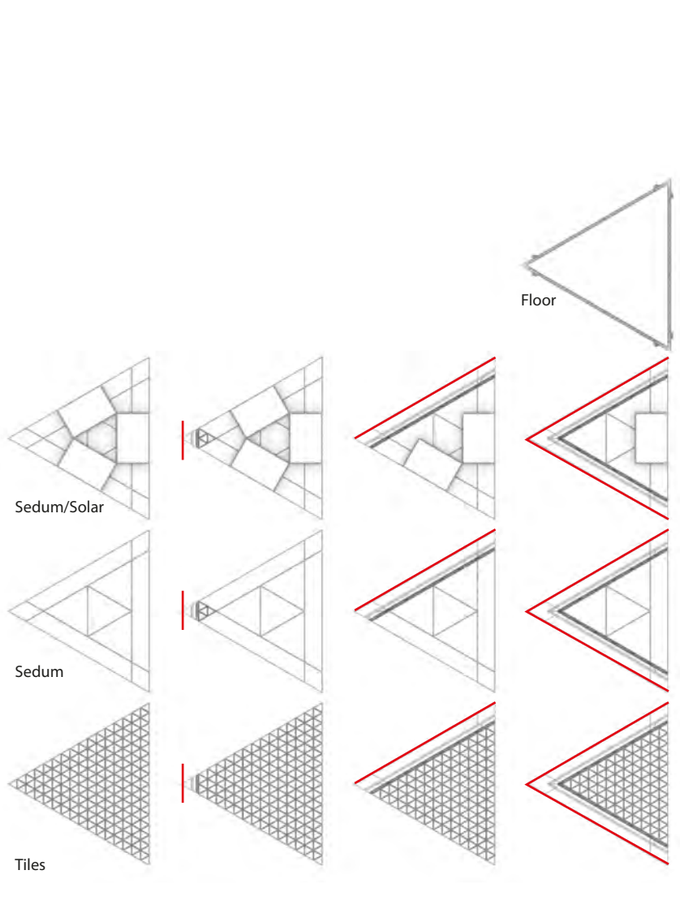


Figure 61. All 13 floor tiles, red line denotes facade boundary.

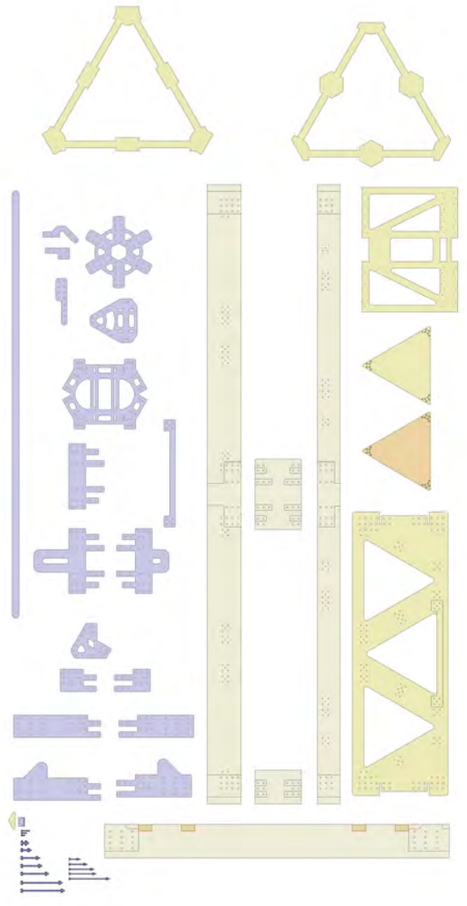


Figure 62. All building elements, present in load bearing system; blue = steel, yellow = CLT, beige = GLT, Orange = wood.

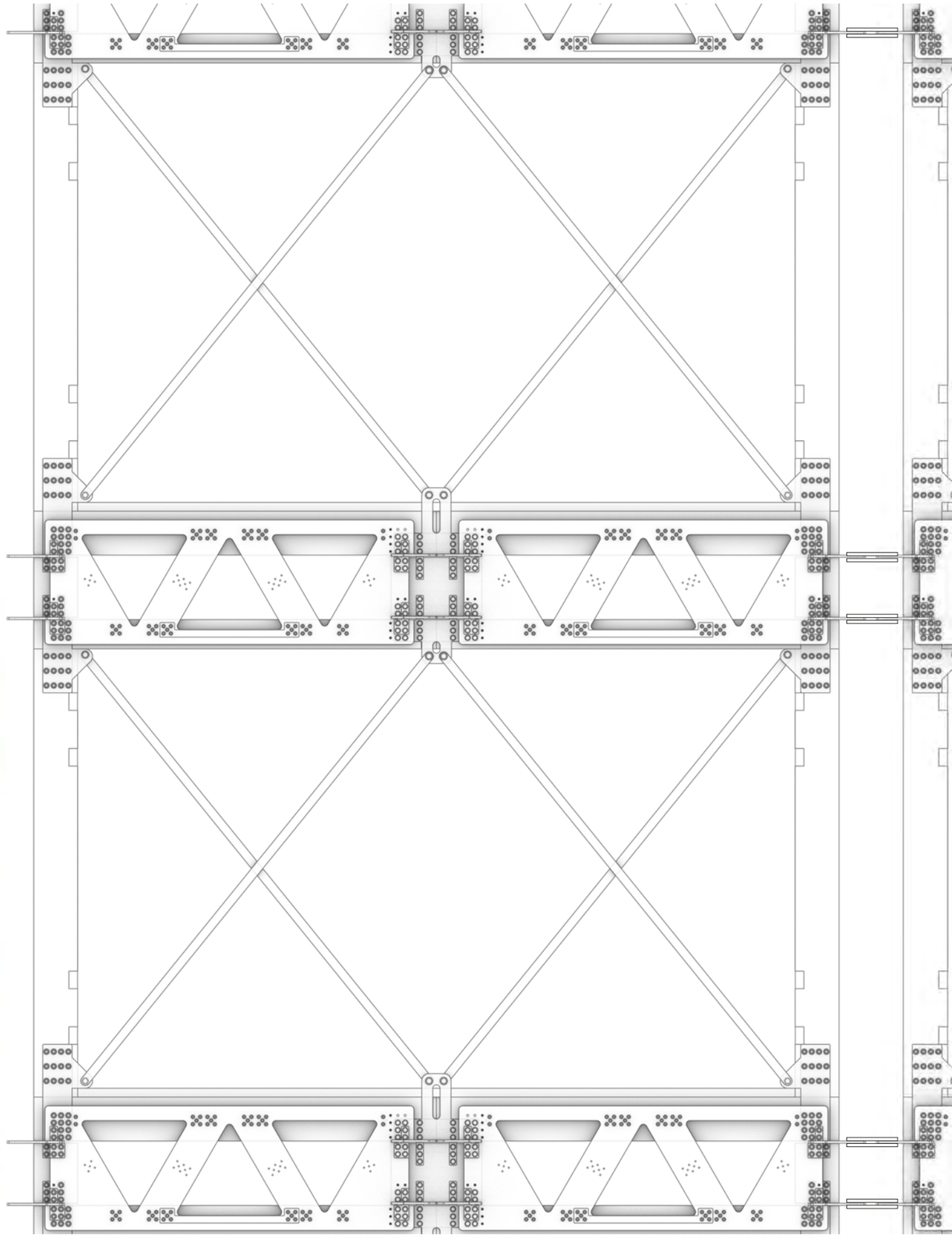


Figure 63, visualisation of integration column-truss connecting parts and possible stability frames.

Results

Structure to open building

Hollow floors support changes in function, appearance and division. The load bearing structure is the same in all stamps, extruded along set profiles of different densities. While the current design might be adjustable in size, other flexibilities respond to the user. The user may still customize the building. Buildings can be adjusted to the needs of the user in facade expression and internal layout. Covering refitable and adjustable flexibilities. Earlier prototypes considered utmost freedom in facade expression, inspired by the MVRDV project Silodam. Problems appeared on the borders of different potential facade styles, with many different approaches and angles, requiring many specific details hampering user-friendly customization.

A new approach was taken to expand freedom of customization through reducing customizable area. Parts of the facade covering structural elements are fixed, remaining space is divided into a grid of squares with a sidelength of 1 meter. A grid of 5x3 was selected due to its prime numbers. Through prototyping this grid forged a balance between simplicity and expression possibilities. The grid of low prime numbers encourages variety as no internal regular divisions greater than 1 are possible. The grid can be filled with materials to the user's liking, such as, but not limited to, timber (painted or stained), glass and polycarbonate. Doors can be added anywhere, with single door modules being 1x3 meters and double door modules 2x3 meters. In the appendix the file ‘facade frame catalogue’ visualises all 25088 options of facade expression. The catalogue was made with the use of AI (ChatGPT Astra 6), as it converted numerical data from a selfconceived space filling algorith into arranged vector files, visualizing the numbers. A previous prototype, with a grid of 3x3 had problems with passageways, only available in the center, alongside a smaller size reducing variety significantly.

Roofs can either be covered in tiles, or by sedum with the option of solar panels, various rooftiles exist to match possible facade configurations, on top, and the corresponding water systems.

Encouraging refitable flexibilities, vertical translations can be installed anywhere within the triangular building system. 3 different sets of stairs have been developed, each of different capacity and size, stairs too are made from modular elements. Services run through the floors and walls are kept simple, putting priority on (noise) insulation. An array of wall elements can be placed freely in the space, following open building principles, to remain convertible.



Figure 64. First facade prototypes, were too different, creating problems when blending different facade types.

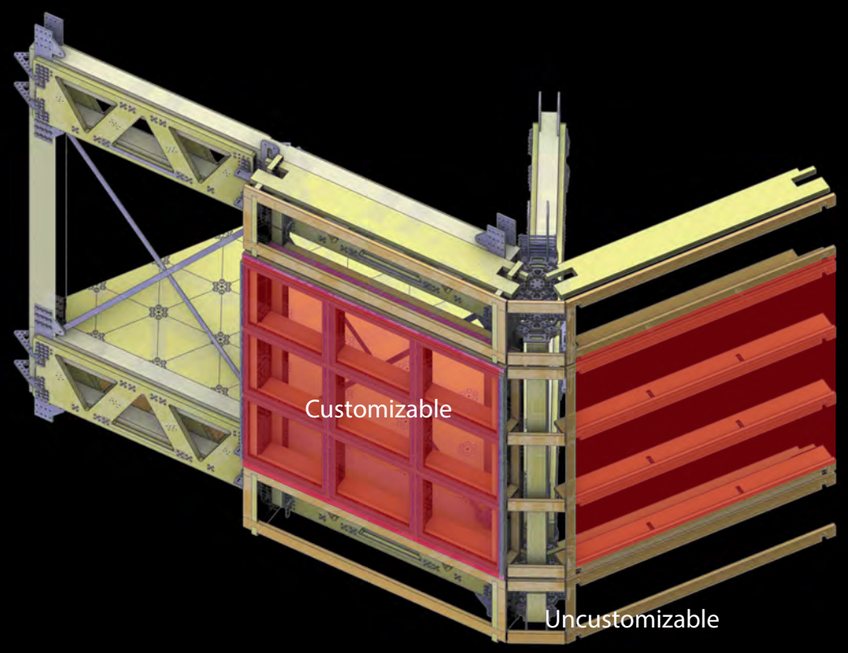


Figure 64. New facade approach restricts, but eases customisability, by working on a grid and splitting the facade into customizable and uncustomizable parts.



Figure 65. Wide columns narrows the grid to 3x3, obstructing variety and doorway positions.

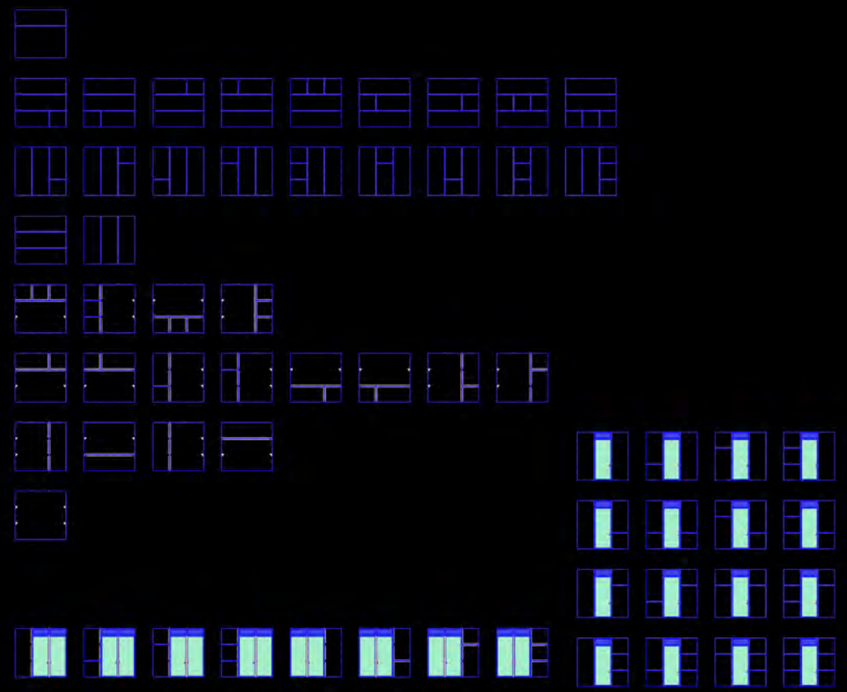
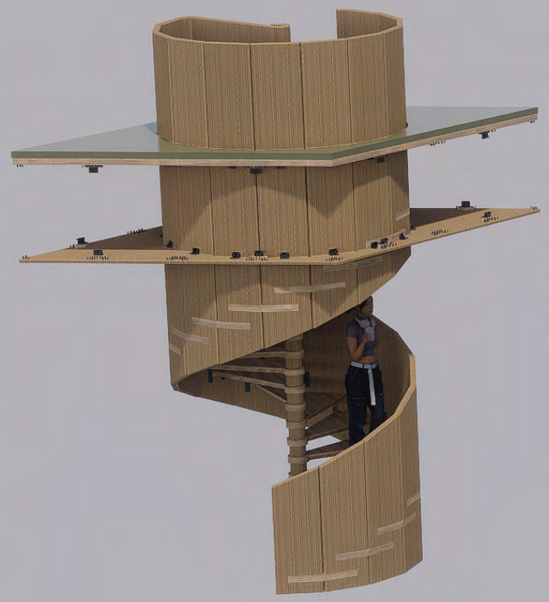


Figure 66. All possible configurations of the 3x3 system is limited.



Figure 67. 5x3 grid, with free door placement the geometry has 25088 possibilities, excluding materiality. 11 examples shown, all combinations listed in the corresponding catalogue.











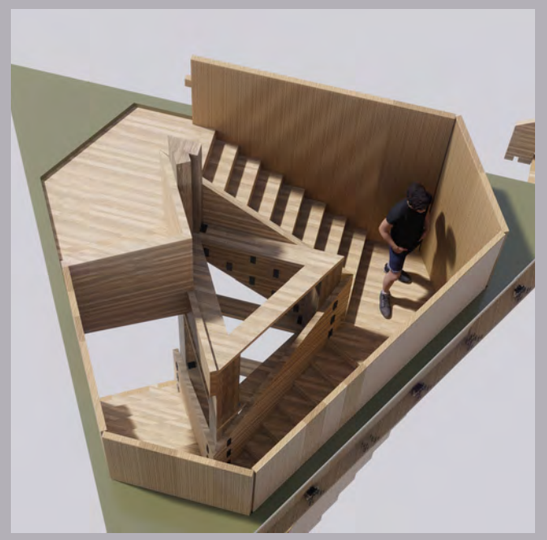


Figure 68. 3 stair variations, larger footprints handle larger volumes. All stairs are made from a moduklar construction and could be relocated by switching floortiles

Polycarbonate presents load bearing structure outside,

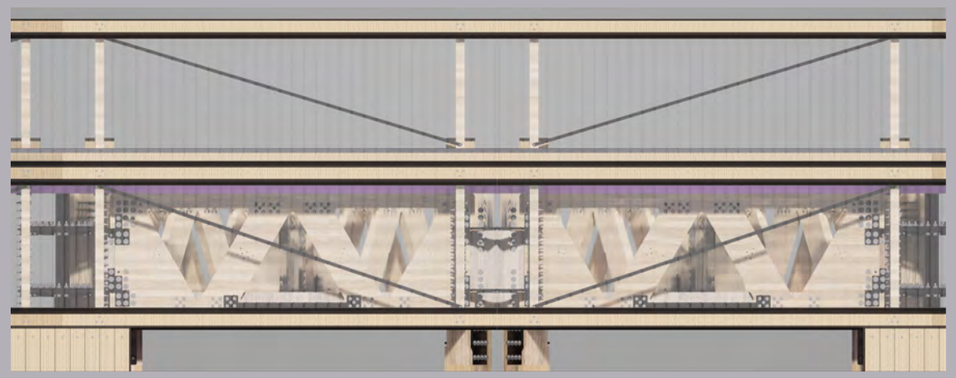


Figure 69, uncustomizable facade parts express the service floor building system.



Figure 71. Interior facade. The facade frame structural grid integrates furniture, and structure.

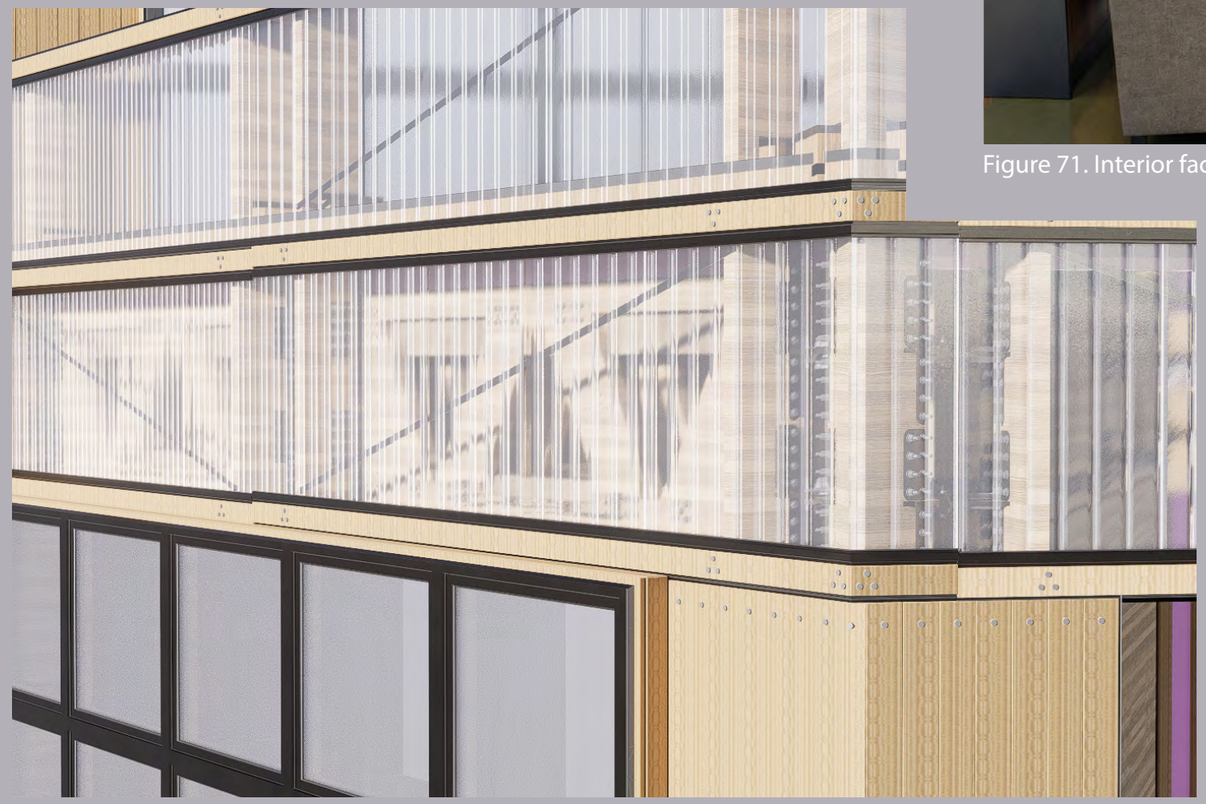


Figure 70. Detail facade.

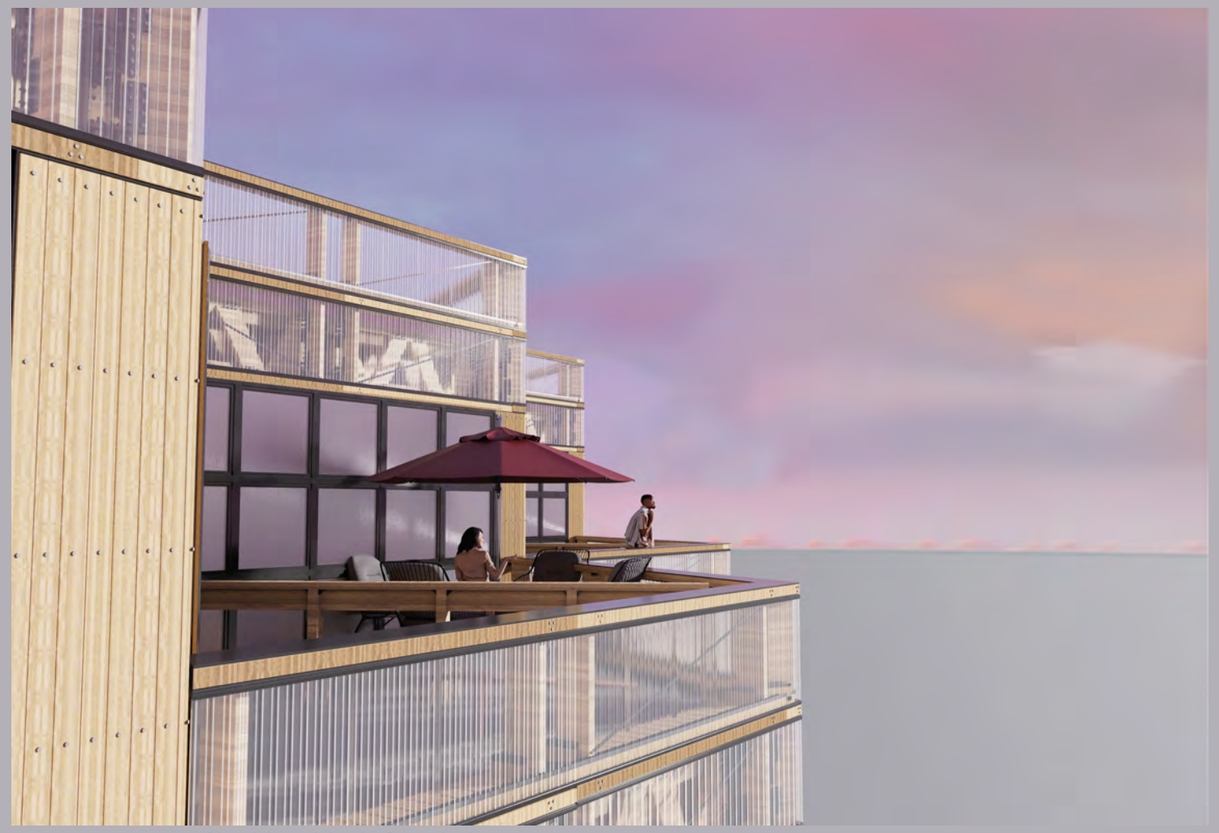


Figure 72. View of building block, from balconies

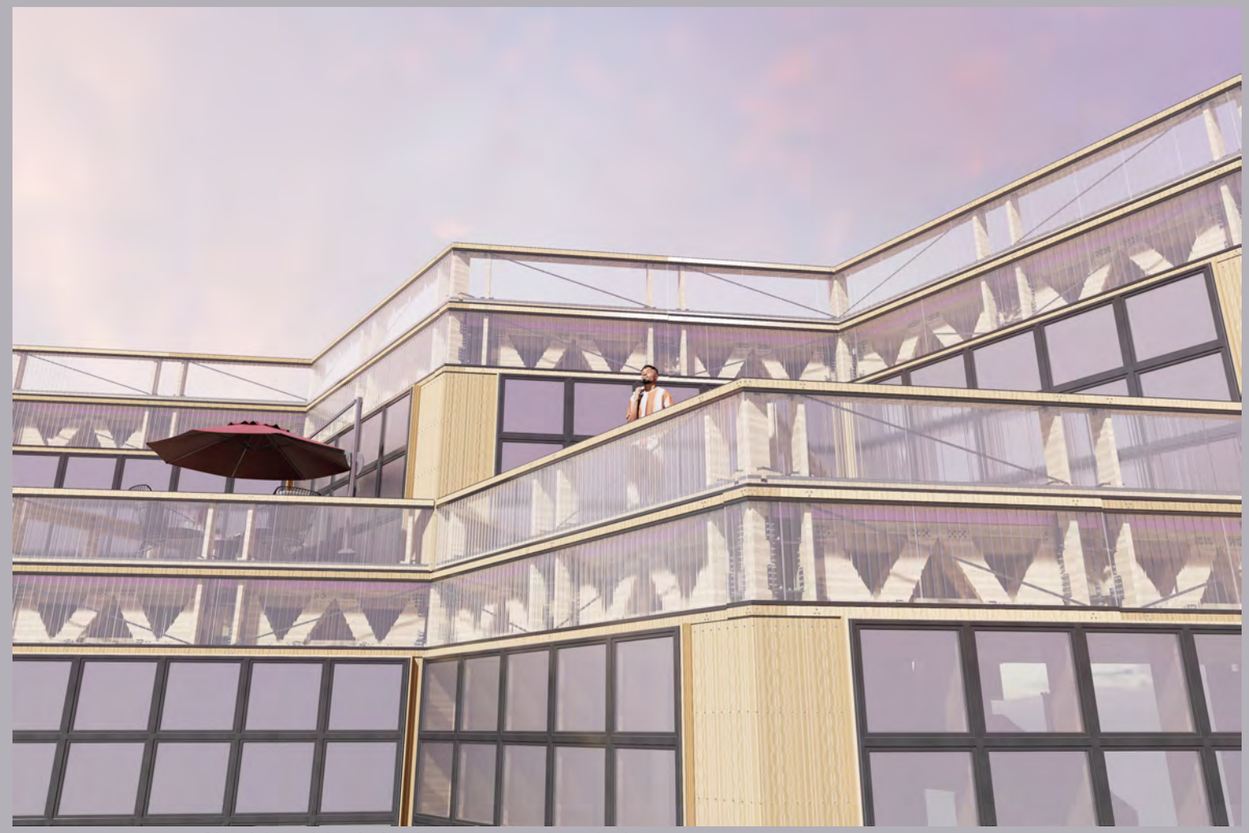


Figure 73. View of building block, looking upwards to balconies

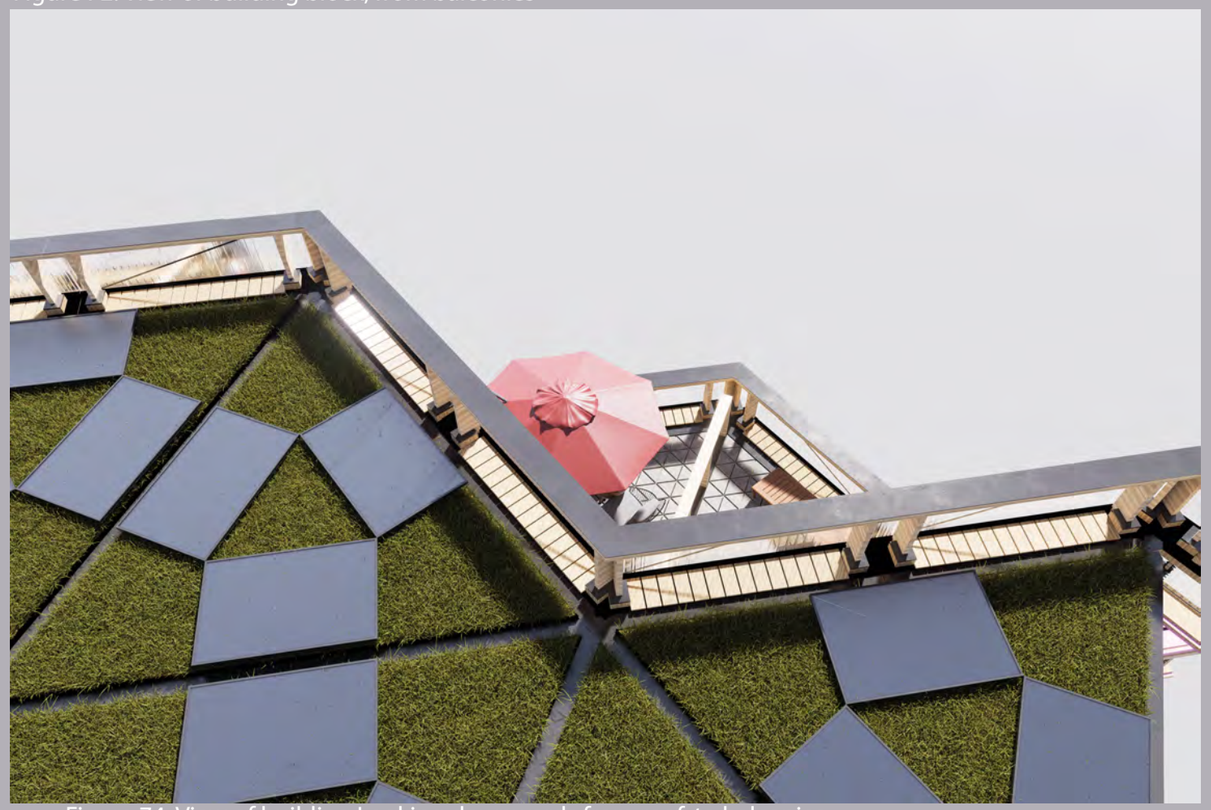


Figure 74. View of building Looking downwards from roof, to balconies



Figure 75. View of building block, looking upwards to roof

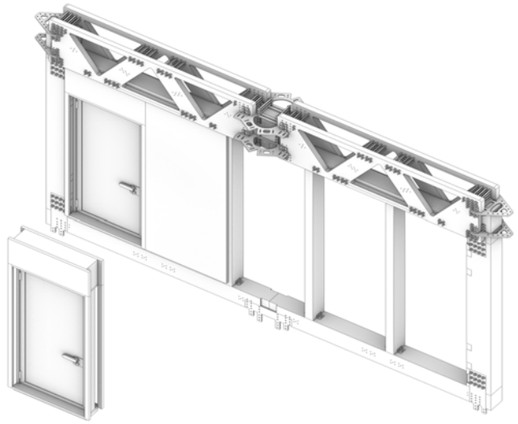


Figure 76. Modular wall elements, allow for easy adjustments of internal spaces, and include 180mm insulation.

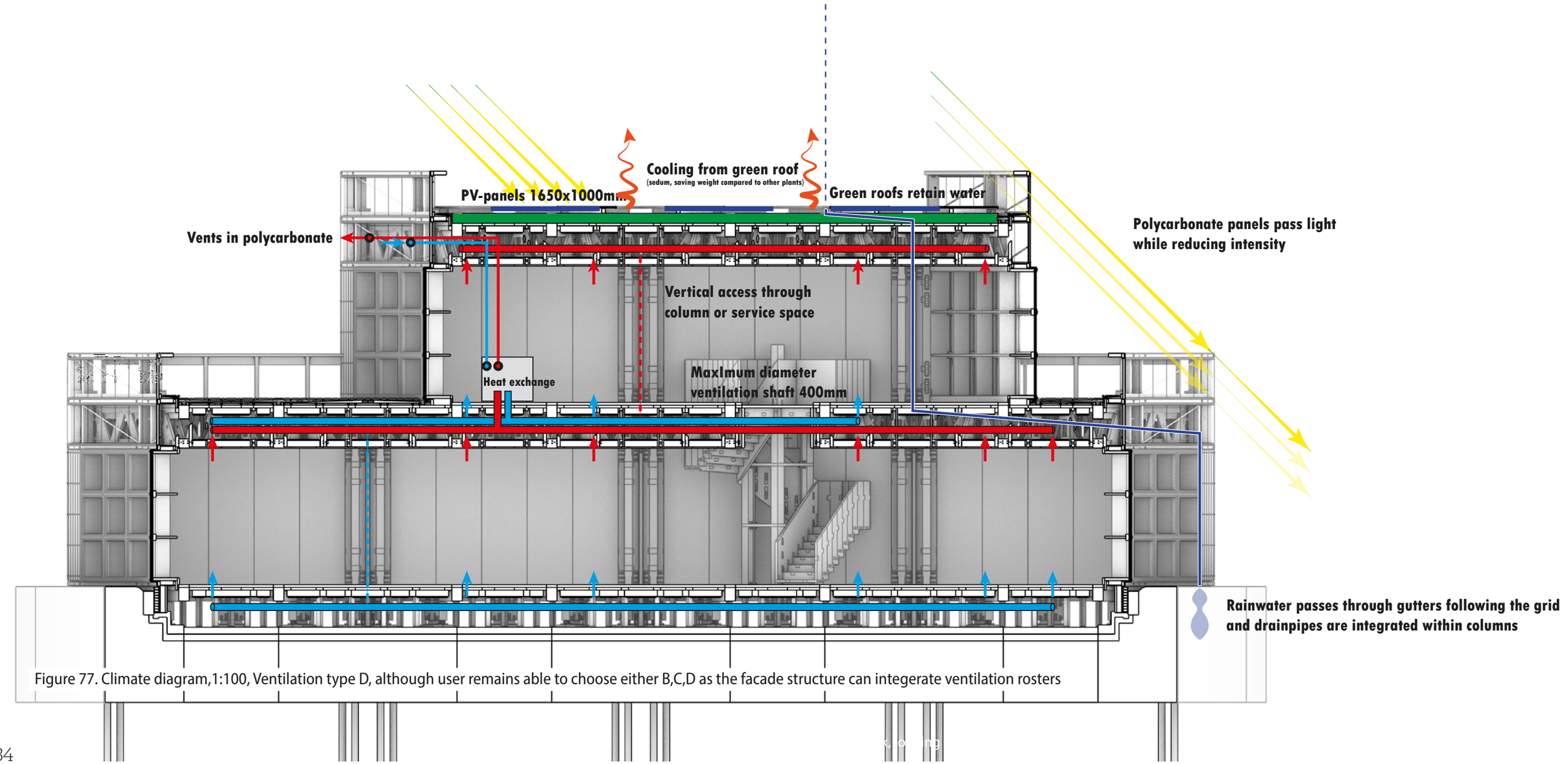


Figure 77. Climate diagram,1:100, Ventilation type D, although user remains able to choose either B,C,D as the facade structure can integerate ventilation rosters

Results

Open building to open neighborhood

With the shape of the stamp, urban volume and structure defined, the stamp can be divided into property lots. Only 3 differently shaped property lots create all building volumes, ‘the slice’, ‘the bend’ and ‘the point’. Combinations of different lots create room for larger structures, such as a supermarket. Each property receives a small landing between structure and street, transitioning straight streets to zig-zagging facades. Streets too are split into different elements, elements have 3 street profiles to choose from. Different street profiles can transition into each other. Variation in street profiles allow different local priorities, maximizing green space, cycling thoroughfare and pedestrian access respectively. Each street profile remains accessible for motor vehicles to allow their presence in case of emergency, delivery or maintenance, but is normally autoluw. The interiors of building blocks are car free green spaces communicating the distinction between public and private. All previous research culminates into a single adaptable stamp, the tool.



Figure 79, Street-tile system, not yet integrating into other street typologies well.

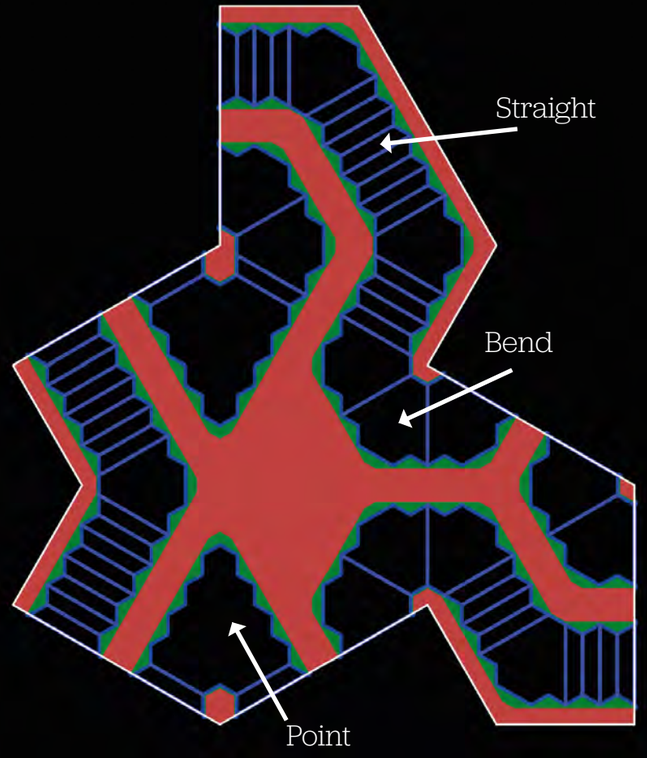
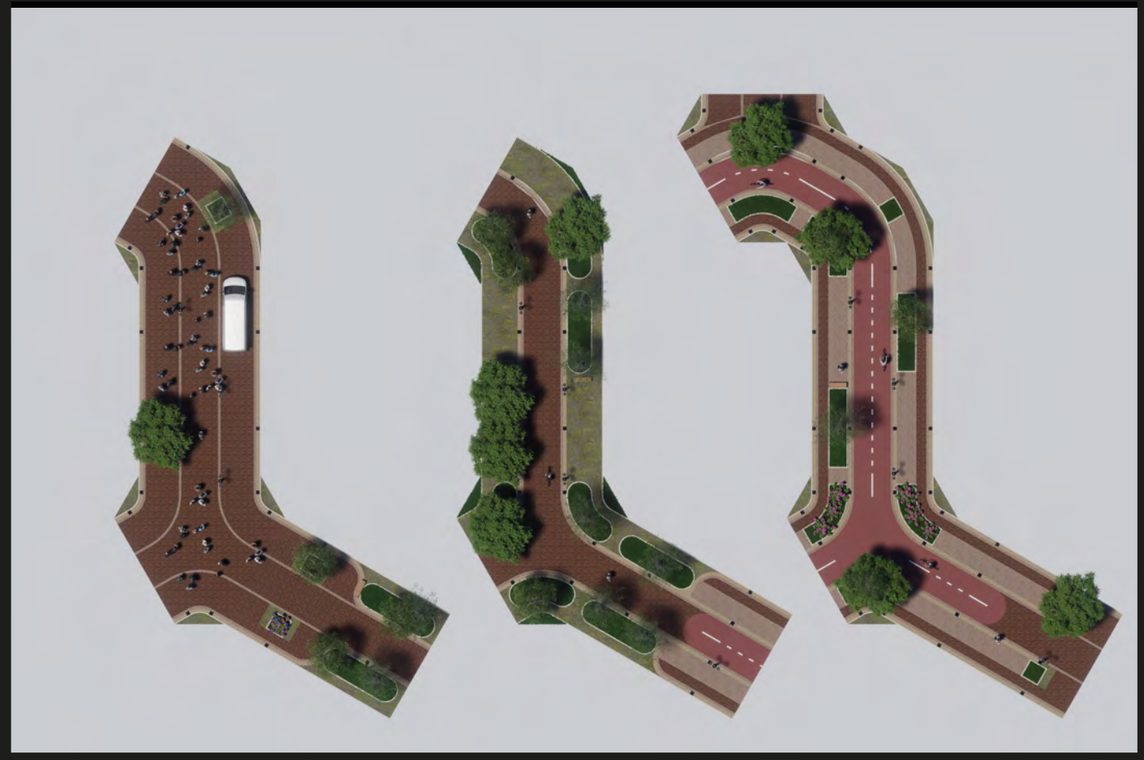


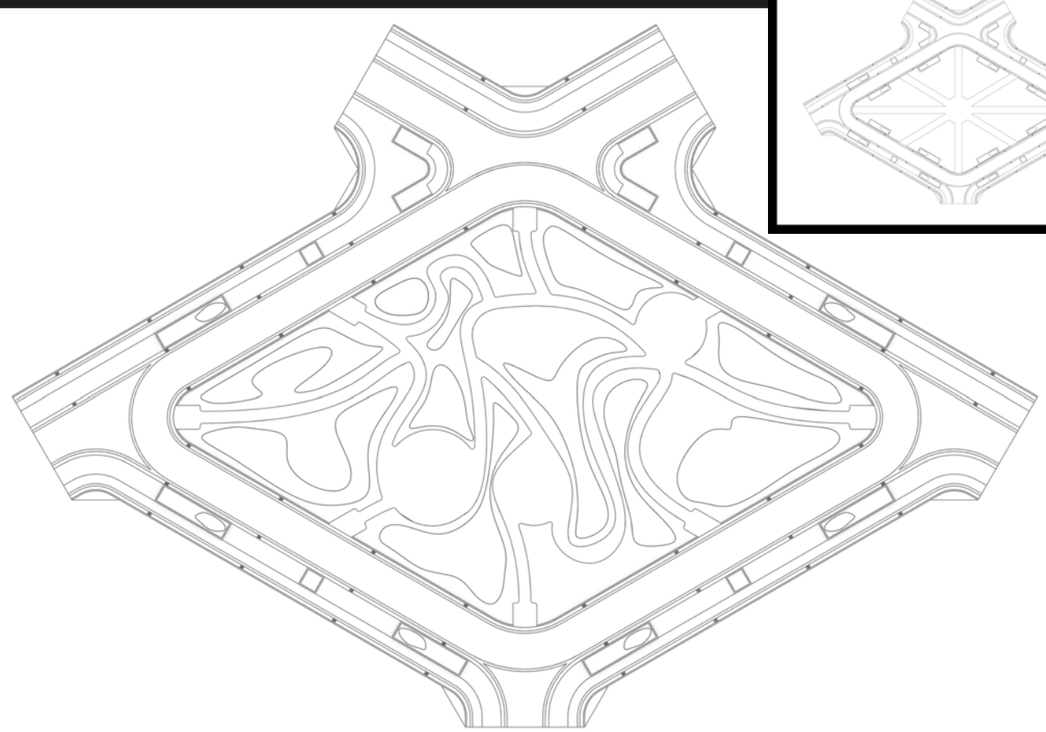
Figure 78, Building lots, and 3 distinct appearing shapes.



Figure 80. Streetprofiles. From left to right: Internal courtyard space, low volume green street, high volume bike highway, and wide shopping street







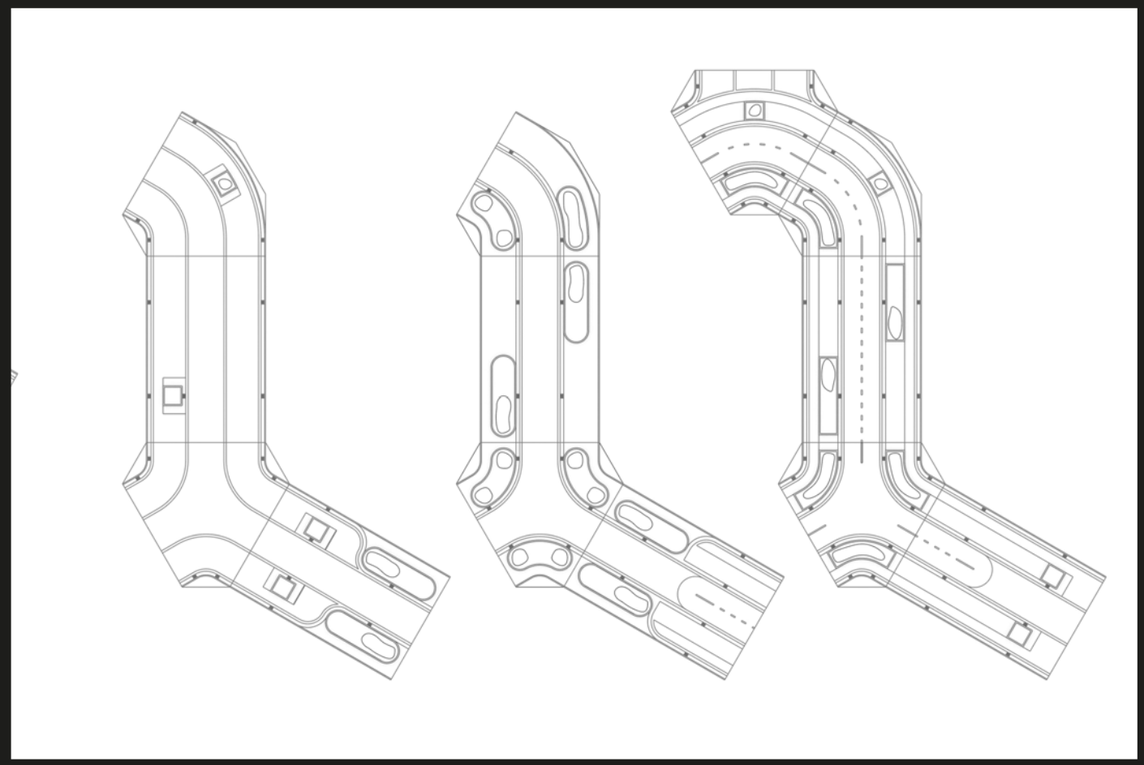


Figure 81. Final design steet profiles and blocks. The central kite shaped square can be changed out for an urban variant, supporting a market or fair.

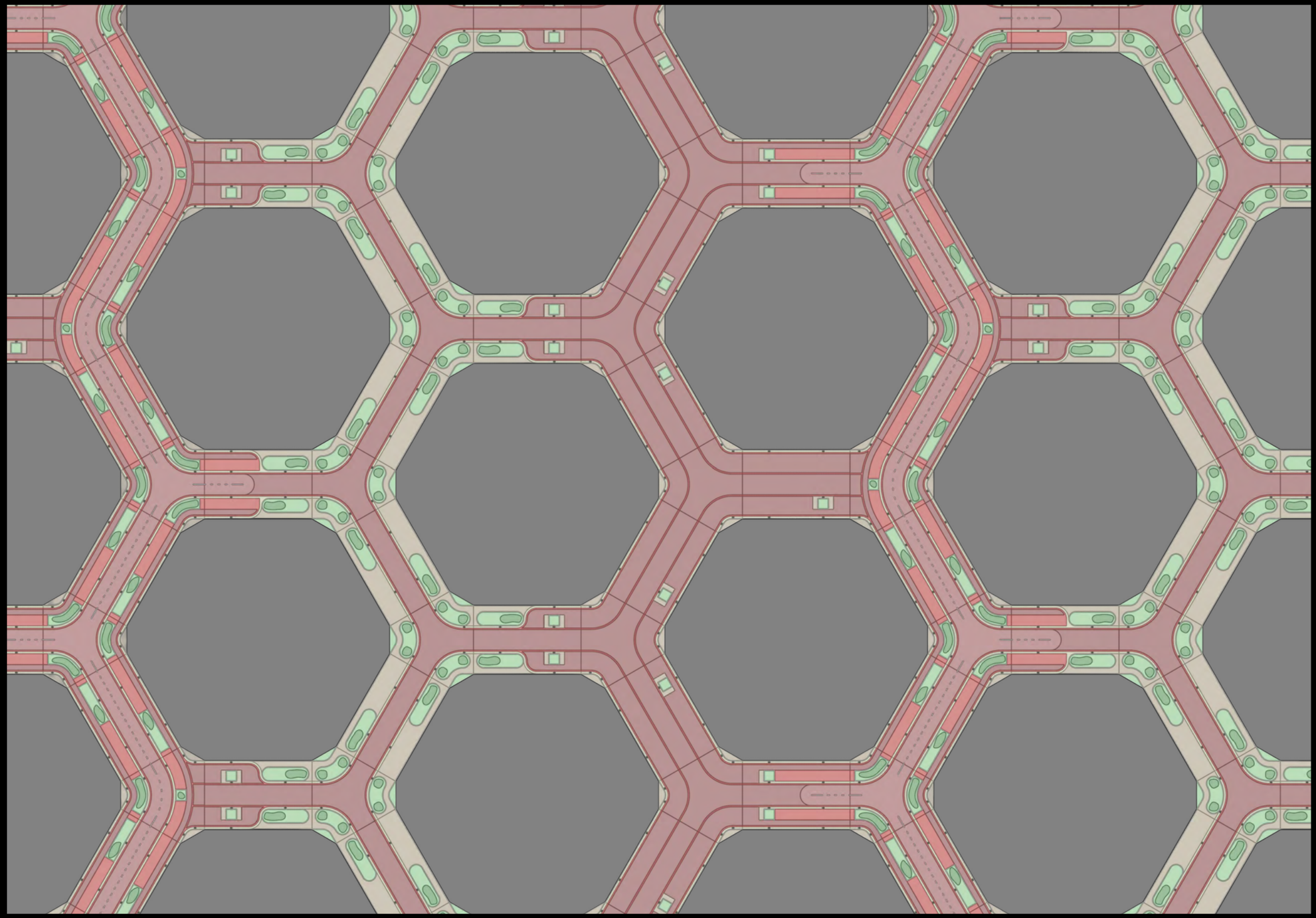


Figure 82. Integration and transition of different road surfaces.

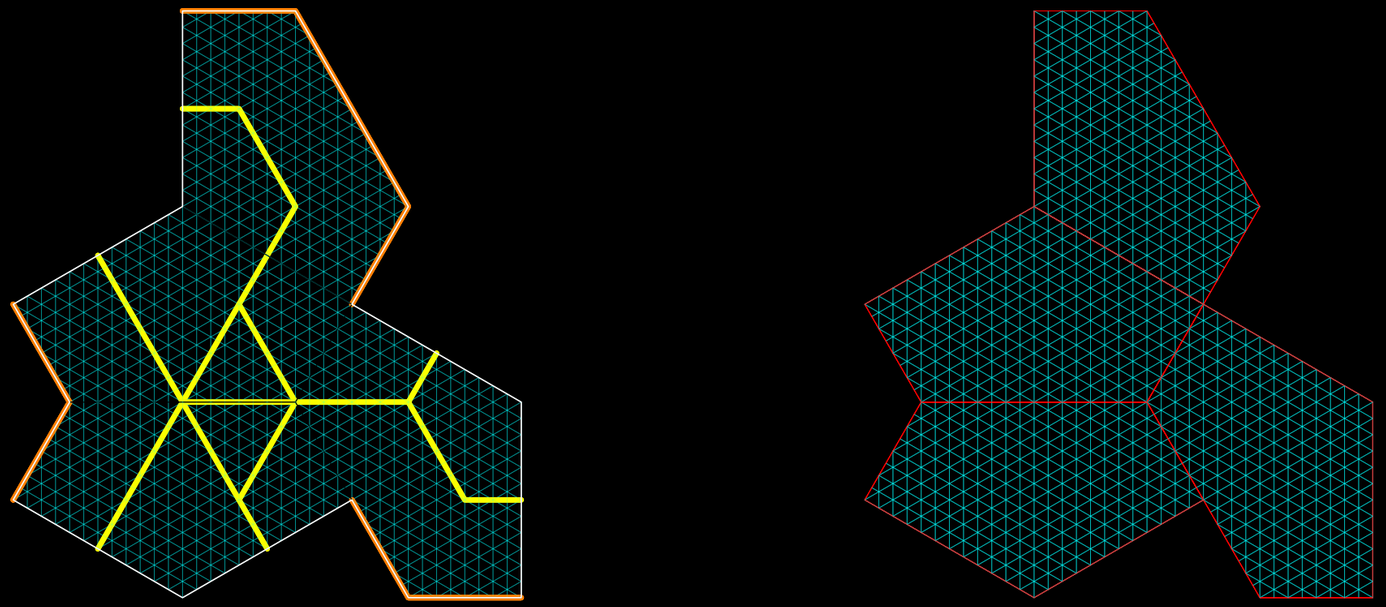


Figure 83. Final stamp: Stamp connections, internal grid, maximum building volume and materialization of public space.

Results

Application Woensel

The site of WoensXL connects to its surrounding fabric in only a few areas. The structure wraps around the tower Portos and northerly located dwellings. Furthermore the new urban core reconnects to existing cycling approaches and Woensel bus station, As the Einstein tile has infinitely many combinations, an organization of stamps can be found that aligns its structure approximately to the selected connection points, and from there expands outwards, filling the site. A small area of the current site remains intact and integrates into the new stamped system, reminding users of the previous urban core. Border parks are established to insulate from the large surrounding arterial roads, fitting in with the rest of the neighborhood. Mobility hubs are placed close to these edges preventing private vehicles from entering further into the urban core. The proposed core provides space for different functions akin to the original plan by Broek & Bakema, while also investing greatly in housing. The redesign introduces new third spaces, such as a library or a gym, increases retail space and introduces office and living space. With higher density mixed use spaces connecting public transport and remaining structures. The proposed plan takes up roughly 65% of the maximum volume, allowing future generations to increase density of the structure inside its original boundaries. If Woensel were to overhaul its transport network of wide car-centric infrastructure the system could continue tiling, expanding the urban core further.

A display of all floorplans can be found in the appendix: ‘floorplans’. Floorplans are included of all shapes, providing multiple variants. Floorplans show various typologies such as, terraced houses, porch houses, studios, co-living, appartments, stores (e.g. clothing or grocer), offices, libraries and a gym.



Establishing site boundary.



Add points of integration and care.



Generate structure, and include function fitting street profiles.



Generate urban volumes and create green boundary park.

Figure 84, application tool on WoensXL.



Figure 85, Satellite image application Woensel



Figure 86, View inner building blocks from roof



Figure 87, View street to square



Figure 88, Approach into centre from the East



Figure 89, View inner building blocks from terrace



Figure 90, Approach into centre from the North



Figure 91, Approach into centre from the North-East



Figure 92, Integration fragment old centre



Figure 93, Approach into centre from the North-West



Figure 94, Birds-eye-view late afternoon



Figure 95, Birds-eye-view summer sunset

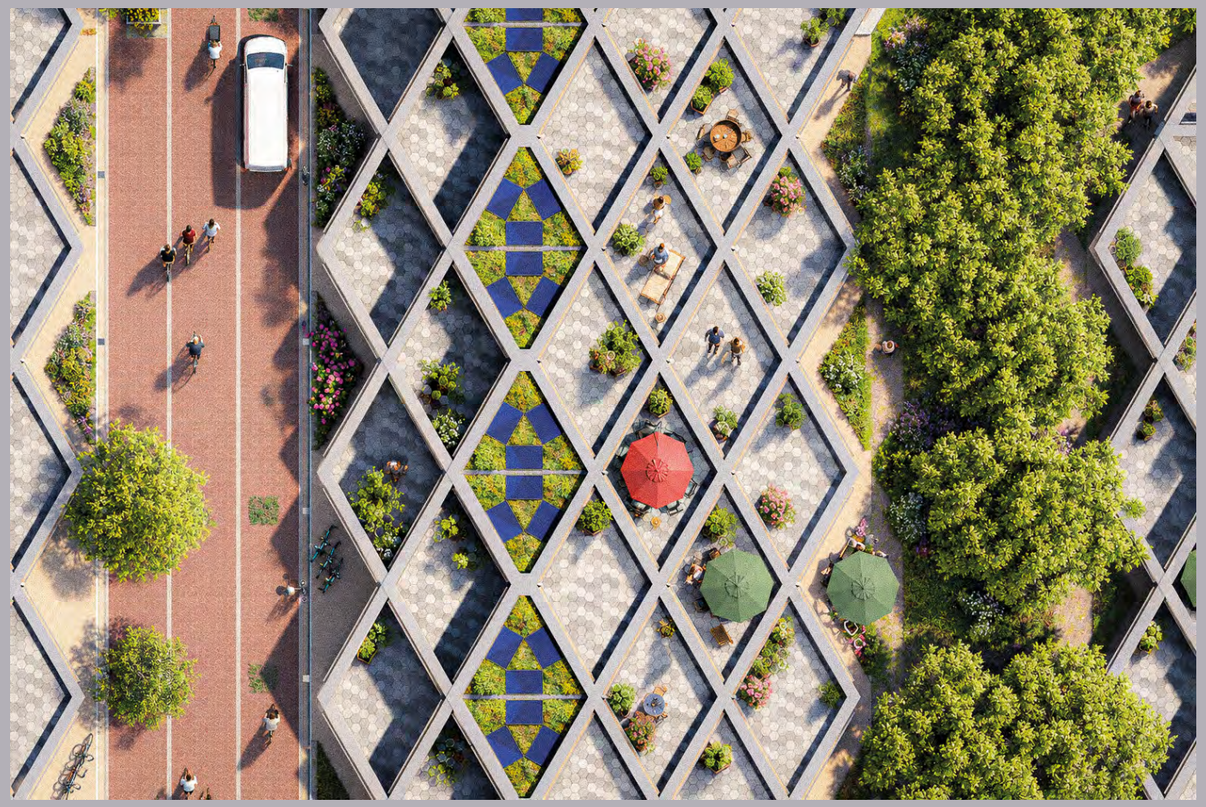


 Figure 96, Top down view, straight segment



Figure 97, Top down view, square fragment

Conclusion

Discovering if the applied solution still relates to the project goal: “Create a space filling structure, providing a multifunctional role as the town center of Woensel, that responds to changes in society, through future adjustments in: size, division, function and appearance.”, individual subquestions should be addressed first.

“How have philosophy and design methodology applied in Woensel affected flexibility?”
While the stamped philosophy of Woensel provided rapid development, and lowered the cost of housing, structures were unable to adapt to future generations, by lacking refitable, readjustable and convertible flexibilities. Space, left free on the original stamps, was filled with structures lacking the same adaptabilities. As structures were repeatedly stamped on a great scale, the same flexibility problems copied throughout the whole neighborhood..

“What generative approach to a space filling structure guarantees liveability, avoids monotony and encourages adjustments in size?”.
A stamp with aperiodic properties forces urban structures to be varied. Internal divisions of the stamp shape unique arrays of building blocks with distinct public and private sides. Rulesets, determining minimum and maximum building volumes maintain liveability in the metabolic load bearing structure. Personalized facade expression, varied property lot sizes and different street profiles mitigate monotony.

“How can a building system provide for future adjustments in function to accommodate changes in society?”
The thick, but lightweight triangular waffle floor supports weights of any function including public meeting and gathering spaces, giving the ability of the structure to change function. The hollow flooring furthermore supports ample space for services. By retaining the ability to remove flooring, like creating lofts or to changing positions of vertical translations, the threshold for function change is lowered.

“How can a building system provide for future adjustments in appearance to accommodate changes in society?”
Careful considerations in shearing layers allow buildings to change expression with lowered costs. The final structure stimulates the user to change facade expressions by providing a clear framework of facade customizability. The metabolic structure made through dry connections supports changes in volume.

“How can a building system provide for future adjustments in division to accommodate changes in society?”
Incorporating values of open building systems, building volumes remain adjustable in the future. Services running through floors stimulate adjustments of internal walls. Since all building lots face both public and private sides, additional divisions and methods of varied entrance locations remain available to later adjustments.

The final tool is in a sense a combination of 2 different projects, one tries to maximise adaptable urban volume for new developments, the other aims to rethink stamp-philosophy for modern practices. Renewed vision of stamps are able to benefit from previous production, planning and design advantages while mitigating problems of a low sense of place. The application of the tool on Woensel did provide one possible solution to the project goal.

Implications

Research showed that the negative stigma of a stamped city is not necessarily related to the idea of stamps itself. Reincorporating large scale stamping offers benefits in reducing planning, designing, manufacturing and construction costs, due to the repeatability of elements of varied scales. Using Einstein tiling as the base for stamps challenges monotony. Carefully selecting stamp geometry, stamp connections and adaptability within structures can strongly mitigate many issues of previous stamped developments.

More research needs to be done to find other possible geometries of aperiodic tiles applicable as urban stamps. The developed tool still communicates a certain ‘monolithic’ urban structure, but further research may find geometries where urban structures are perceived as unique and varied throughout by the user, while secretly utilizing a clever stamped metabolic structure, saving development in design, planning, manufacturing and construction, reducing both cost and time. The structures themselves will see an increased lifespan, through refitability and scaleability.

Introducing structures in post World War 2 neighborhoods with convertible, refitable, adjustable and scalable adaptabilities may lengthen the lifespan of these districts. As these new structures will take on societal changes in demand through changing in function and division, supporting inflexible zones of the neighborhood. Mass adoption of high density adaptable structures in monofunctional environments, free of housing, can allow positive changes to be made to monofunctional neighborhoods without the displacement of local residents. Similar tools can also be used on green- or brownfield developments, creating new multifunctional adaptable districts.

Reflection

The dichotomy of the project introduced a lot of complexity. While the ability for the neighborhood to grow into an infinite unique composition is appealing, the Einstein tile produced a triangular based building system. While great in strength, stability and a reduced number of unique parts, drawing floorplans and designing vertical translations were challenging. The small lift, present in some floorplans, needs more development. This fusion of complex tasks reduced the amount of similar case studies, as no triangular based, open building, deconstructable metabolic, stamped urban development tool exists. Therefore a combination of references had to be gathered which were often not immediately compatible, resulting in more time spent on the complex task of integration of different elements. Perhaps splitting the research in 2 provided could have provided a stronger case for both elements. The final structure is reminiscent of a fusion between 'bloemkoolwijken' and more traditional courtyard cities, such as Eixample in Barcelona. While this structure does fight monotony, a more grand hierarchy in the stamped pattern is still missing to mitigate a low sense of place. The adjustable urban volumes, variation in street profiles and customization in facade expression might relieve this issue from the duty of the stamp, although these properties were not considered at the start of the research.

Soon after research commenced the second subquestion had to be altered; *"What generative approach to a space filling structure guarantees liveability, and encourages adjustments in size?"* was originally phrased as "*What generative approach to a space filling structure encourages adjustments in size, to accommodate changes in society?"*. The older subquestion abstained from considering liveability and hindered the judgement of solutions.
Final results of urban building volumes are heavily restricted by adequate sun-access and ample public space. Generated structures before readjustment had no restrictions and therefore easily snowballed into undesirable urban structures rhyming in typology with the former Walled city of Kowloon in Hong Kong, able to consume all space.

The use of CAD-software to tessellate stamps was crucial to the design process. Many original plans of physical models had to be cancelled due to the needed repetition of parts to test them. Numerous times sparking the curiosity if stamps from the 60's would have been different with modern day technology, and if these building philosophies would have continued on large scales today.

The final greatest caveat of the developed tool is the restriction of total project size. While the tool can generate structures of infinite size and complexity, generated areas larger than 1 square kilometer are lacking in internal structures. While the applied site is slightly too small to fully demonstrate the special properties of the Einstein tile. New street profiles could be developed such as bus- or tramways. New stamps need to be able to vary urban structures and route large scale transportation infrastructure like arterial roads or trainlines, possibly through varying square size and street width.

The stamps with a low-car environment have difficulty transitioning with the car-dependent philosophy of Woensel The placed mobility hubs are not a solution applicable on a larger scale, and introduce an unfortunate transfer monolith at the border of the development. Furthermore edges of developments are jagged due to the connections of Einstein tile tessellations, perhaps other aperiodic tiles can produce a more efficient edge, introducing more adaptable space in the site. Still I personally believe that the developed tool did grant Woensel a multifunctional space filling structure, that could respond to changes in society, through future adjustments in: size, division, function and appearance. However, more research remains to be done to have similar tools be applicable on larger or standalone sites using to be (re)discovered tile geometry.

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