TIMBER METROPOLIS

The potential of lightweight timber constructions for inner-city densification and the integration of vegetation into the urban fabric

MASTER THESIS BARBARA WINKLEHNER

"We do not just build because more housing is needed - we build a city of the future".[1]

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1 Peder Hallkvist in the Interview for *Urban Density Done Right* by The Swedish National Board of Housing, Building and Planning 2017, p.11

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MASTER THESIS

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PROLOGUE

PROLOGUE

Worldwide, cities are expanding. More than 50% of the world's population currently lives in urban areas, a proportion that is expected to increase. Urbanisation combined with the overall growth of the world's population makes the managing of urban areas one of the most challenging developments of the 21st century.[1] It is for us to decide how to approach this expansion, because it also provides us with a great opportunity: the opportunity to shape the future of our cities in a positive way. The following work suggests a solution to sustainably and optimistically plan this progress. I personally think of houses like trees and cities like entire woods.

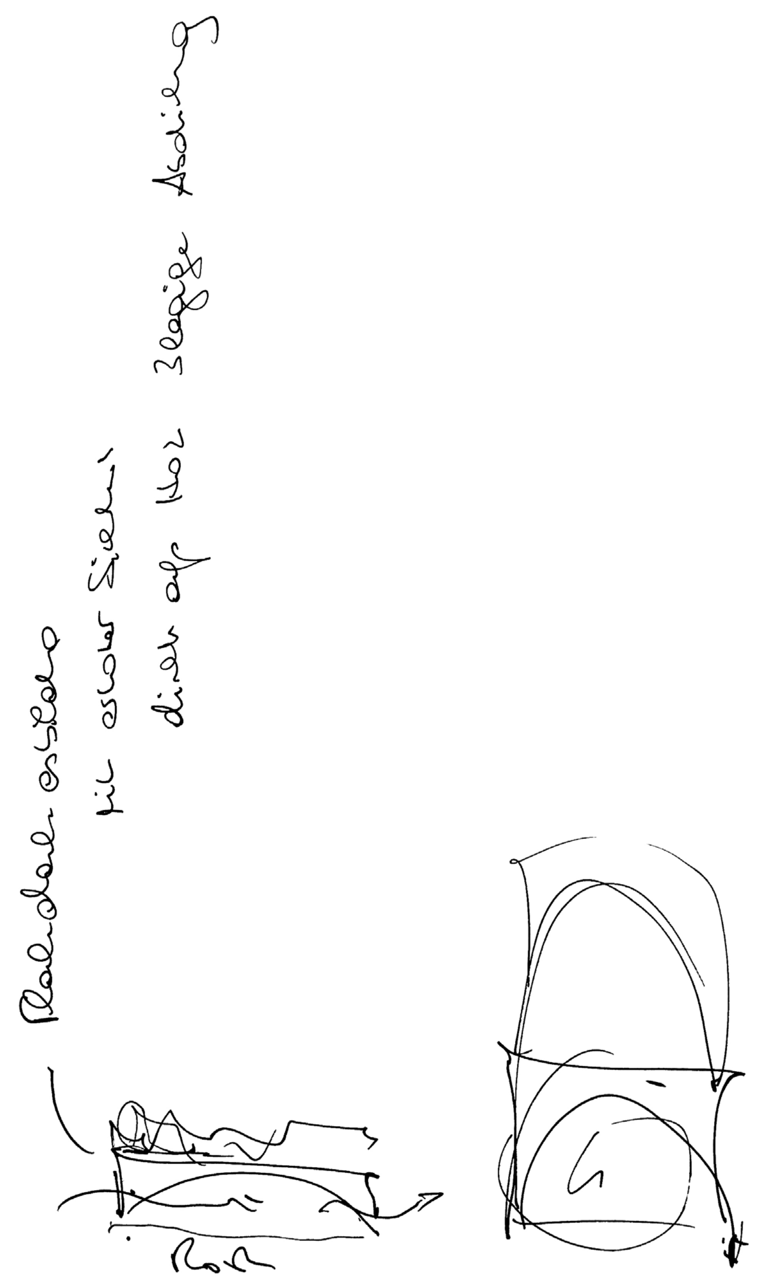
The growth of our cities has to go hand in hand with densification and it asks for more than the further construction and provision of housing. It is also about creating a good built environment for the people who live, work and spend time there. The essence of the city consists in maximising interactions between people, but it has become progressively disconnected from nature. The implementation of plant life into the urban environment has many ecological benefits and the presence of nature can be a powerful fuel for our recreation. I therefore suggest to bring its positive aspects back into our cities.

This study focuses on the geographical and demographic conditions of European cities and the resources that lie in their historic housing stock. London is one of the largest cities in Europe and a world metropolis. On the premise that the major trend of urbanisation is continuing, it can be considered as a model case for the fabric of a future European city.

Finally, this work is about timber and its manifold qualities as a construction material. Due to its lightweight and its ecological qualities it should play a quintessential role in the whole lifecycle of a modern city. This study shows the potential of timber roof extensions for cities, which can grow into the future like trees.

1 United Nations Department of Economic and Social Affairs 2014

DISCOURSE



01 Concept Sketch

1.1. HYPOTHESIS

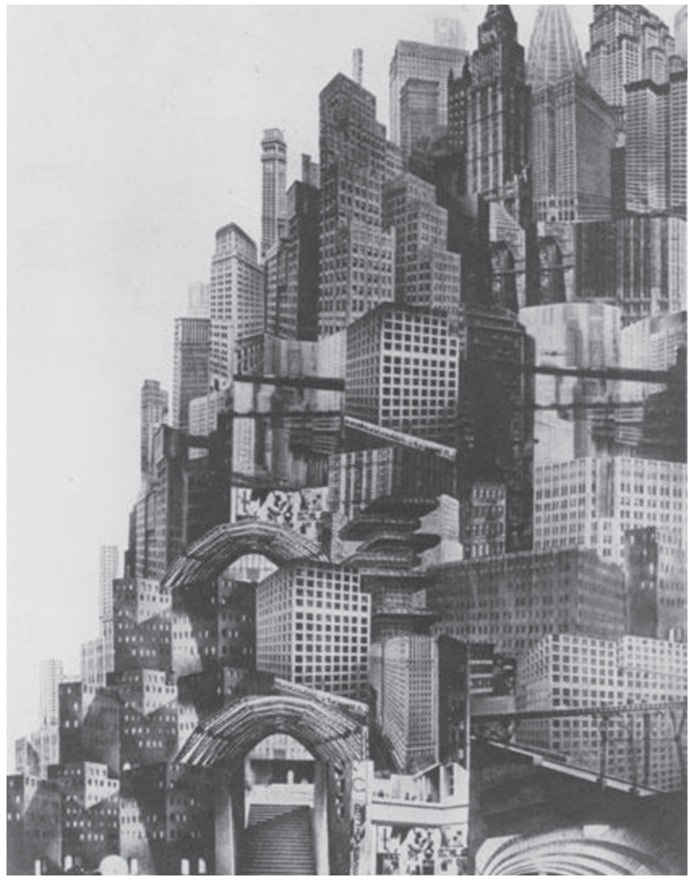
This thesis examines the potential of lightweight timber constructions within the framework of inner-city densification, combining the provision of social housing and the integration of vegetation into the urban fabric.

It states that lightweight timber constructions can significantly contribute to the further construction of the historic building stock in European cities.

It argues that these constructions can be combined with the provision of vegetation and urban green spaces to enhance the social and natural quality of modern city life.

It focuses on the extension of social housing schemes and shows how these additions can deal with and respond to the challenges of statics and building physics arsing within this scope.

It finally illustrates a possible development for growing cities by showing a prototypical construction system that can be applied to a set of building typologies



02 Metropolis

1.2. SCOPE AND FOCUS

The key aspects of this work's hypothesis can be grouped into three main topics:

Inner City Densification

Lightweight Timber Constructions

Urban Green - Our Cities need Vitamin G

The following pages give an overview of these categories to examine their interdependencies.

1.2.1. INNER CITY DENSIFICATION

The first aspect is based on the hypothesis that many metropolises worldwide and almost all European cities with over a million inhabitants are prone to undergo densification processes. The 2017 edition of the *State of Housing in the EU* provides proof that Europe's major cities face a structural housing shortage.[1] Many of these cities have developed by growing outwardly, creating a phenomenon called urban sprawl increasing car dependence and claiming valuable land.[2]

There is a relation between the layout of a city and its carbon emissions. Alongside other social benefits, it would typically be more sustainable to further develop cities into being more compact.[3] Inner city lots for new developments are, however, very scarce. City and municipal planning must therefore activate the existing building stock as a base for new developments.[4]

However, the efficient further construction of our built environment is not enough. "The actual essence of densification is to create a more varied and rich environment, one that offers more for everyone at close proximity" [5], says Peder Hallkvist, City Architect in Örebro, Schweden.In order to achieve a highly varied and dynamic city, most things should be mixed: functions, building types, forms of tenure and the socio-economic composition of the population.[6]

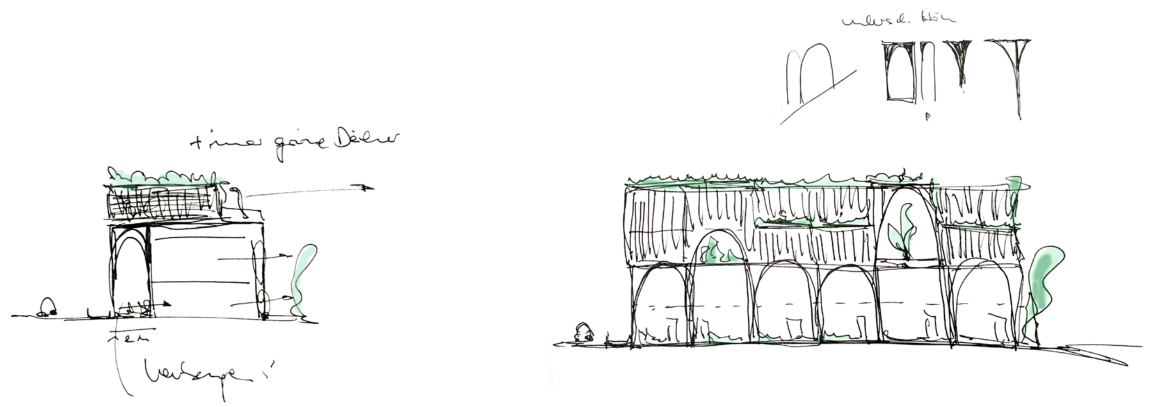
1 Housing Europe, the European Federation of Public, Cooperative and Social Housing 2017, p.10

2 cf. The Swedish National Board of Housing, Building and Planning 2017, p.7 **3** cf. Wiegand 2016 cf. **4** cf.Lattke in Zuschnitt Nr.66 2017 p.6
5 cf. Hallkvist in *Urban Density Done Right* 2017 p.11 **6** cf. The Swedish National Board of Housing, Building and Planning 2017, p.11

The provision of housing in general is one of the main aspects of this process and the demand for social housing in particular is one of the key issues within this scope. The further construction of the the existing social housing stock is therefore a substantive way to bring affordable living space back to the urban area and closer to the city centre.

From a construction point of view, there a various ways to tackle this compaction. Depending on the condition of the existing buildings and considering legal and structural requirements[7], interventions can be grouped into four main types:[8]

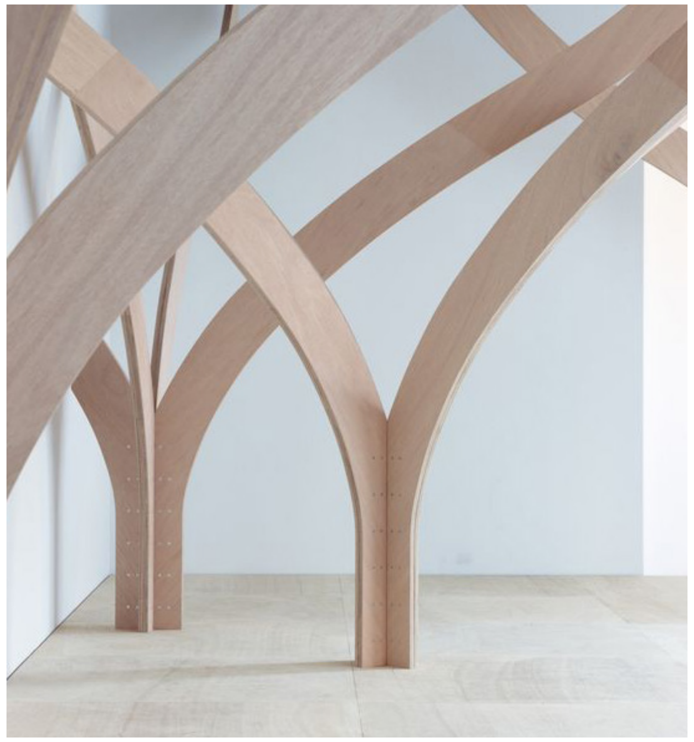
As this work explores the potential of timber constructions with regard to their lightweight, it focuses on the fourth intervention type with its storey additions and roof extensions. The prospect is to suggest a form of densification without claiming new ground, creating additional housing space while taking advantage of the existing infrastructure.



03 Courtyard in Bermondsey, London

04 Modernisation and Concentration of Existing Buildings 05 Concept Sketches

7 This refers to fire and earthquake safety, sound protection, stability of the the existing structure, site conditions and building regulations.
8 cf.Lattke in Zuschnitt Nr.66 2017 p.6



06/07 Examples of Timber Constructions

1.2.2. LIGHTWEIGHT TIMBER CONSTRUCTIONS

"The roofs of today are the plots of tomorrow."[9] Research shows that almost a quarter of urban buildings around the world are strong enough to carry additional floors made of wood.[10] Various characteristics predestine timber for inner-city developments:

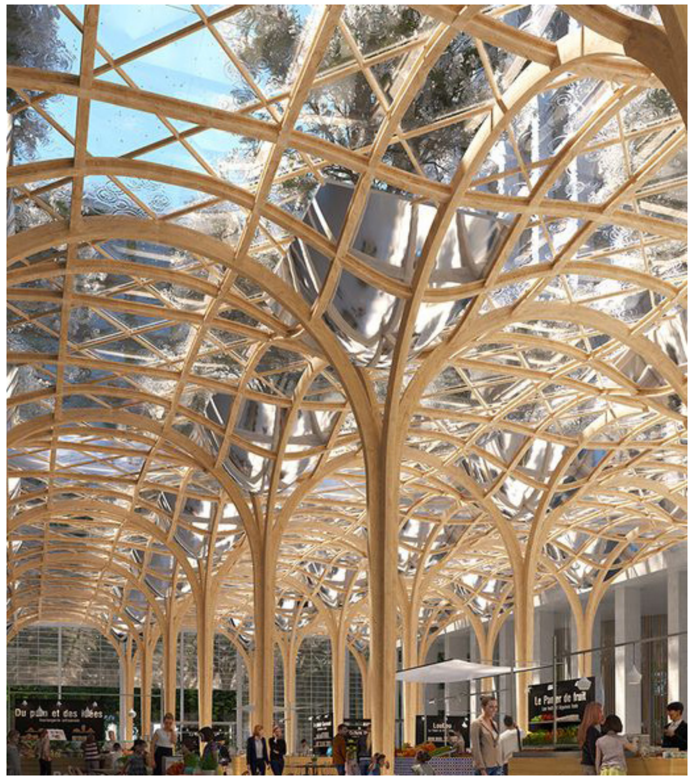
Lightweight: Wood has high strength in relation to its weight. This lightweight is its great potential when it comes to upward extensions of existing buildings. The lower transport weight can furthermore reduce the grey energy of the overall construction process.

Prefabrication: Timber constructions are suitable for various degrees of prefabrication, which allows for straightforward and precise building site logistics, abbreviates the construction process and minimises disturbances. This is key for inner-city developments where space conditions are confined and roof extensions are typically carried out while the building below stays inhabited.[11, 12]

Ecological Footprint: The use of timber as a construction material is of great importance when it comes to the ecological footprint and the lifecycle of a building. Biogen materials like wood and its secondary products have a high performance regarding ecological assessments and C2C-principles.[13] They are renewable resources, can be extracted, reused and recycled requiring less energy than many other building products. Wood traps large amounts of carbon from the atmosphere and stores it until it is thermally used by the end of its life.

13
Cradle to Cradle® is a design concept that was developed in the 1990s by Prof. Dr. Michael Braungart, William McDonough and the scientists of EPEA Internationale Umweltforschung in Hamburg. It describes the safe and potentially infinite use of materials in cycles.

9+10 MetsäWood www.metsawood.com/global/news-media/articles/Pages/default.aspx ***11*** cf.Lattke in Zuschnitt Nr.66 2017 p.6 ***12*** cf. Working group for ressource-orientated construction – Institute for constructive engineering – BOKU Vienna, alpS GmbH (publ.) 2016

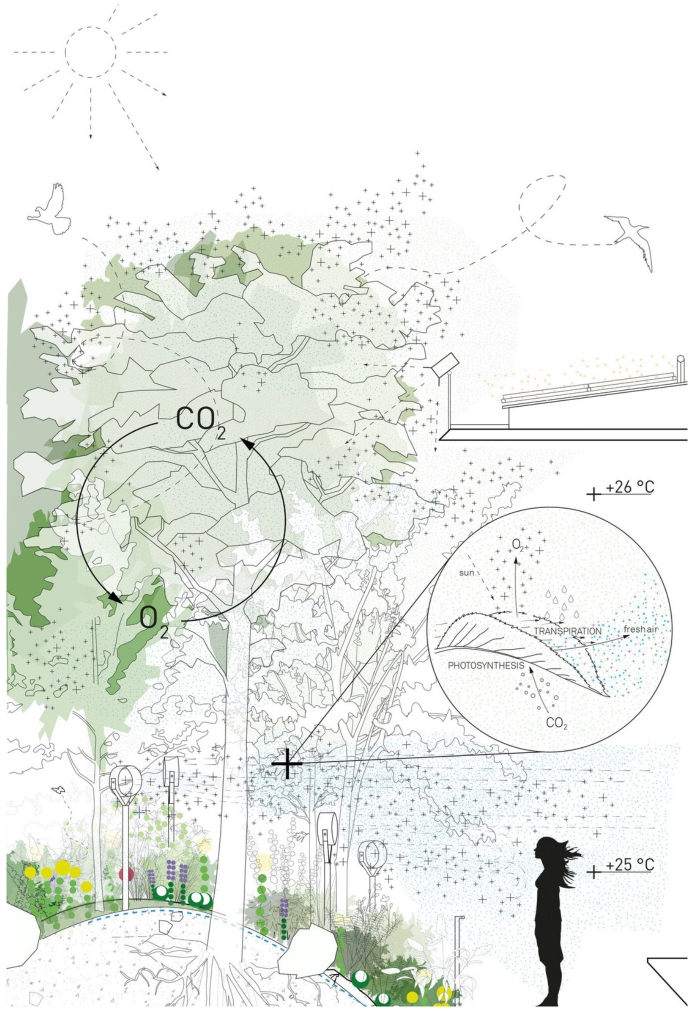


It can be summarised that timber constructions in general, and vertical timber frame extensions in particular, represent a valuable solution for a sustainable densification, even more so if the load bearing capacity of the existing structure has to be maxed out.

On condition that the acceptance of timber structures for inner city developments increases, this holds a great potential for a culturally interesting, economically relevant and ecologically sustainable city planning.

Chapter 4 of this thesis is entirely dedicated to the development of a flexible solution for a lightweight timber construction system. It presents a design proposal, showing typical design drawings and elaborates the key structural joints with typical detail drawings.

08 Lightweight Timber Construction



09/10 Breathe, Autsrian Pavllion

1.2.3. URBAN GREEN - OUR CITIES NEED VITAMIN G

Another aspect for a balanced densification process is the role of green space within our urban areas. The essence of the city consists in maximising interactions between people, enhancing activities, creating new ideas and allowing for innovation. The process of continued urbanisation has however gone hand in hand with the city becoming progressively disconnected from nature and subsequently with a loss of natural green space. [14]

The presence of nature can be a powerful fuel for our creative thinking and our recreation. It is beneficial to bring some of its positive aspects into the urban fabric. By implementing threads and nodes of biophilic interventions in strategic and specific urban places, we may find an acupuncture-like approach to enhance our urban habitat with natural qualities while at the same time keeping the very essence of contemporary city life with its advantages.[15, 16]

There is especially an ecological benefit of implementing botanical life into our cities. Plants can be a key element of the solution for the following necessities:

Cleaner air: Plants are able to capture airborne particles like smog, heavy metals or volatile organic compounds from the local atmosphere. This has a positive effect on air quality and consequently benefits the health of inhabitants.[17]

Reduction of Urban Heat Island (UHI) Effect: Bringing in plant life can reduce the ambient air temperature in urban areas. Due to buildings' and roads' heat absorption, summer temperatures in cities can be much higher than in the countryside. According to research carried out by the Tyndall Centre for Climate Change there is a need of 10% more greenery in towns to mitigate the UHI Effect.[118]

CO2 reduction: Plants can furthermore help to reduce the amount of CO2 in the air, which is considered one of the most important causes of global warming.[19]

14+15 cf. Yudina 2017, p.6 ***16*** Leung 2016 ***17+19*** cf. Urbanscape 2017, p.4 ***18*** cf. U.S. Environmental Protection Agency 2008

11 Installation Not Red But Green - Per Kristian Nygård

Rainwater retention and purification: Another advantage is the reduction of storm water run-off, which then leads to a decrease of the burden on sewer systems, reducing flood risk and increasing resilience.

Noise reduction: Green facades, green roofs and green open spaces with vegetation can reduce sound levels and work as a noise buffer.

Biodiversity Enhancement: As urbanisation increases, ensuring biodiversity is one of the key requirements. Plants can provide a habitat for various species and restore the ecological cycle disrupted by urban infrastructure.[20]

Urban agriculture: Additional to the benefits mentioned above, it is also possible to create opportunities for urban agriculture. This can help to reduce a community's urban footprint thanks to local food system creation foster a the social fabric.[21]

20 cf. Cooper 2017 **21** cf. Urbanscape 2017, p.4

1.3. CHALLENGES

In order to achieve the objectives antecedently mentioned, it is important to identify their implications. This chapter therefore discusses the various challenges from different terms of reference and their potential impact on any design proposal. Following an initial determination of suitable roof tops for extension projects, an assessment of their capacity should be conducted relating to technical, structural and legal constraints.

Structural Capacity of the Existing: The first pivotal aspect in the feasibility of delivering rooftop developments is the structural assessment. The load-bearing safety of each existing building has to be proven according to building codes. As they are ideally refurbished while inhabited, certain testing methods may be problematic. There is a potential risk that the existing structure has to be reinforced, implying additional costs from respective strengthening measures,. Modular upward extensions still represent a cost-effective alternative to newly built houses, especially when the latter involve the demolition and disposal of an existing building.[22, 23]

Haulage and Transport Restrictions: The dimensions of the new-build elements need to correspond to the transport restrictions of the respective city layout and can vary depending on the urban zone. With regard to the city of London, delivering part of the goods by water could be a cost-effective and efficient method taking advantage of this under-used resource, which would remove lorries from the street and reduce emissions.

Access, Height and Fire Safety: As per the *HTA-P-Rooftop Development Report*[24], the access via the existing vertical circulation routes is often the most cost-effective solution. Existing stairs are likely to form the main means of escape in the event of fire and for fire-fighting by the local Fire Brigade. Proximity to the final exit will be crucial, as this impacts on travel distances. The use of open deck access between accommodation and core can extend these distances. There is one particular challenge that needs to be addressed regarding the fire safety of timber constructions: Wood is flammable, but its burn-up is calculable and controllable (average combustion velocity of 0,7 mm/min). With sufficient dimensioning, timber can maintain its load-bearing safety in the event of fire due to its specific characteristic to form a

22 cf. Working group for ressource-orientated construction – Institute for constructive engineering – BOKU Vienna, alpS GmbH (publ.) 2016
23+24 cf. HTA Design LLP for Appex Airspace Development 2016, p. 33

surface charcoal layer leaving the core of the structure intact.[25, 26] The acceptance of wood as construction material with regard to fire safety, is a sensitive issue and will be subject to further discussions in the years to come.

Existing Services Infrastructure: The assessment of services such as electricity, gas, water and refuse facilities involve two different aspects. Alterations to the existing infrastructure need to be planned in an early stage in order to detect potential challenges and cost risks. Typical elements such as lift over-runs, chimneys, gas flues, ventilation shafts, plant rooms, PV panels, rainwater facilities, smoke vents or roof lights may inhibit the utilisation of the roof space and need to be considered.

Maintenance: Safe access for cleaning and maintaining the extended structure needs to be provided.

Acoustics: Internal and external noise levels need to be considered for the new built lightweight constructions themselves and acoustic separation needs to be provided between the existing dwellings and the new housing built on top.

Sustainable Technology and Green Space Factor: Adding onto existing roofs comes with the opportunity to improve and enhance the status quo. The implementation of sustainable technology is one aspect for this approach, the addition of green space alongside these measures is another important factor within this scope. Potential challenges occur when it comes to the capacity of the load bearing system. Vegetation as well as plant services for renewable energy have a significant effect on the overall weight of the new build structure and have to be aligned with the outcome of the structural assessment mentioned above.

Legal and regulatory Design Constraints: In order to understand the potential risks deriving from issues such as land ownership, tenure or rights of way, the provision of a legal assessment is a significant step prior to the design development.[27] Equally, the delineation of conservation areas and listed buildings has to be part of the feasibility study as it may impact or even prohibit the overall design approach. Crucial issues such as shortage of view, daylight and sunlight requirements need to be addressed with appropriate studies and reports.

Systemic challenges: More housing increases the need for public services. The analysis and above all the consequential adaptation of the existing infrastructure should be a key aspect of all densification measures.

Social mix of an area: Successful densification should contribute to a balanced mixed city. The alteration of the existing estates also holds the great potential of improving the profiling of the complex and enhancing the wider area. On the other hand, developments in central locations risk to result in higher housing prices, often leading to gentrification and social inequality. This is why the provision of social housing with all its implications is an important aspect of this work.

Finally, we must bare in mind that there might be a limit to how dense we can build. Too much densification could at worst result in communities with poorer life quality because of too much noise, too little light, or too little access to open space. It holds the risk of declining the attractiveness of an area causing citizens to move away.[28]

12 Additional Cycle Storage

25 cf. Guttmann 2008 in Zuschnitt Nr. 30 p. 33 ***26*** Wegener et al. TU Munich 2010 ***27*** cf. HTA Design LLP for Appex Airspace Development 2016, p. 33

28 cf. The Swedish National Board of Housing, Building and Planning 2017, p.7

ASSESSMENT

2.1. CASE MODEL - LONDON

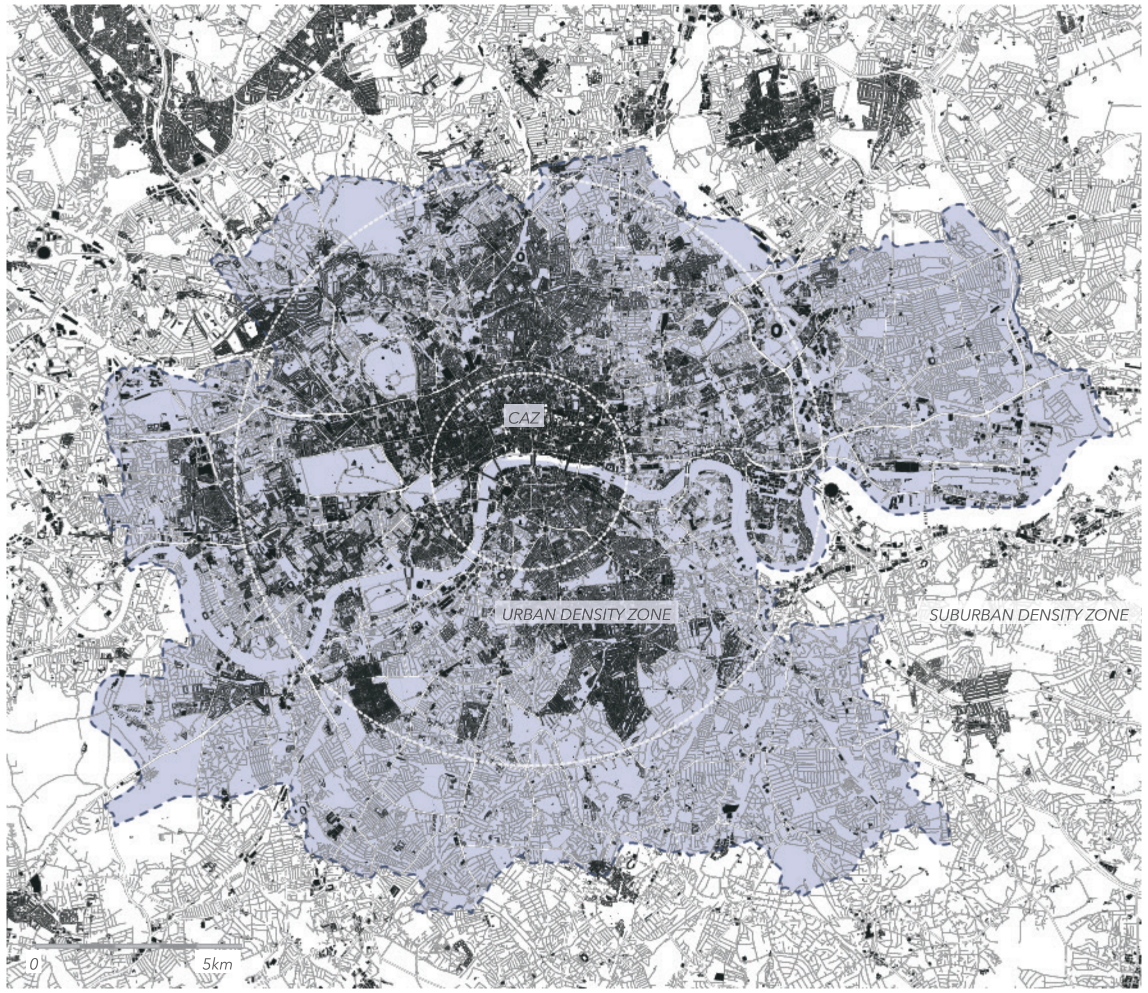
According to population within city limits, London is one of the largest cities in Europe.[1] In relation to comparable world metropolises, it is at the same time a low-rise city with a large amount of historic building stock.[2] On the premise that the major trend of urbanisation is continuing, the metropolis of London can be seen as an example for the future fabric of a European city.

This thesis therefore considers London as a case model to elaborate a strategy and illustrate a design proposal.

The information required for the following analysis is in large part extracted from the tables and diagrams provided in *The London Plan 2017*, the spatial development strategy for Greater London.[3]

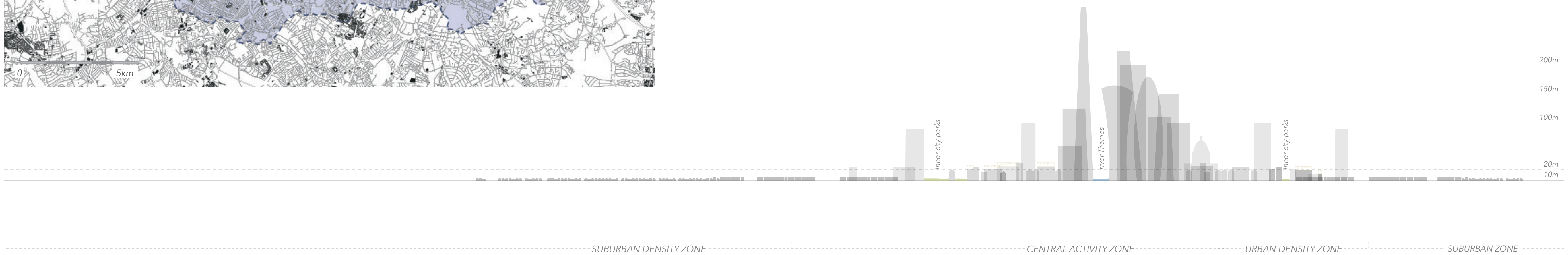
13 Lonond by Jason Hawkes

1 cf. Eurostat 2017 ***2*** cf. Kahn and Greater London Authority (publ.) 2015 ***3*** cf. Kahn and Greater London Authority (publ.) 2016



The total area of Greater London is comprised of three main zones: Outer London, Inner London and the Central Activity Zone (CAZ).

This study focuses on the area of Inner London with its twelve boroughs, excluding the financial and economic centre of the local authority of the City of London and drawing attention to the so called Urban Density Zone between the Central Activity Zone and the Suburban Density Zone. This area mainly lies within Zone 2 defined by London Transport and forms a ring around the commercial centre of the city.



14 London Zones

15 Diagrammatic Section: Building Heights enlarged by factor 10

These two figures are based on the information provided by *www.parallel.co.uk/#building-heights* and *www.buildingheights.emu-analytics.net*

16 London Housing Stock, Borough of Camden

This limitation is based on the following arguments:

First of all, this thesis suggests to bring social housing and affordable living space back to central areas, working against the phenomenon of urban sprawl and enhancing heterogenous functions and a social mix within the city. It therefore makes sense to focus on the urban area close to the centre.

This work seeks to enhance the image of deprived areas by altering and adding value to existing social housing estates. *The London Plan 2017* states that "the part of Inner London outside the central area of CAZ and Canary Wharf (...) contains both (...) the country's largest concentration of deprived communities (...) and places that have experienced remarkable growth and development." [4] The fact that these two contrasts can be found closely next to each other makes this area eligible for the intended interventions.

The Urban Density Zone covers to a great extent what is referred to as Inner London with its twelve boroughs, except the City of London. The percentage of existing housing estates within this area is relatively high compared to the very centre or the outskirts.

Outer London in contrast is characterised by two and three storey high detached and semi-detached houses. These are mainly privately owned and are not part of this study.

Many of the so called *Opportunity and Intensification areas*[5] defined in the London Plan can be found within the Urban Density Zone, supporting the proposition that interventions and redevelopments in this area are likely to be successful.

The city centre of London is the „geographic, economic and administrative core. (...) It brings together the largest concentration of London's financial and globally-oriented business services." [6] This dominance of commercial and financial functions goes hand in hand with a lower rate of existing social housing. Although this zones could provide an interesting feasibility study regarding the existing building stock and the possible elaboration of a new social mix, it is not subject of this study. It is furthermore excluded because the high percentage of conversation area and listed buildings forming the heritage of the

4, 5, 6 The London Plan 2017 p. 61-67 historical centre holds the risk of impacting or even prohibiting the implementation of the intended extension schemes.

There is a certain threshold to which densification can be achieved without risking the equilibrium of a certain area. This thesis suggests a healthy balance between existing resources and new built structures and looks for areas that can comfortably accommodate more living space. The very centre of London has "historically experienced the highest rate of growth".[7] Its high proportion of tall buildings and its very dense fabric does not qualify for the intended interventions of this thesis.

The potential of the Urban Density Zone for innovative ways of densification is furthermore recognised in the London Plan stating as a "combination of challenges and opportunities, (...) that justifies a distinctive planning policy approach." [8]

The Urban Density Zone is characterised by high levels of public transport accessibility. Within the London Plan these levels are seen as a "basic starting point"[9] for areas with higher density developments.

As alluded to previously, the design proposal focuses on the further construction and extension of social housing. Within the framework of London as a model case, this respectively refers to the so called London Council Houses.

Bevin Court is a former Local Authority apartment block. It was designed in the early 1950s by the revered Modern Movement architect Berthold Lubetkin, in conjunction with Francis Skinner and Douglas Bailey. It has been given a rare Grade II* listing by English Heritage in recognition of its architectural significance.

7,8,9 The London Plan 2017 p. 61-68

2.2. LONDON'S COUNCIL HOUSES

Whilst a large number of individual attic extensions are carried out in London like in many other European capitals - the provision of social housing on top of the existing is a potential that is still relatively untapped. The building stock tested within this thesis is limited to London Council Houses. The upward extension of their existing estates can be seen as a potential way for councils to provide additional social housing close to the city centre.

17 Bevin Court, Islington

18 Balman House, Bermondsey

2.2.1. FINDING A TYPOLOGY

In order to propose a typical design, general construction methods and basic details, it is necessary to select and define a certain type of building stock and limit the characteristics of potential rooftop-plots to a manageable number with similar conditions. The first step of this limitation is the determination of pivotal qualities and the definition of areas where the intended alterations can generally make sense:

The study examines potential alteration of housing stock not falling under certain restrictions of listed buildings or conservation areas.

It only deals with purpose built housing stock, excluding flats in commercial as well as in converted buildings.

Documentation shows that the purpose built housing stock in the designated area is defined by buildings of various typologies, but predominantly ranges from four to seven storeys.

Towers shall be excluded.

Detached, semi-detached and terraced houses are typically one to three storeys high and mainly privately owned.[10] While the alteration and especially the upward extension of this building typology holds potential for further densification developments, it is not part of this study.

Despite the prospect that the intended implementations have the potential to enhance socially difficult or deprived areas, the research is narrowed down to housing estates that are in structurally stable conditions and deemed fit for revitalisation.

This thesis acknowledges that roof extensions often include the thermal renovation of the entire existing building. These aspects are nevertheless excluded in oder to solely focus on the core strategy of rooftop additions.

10 cf. Kahn and Greater London Authority (publ.) 2015

The next step filters the main housing typologies in the designated area in London. This categorisation is based on various sources and is the result of their superimposition: The 2015 report *Housing in London*[11] includes a survey for existing types of home in London conducted by the *English Housing Survey*[12] showing a categorisation in relation to the type and height of the buildings. This data was compared to the figures provided by the *Office for National Statistics from 2014.*[13] *The NHBC Foundation Report - Homes through the decades*[14] analyses the history of housing in London and elaborates the different types with regard to their period of construction. The book *British Housing Design*[15] provides further background information on these typical construction methods. Finally, the *Rooftop Development Report*[16] conducted by HTA Design LLP shows a qualification and quantification of housing types within the Borough of Camden. The latter was roughly applied across the Inner London Boroughs in order to be further tested by a randomised documentation survey in significant locations within the relevant radius. The character of London's residential neighbourhoods is hugely influenced by the period within which the buildings originate. This includes Victorian buildings, buildings from the first half of the 20th Century, post war housing and housing from the latter part of the 20th Century.

The following typologies can be delineated:

Type 1: High-rise Purpose Built Towers

Type 2: Low- and Medium-Rise Local Authority Estates

Type 3: Mansion Blocks (four to five storeys)

Type 4: Small flatted blocks

Type 5: Terraced Houses (two to three storeys)

Type 6: Detached and Semi-detached Houses

Type 7: Miscellaneous[17]

2.2.2. CLASSIFICATION

This thesis from now on focuses on the potential of T*ype 2 - Low- and Medium-Rise Local Authority Estates.* The aim of the following chapter is to classify this specific typology and to show its qualities for lightweight timber roof extensions in combination with urban green space. The classification is based on the findings previously summarised as well as a randomised documentation of existing housing estates, conducted from October to December 2017 in relevant locations conducted within the designated area in London.

19 Housing Stock, Bermondsey

11 cf. Kahn and Greater London Authority (publ.) 2015 ***12*** English Housing Survey stock data, 2010/11 to 2012/13 ***13*** https://www.ons.gov.uk
14 cf. Turner and Partington for NHBC Foundation (publ.) 2015 ***15*** Sim, D. 1993 ***16*** HTA Design LLP 2016

17 comprised of inter-war residential blocks and a variety of converted building types

Low- and Medium-Rise Local Authority Estates.

This building type is strongly represented within the designate area of the Urban Density Zone.

It was mainly built in the time between 1945 and 1980.[18]

The estates built in this period are often shaped by the modernist approach to town planning and typically founded on the principle of the „neighbourhood unit with the same building type repeated extensively over a large site."[19] This repetition qualifies them for modular systems on a larger scale.

There is also a strong repetitive element in the structure of the buildings themselves. This makes them suitable for prefabricated elements, that can easily be adapted for different estates.

Blocks are typically of concrete frame constructions with brick facades and simple detailing. They usually have continuous concrete foundations beneath the main load bearing walls.[20]

Some buildings are rising to up to twelve storeys, the majority however are four to seven storeys high.

Although they show a variety o shapes, straight long single volumes and L-blocks are predominant.

They are typically between six and nine metres wide and up to forty metres long with span lengths of four to six metres between load bearing partition walls.

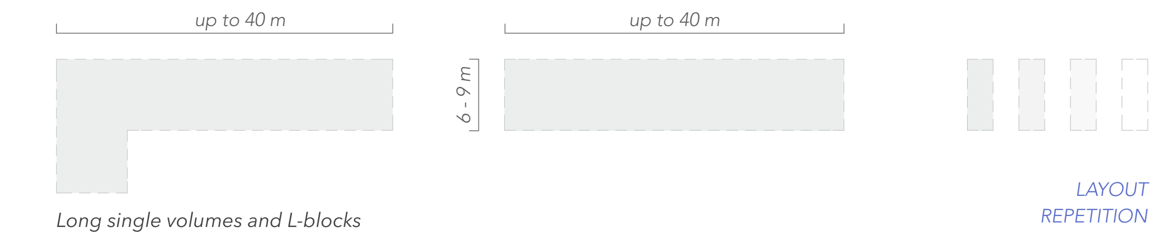
Although this building type shows various forms of access systems from central corridor to stair core access, balkony access developments are predominant.

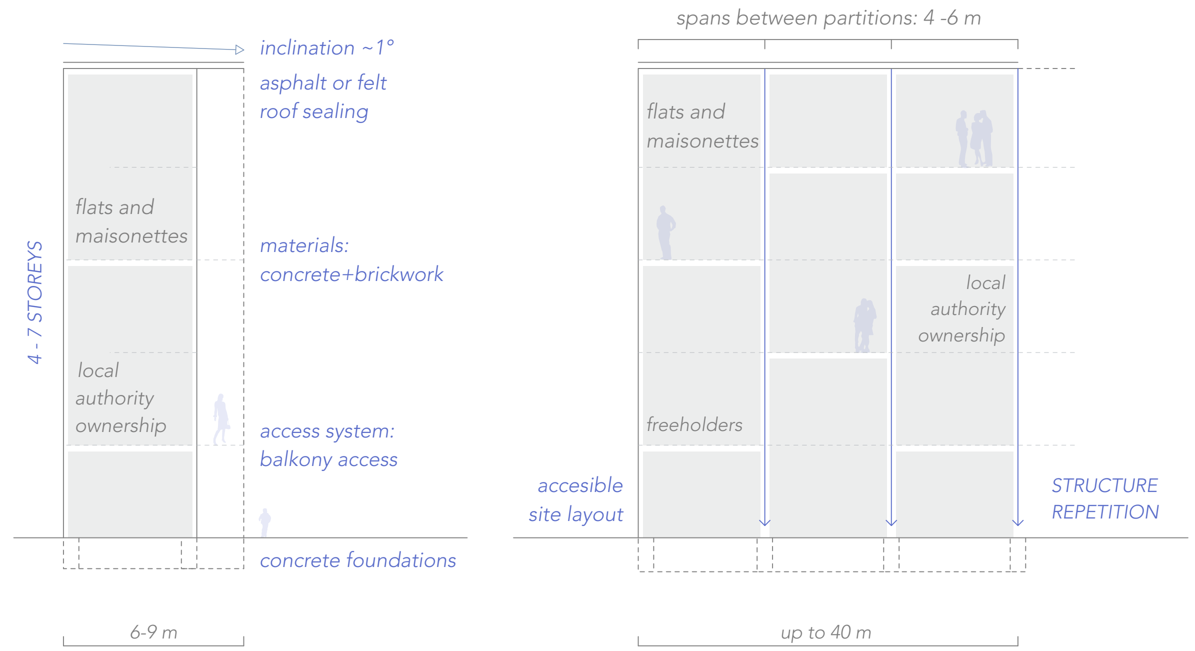
Many of the selected buildings have flat roofs with an inclination of around one degree.[21] Pitched roofs (typically timber construction above a concrete slab) are also common and would need to be removed before further construction. This study however, focuses on the flat roofed specimens.

The material predominantly used for the final roof sealing is asphalt or felt sealing.[22]

The ratio of local authority ownership for the selected buildings is still relatively high. They are therefore more suitable for interventions lead by councils and wider scale developments, especially when compared to terraced houses, which are mainly individually owned.[23]

Thir layout and settings in the urban context make these estates more accessible and manageable compared to the housing stock in the Central Activity Zone.





Based on the qualities listed above, the selected typology holds a great potential to support the hypothesis of this thesis. Although planning, design and technical constraints are unique from site to site, the building stock provides a characteristic structure, that serves as a basis for the following concept

20 Classification: Low- and Medium-Rise Local Authority Estates

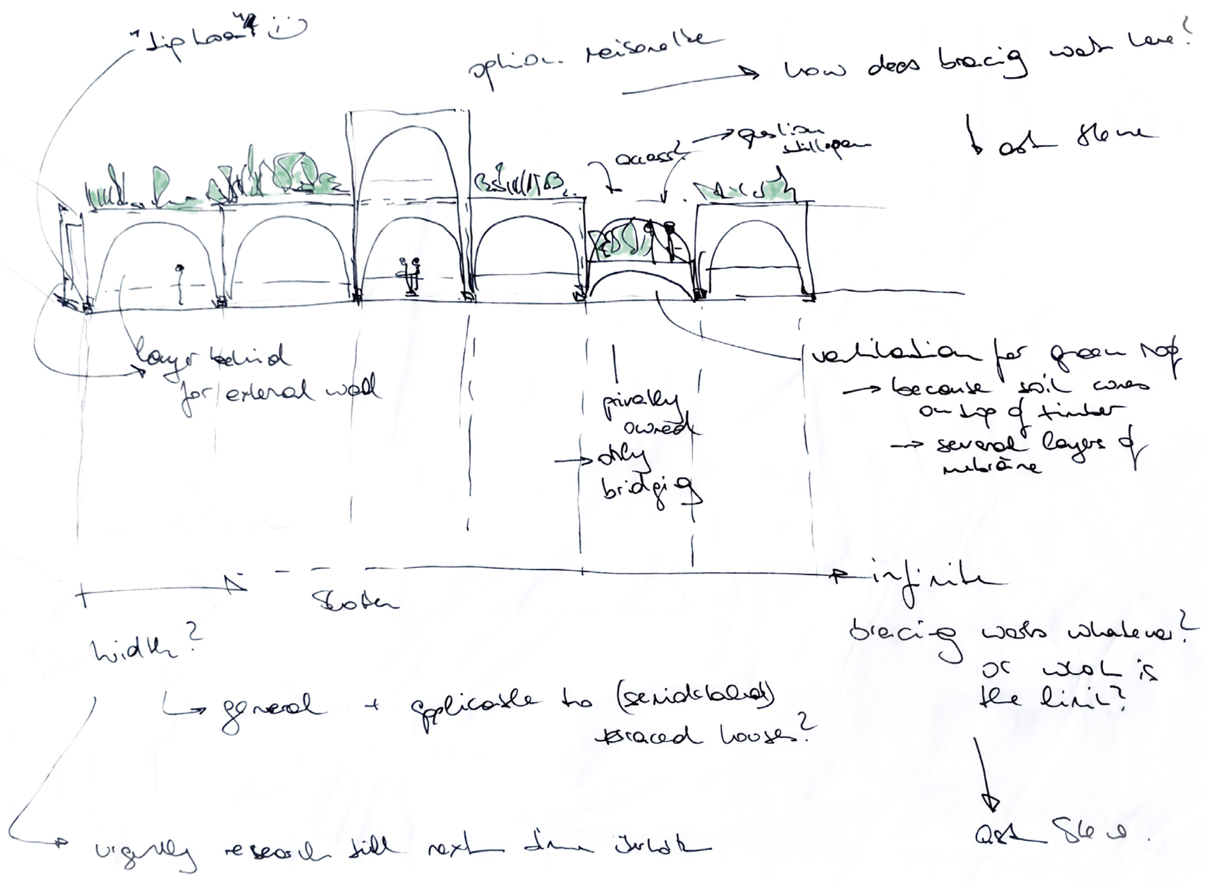
18+23 cf. English Housing Survey 2016/17 **19+20** cf. HTA Design LLP for Appex Airspace Development 2016, p. 28
21+22 Interview with London Platforms LTD 2018

CONCEPT

3.1. BASIC DESIGN IDEA

The subsequent chapters show the design development of a lightweight, partially prefabricated timber construction system, which is applicable to the designated building typology.

21 Concept Model



22 Concept Sketch

The design idea emphasises the following key aspects:

The new structure should visually and metaphorically elevate itself from the existing roofs: like on tip toes.

The timber arches structurally respond to this idea. Their cross bracing function allows the extension to work as an additive system that can be repeated on a wider scale.

The provision of open green space is an essential part of the scheme.

In combination with the vegetation and the green roofs, the extensions resemble the picture of trees in the sky while a the same time evoking associations to their archaic sheltering function.

The architectural design takes the characteristic deviations of the existing buildings into account and proposes a flexible and adaptable system comprising the following elements:

MODEL *1A* with bridging element MODEL *1B*

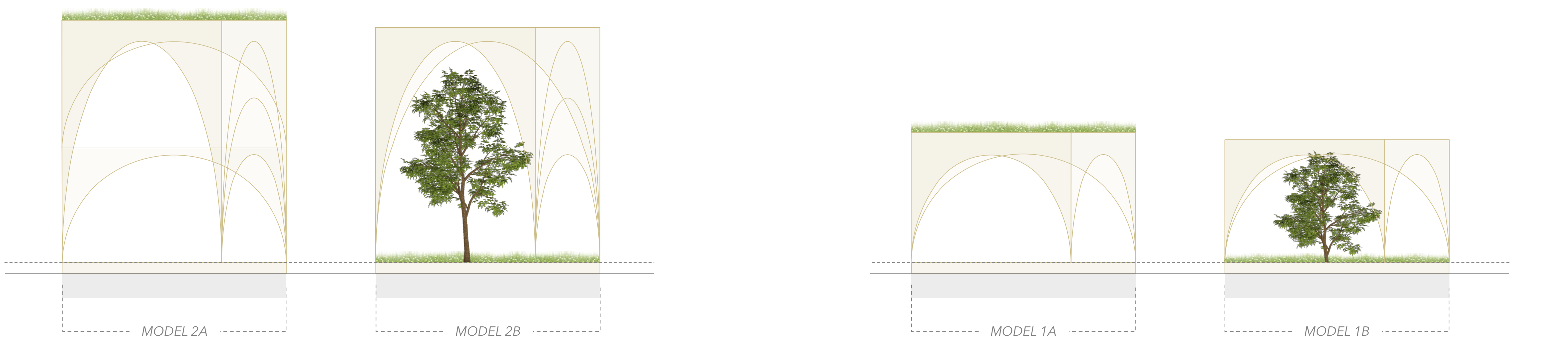
MODEL *2A* with bridging element MODEL *2B*

Models *1A* and *2A* form the typical units to accommodate the various dwelling types depending on the condition of the existing and on the demand of the specific project. Models *1B* and *2B* are referred to as bridging elements. They allow to maintain the basic system of cross bracing arches even if segments of the structure have to be skipped for reasons such as immovable existing services or ownership issues of the subjacent flat. These elements are especially used to integrate vegetation and open green space.

Further alterations to parts of the models are foreseen:

MODEL 1A *cantilever* and MODEL 2A *cantilever* are designed for buildings, where the the existing access system does not allow for any load transfer.

MODEL 1B *short* and MODEL 2B *short* match lift overruns and staircases where needed.

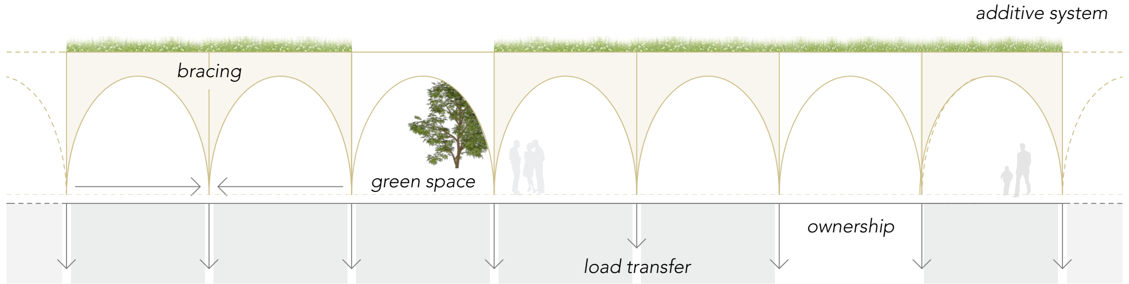


Basic Models

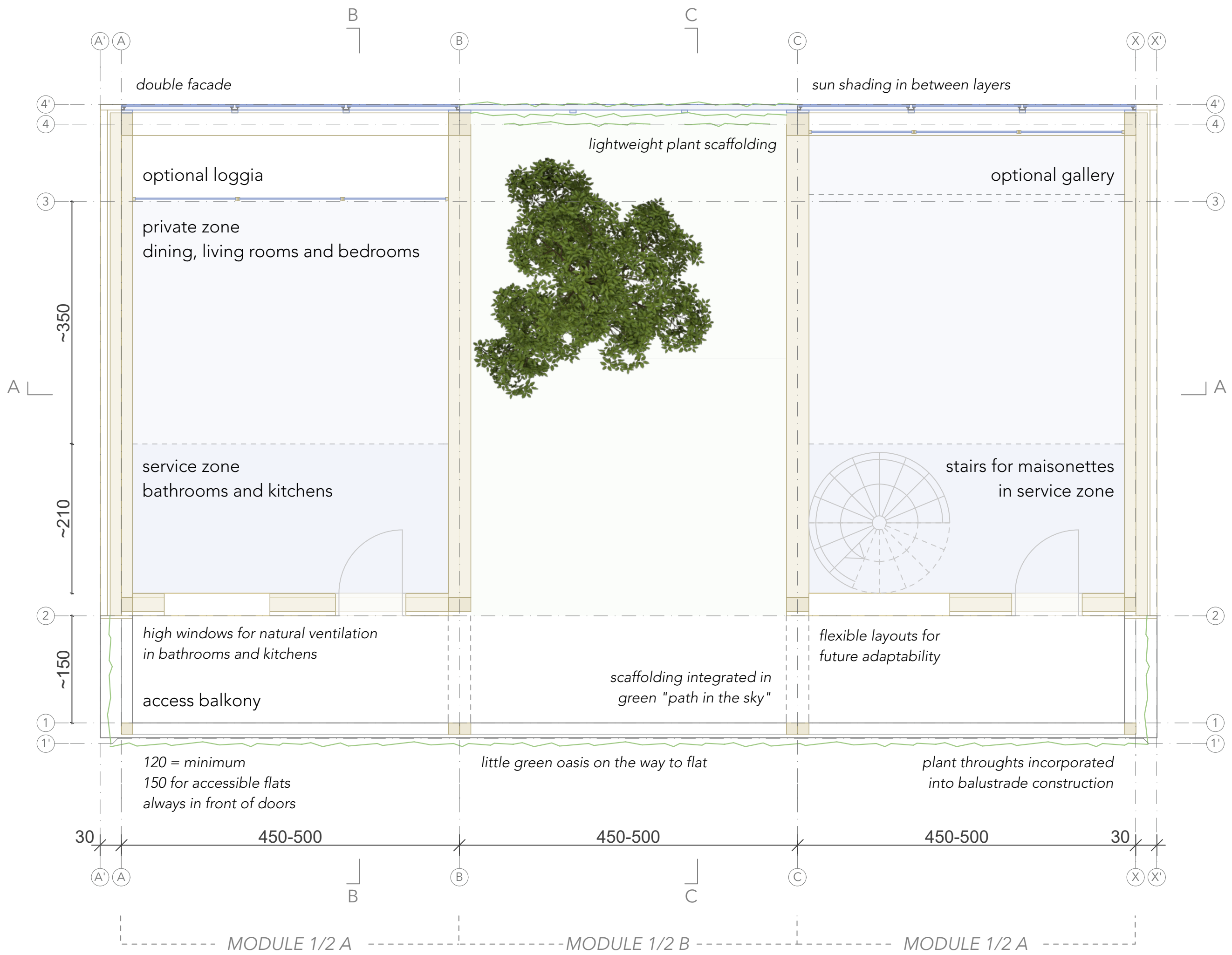
As the overall design responds to certain deviations of the existing buildings, the plans in particular respond to this demand by allowing for flexible layouts and adaptable flats within the established leeway. They also embrace the additive character of the scheme by following a certain system and obeying a set of predefined rules. The layouts of the flats are divided into four zones:

1. Access balcony
2. Service zone: predefined position of sanitary blocks, kitchens and stairs for maisonettes
3. Private zone: dining, living rooms and bedrooms
4. Open Space: optional loggia or double facade windows

The floor plans in chapter 4 show this system applied to the most relevant dwelling types in line with the "London Housing Design Guide".



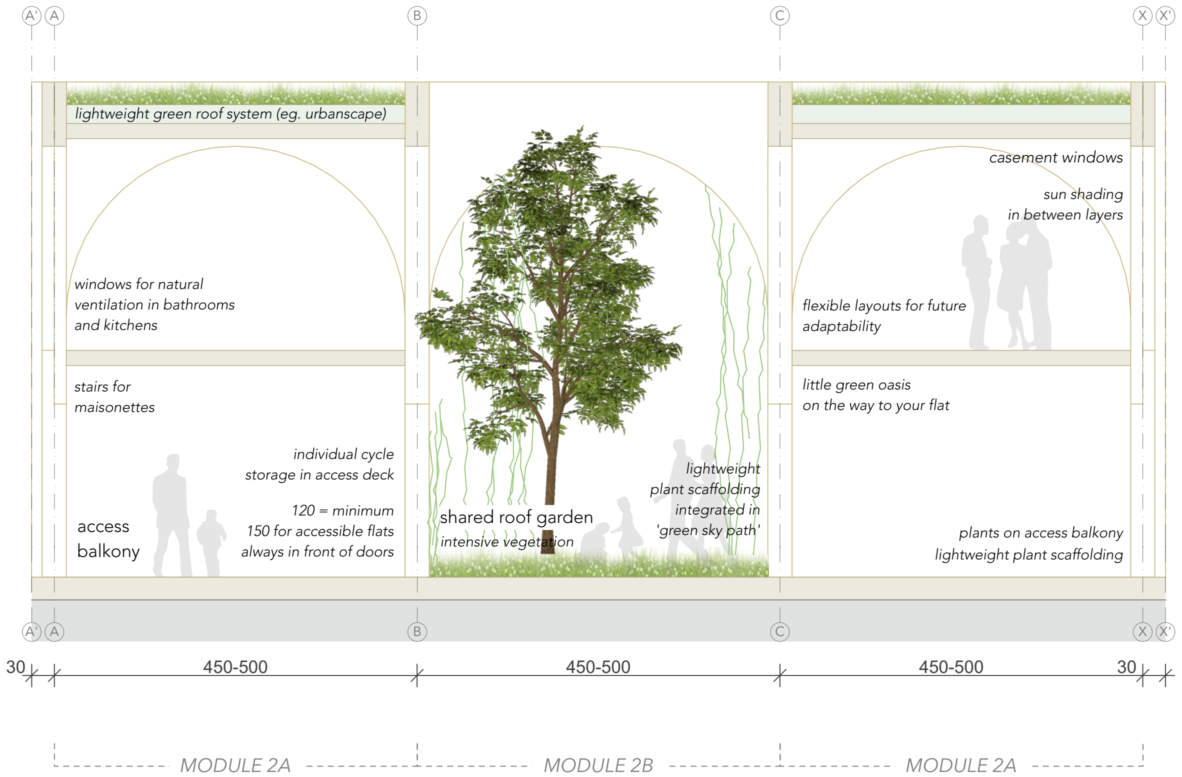
Proposed arches system elements

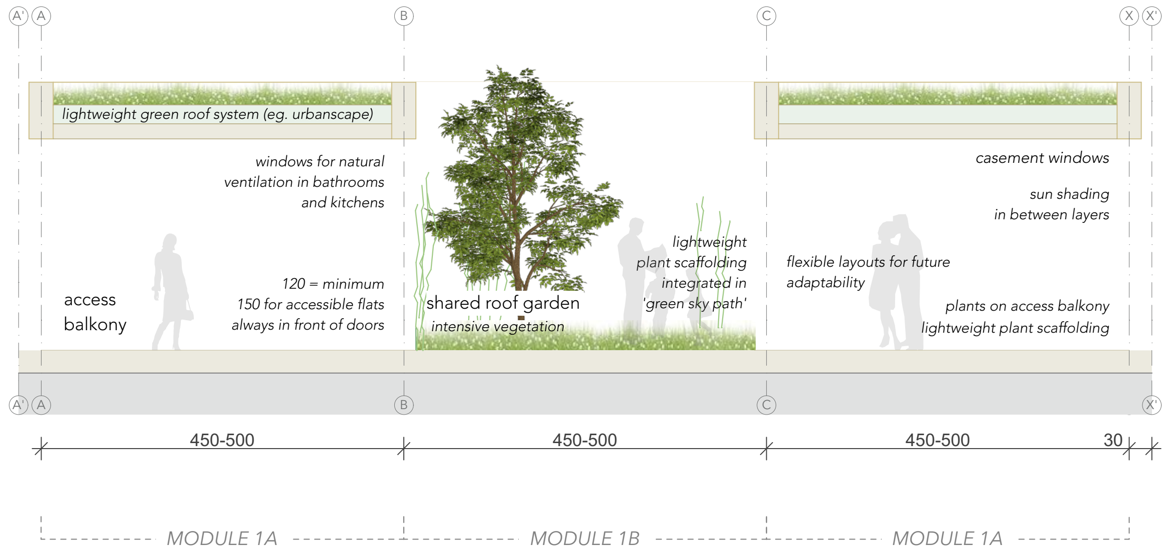


23 Concept Overview

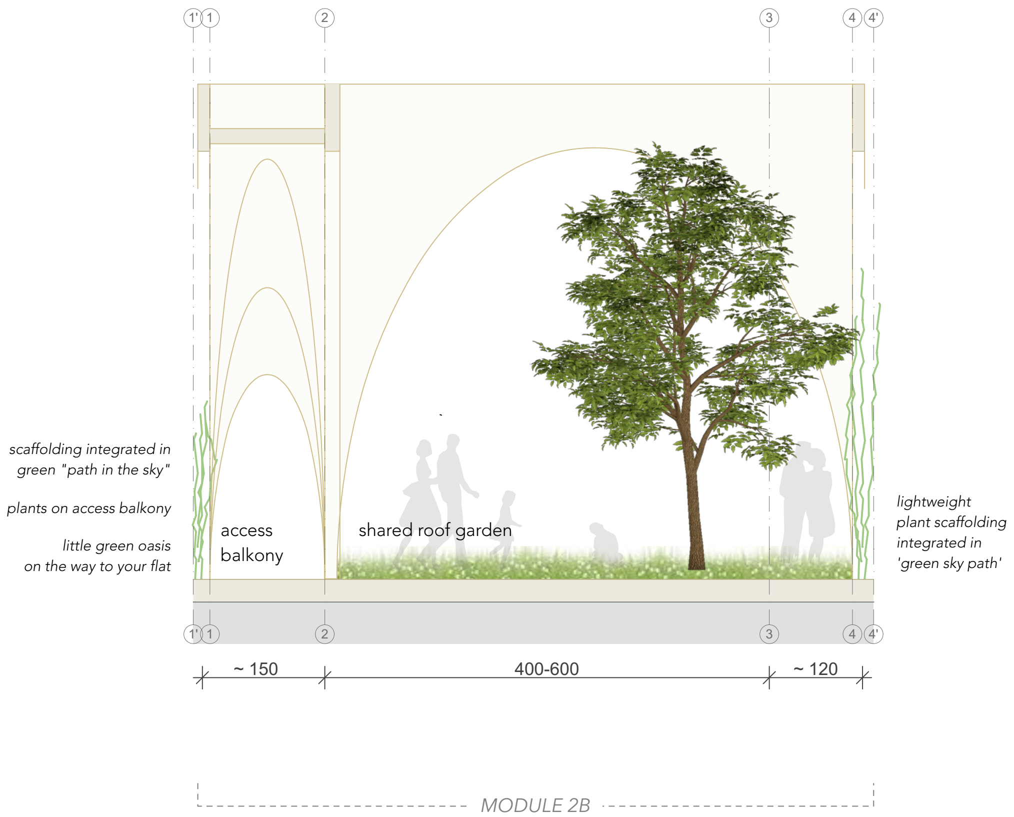
Generic Floorplan 1:100

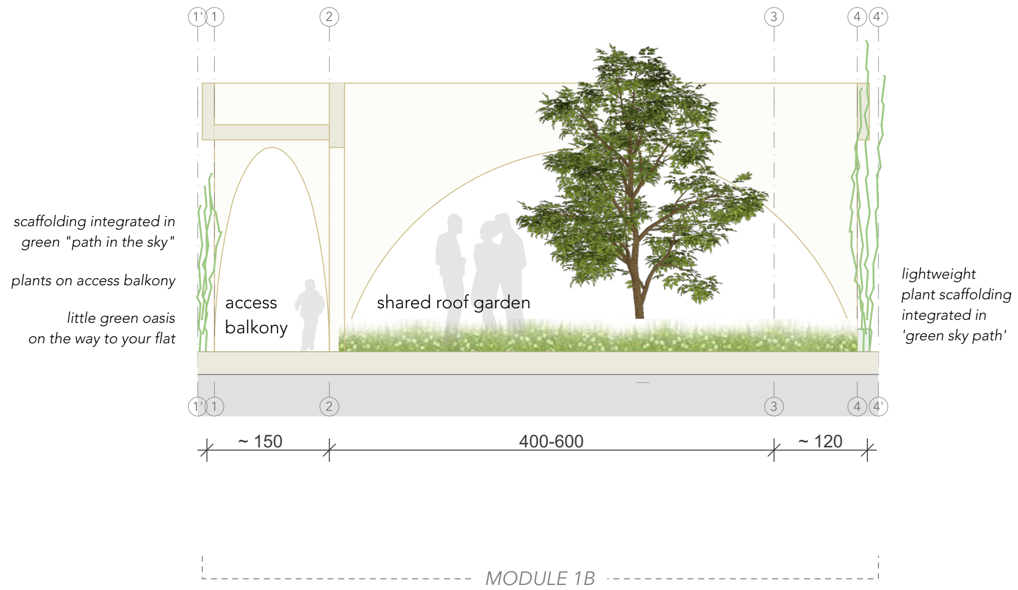
The provision of open green space is an essential part of the scheme. This includes small private open spaces related to the individual flats as well as common roof gardens in the bridging elements, creating a green buffer zone for inhabitants to share. Green roofs are designed throughout the scheme to bring a natural element back into the urban environment and to favour various ecological effects such as cleaner air, reduction of UHI, CO2 reduction, rainwater retention, noise reduction, biodiversity enhancement. The intensive vegetation in the bridging elements maximises these effect. Services are partially prolongated from the existing structure. Where possible, renewable energy devices such as solar panels are integrated into the scheme.





Sections A 1:100





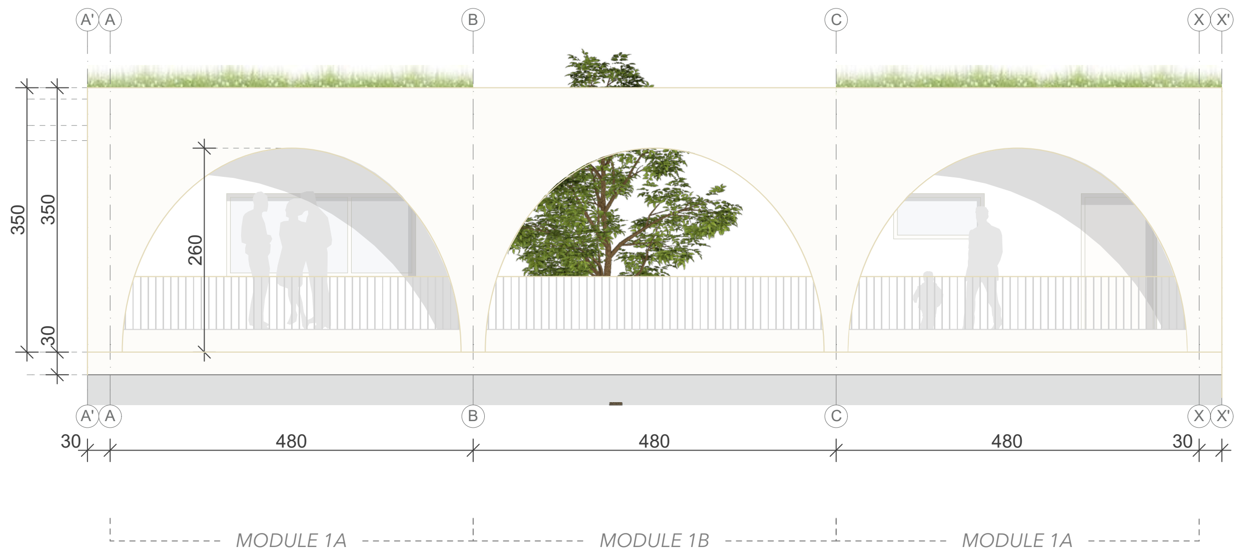
Sections C 1:100

1. Outer skin for access balcony

This facade shows the light tip toeing arches and the green open spaces. A bright cladding protecting the timber construction emphasises the open arches, which form a covered pathway to the flats. This walk is lightened up by the occasional bridging element providing a roof garden as well as by the plants foreseen along the balcony's balustrade.

2. Wall between access balcony and individual dwellings

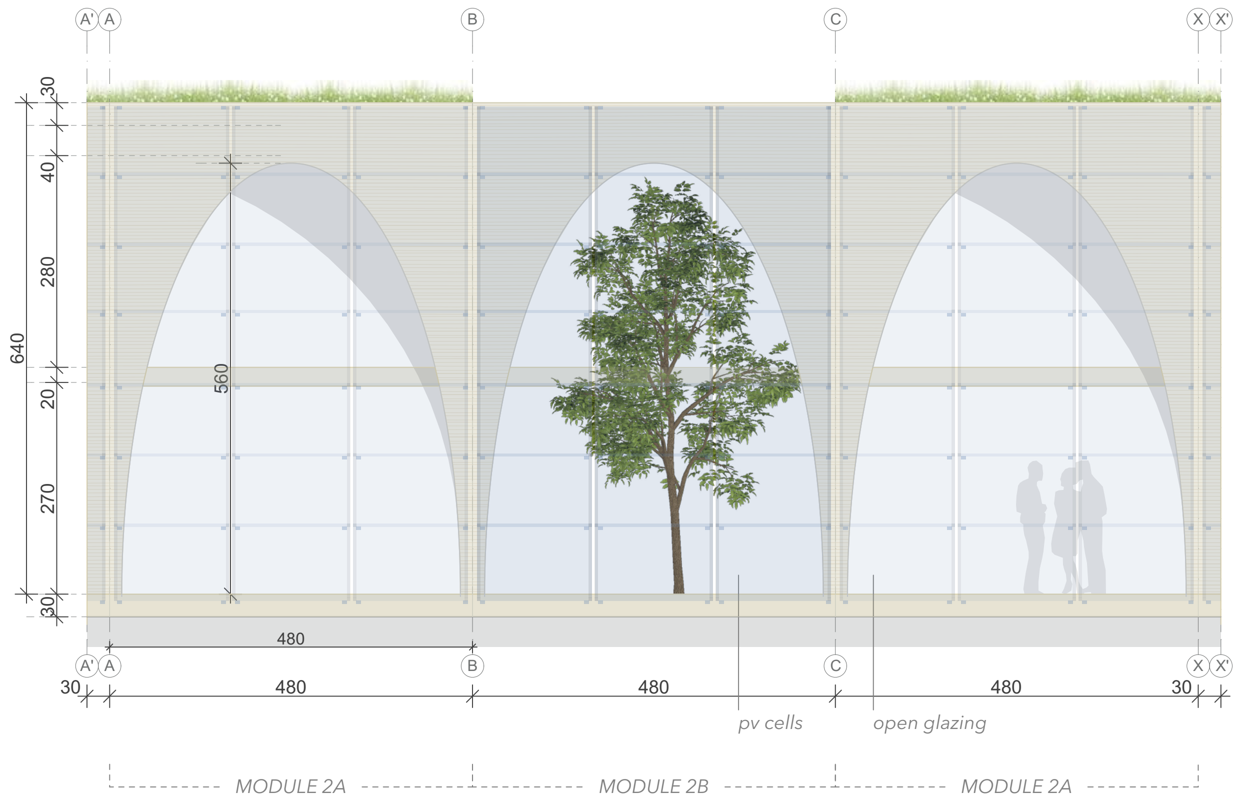
With a bright cladding or white render finish, this punctuated facade holds the entrance doos to the flats as well as the bathroom and kitchen windows. It forms a supporting background for the bright open arches and the green plants, creating an interesting contrast before entering the warm inner shell of the flats with its wooden surfaces.

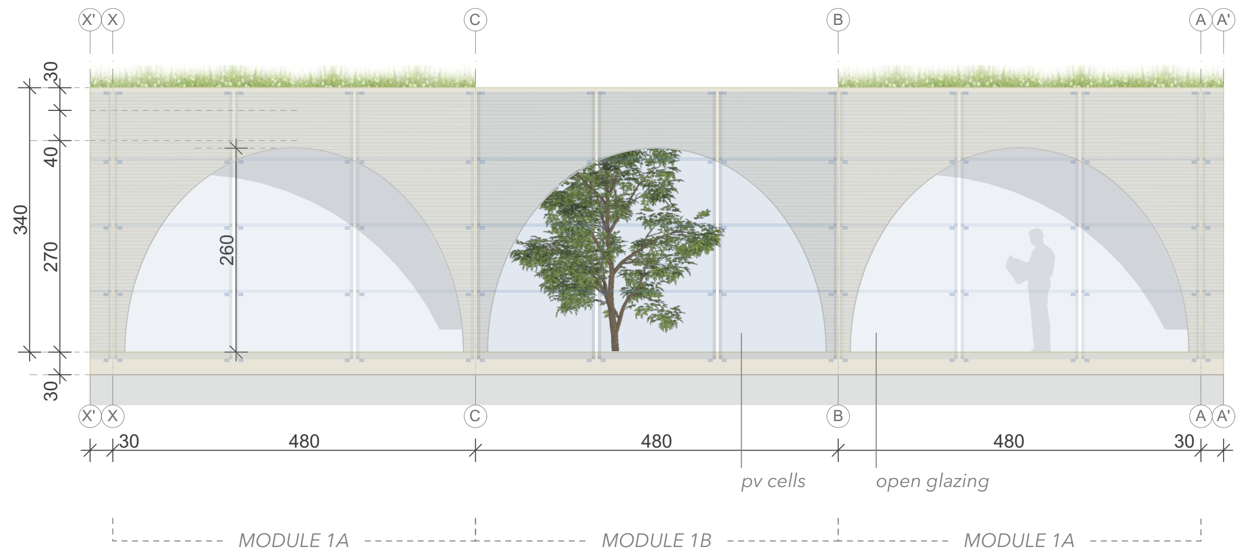


Elevations 1:100

3. Outer skin for dwellings

The fully glazed double facade system on the opposite side makes the timber structure visible behind the first outer layer of single pane glass and communicates the use of timber to the outside while at the same time protecting it from weather. The interspace between this first pane and the inner thermal glazing with conventional openable windows varies in size. Depending on the dwelling type, it forms the gap of an enlarged casement window or alternatively opens up to form a loggia. This gap also holds the sun protection system. The duo facade system and the sheltered loggia in particular allow for natural ventilation independent of weather conditions. It shows a good thermal performance and provides the flats with the sound insulation needed for inner city housing.





Elevations 1:100

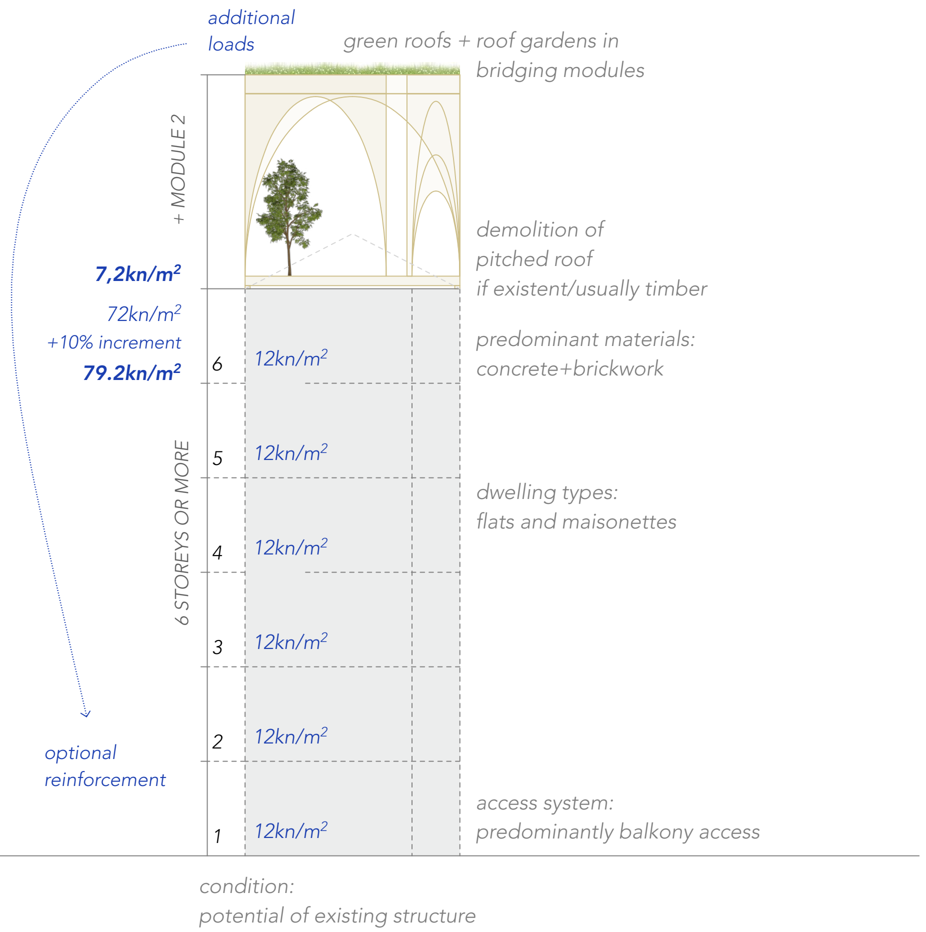
3.2 STRUCTURAL SPECIFICATION

The analysis of the building stock could identify a typical pattern for the load bearing system of the selected housing typology. The following basic verification scheme can be used for a first structural feasibility study, leaving the existing flat roofs in place.

24 Concept Model

3.2.1. FEASIBILITY

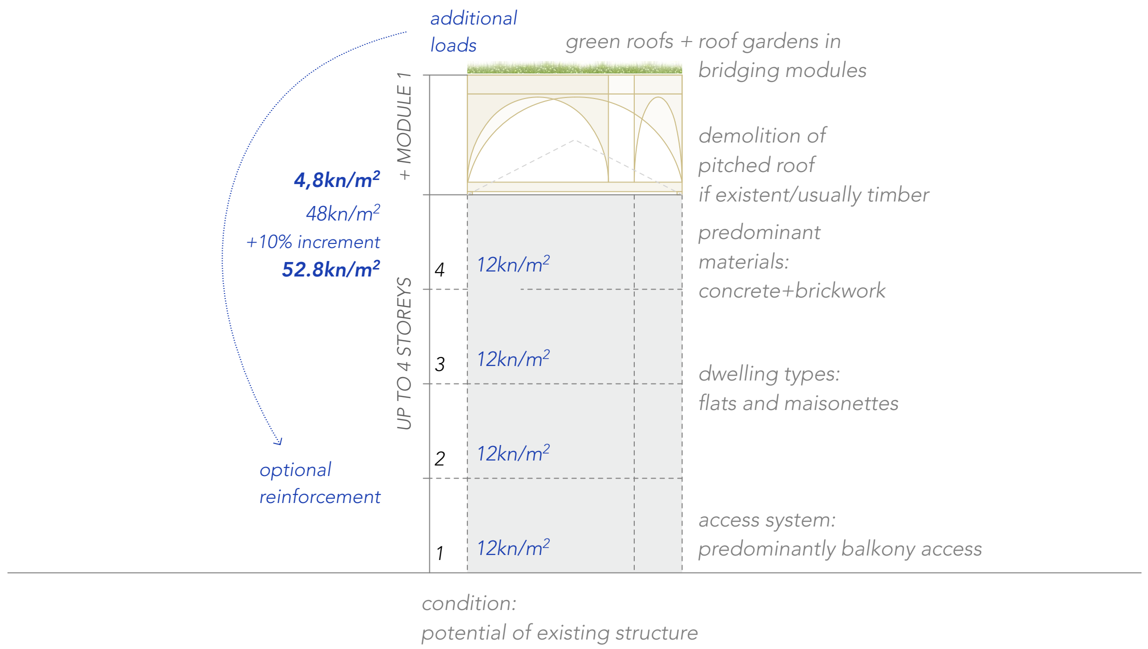
This scheme can be used as a rule of thumb for a preliminary check of a building's potential to bear one or two storey attic extensions without major reinforcements. This is based on the assumption that the existing structure typically allow for a 10% increment in load. Assuming the weight for one storey of concrete and brick to be approximately 12kN/m², this would allow for 4,8kN/m² for a four storey and respectively 7,2kN/m² for a six storey building.



Following these estimations, the additional structure can accommodate the proposed one or two storey timber frame constructions (~4kN/m² or 6,5kN/m²) with extensive green roofs above the flats. The bridging units in between allow for the provision of intensive vegetation including small trees.

The load bearing capacity of the existing building needs to be proven on a case-to-case basis. Especially the top slap construction, the load bearing walls and the foundations have to be assessed according to the effective building codes.[2]

The earthquake security of the existing and consequently of the refurbished state is standardly part of the overall assessment. According to the Eurocode 8 seismic hazard zoning map for the UK, London lies within the lowest PGA zone of 0.00 - 0.02 and is therefore not as impacted as other European cities.



Structural Concept

1 Interviews with Konrad Merz (überholz and Merz Kley Partner, Dornbirn) and Steve Webb (Webb Yates Engineers, London)

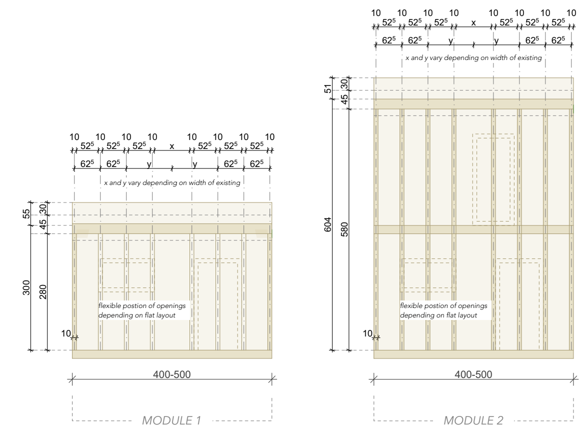
2 cf. Working group for ressource-orientated construction – Institute for constructive engineering – BOKU Vienna, alpS GmbH (publ.) 2016

3 Eurocode 8 seismic hazard zoning maps for the UK, Seismology and Geomagnetism, Programme Technical Report CR/07/125, Issue 3.0

3.2.2. CONSTRUCTION METHOD

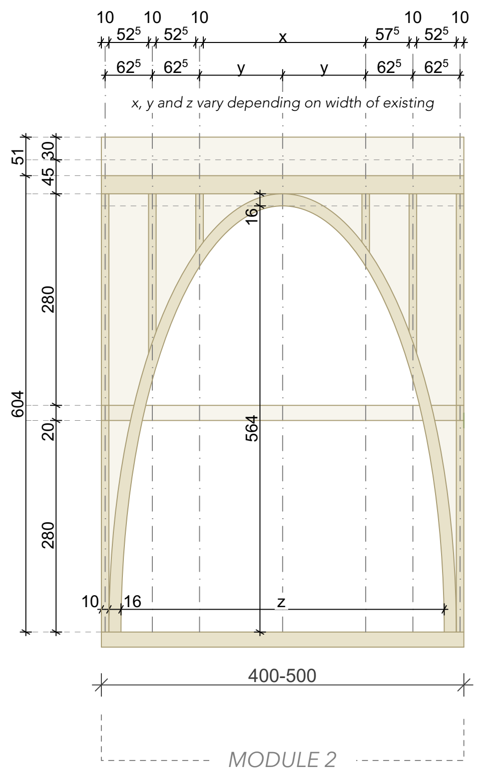
The design proposes a partially prefabricated timber framework construction. This decision was based on a variety of arguments:[4]

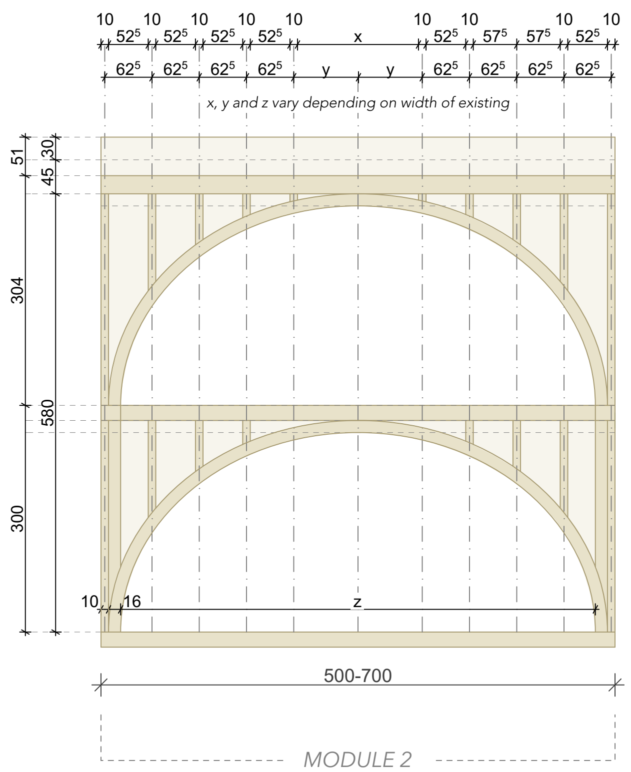
- It can fully exploit and maximise the material's inherent potential of its light weight.
- The segmented bent timber arch significantly reduces the cutting waste of the elements compared to the same shape cut out of a CLT-panel.
- The bracing capacity of the arch in combination with the top beam, the ceiling and the OSB-board is equivalent to a comparable milled shear panel.
- It additionally avoids the exposure of end grain areas.

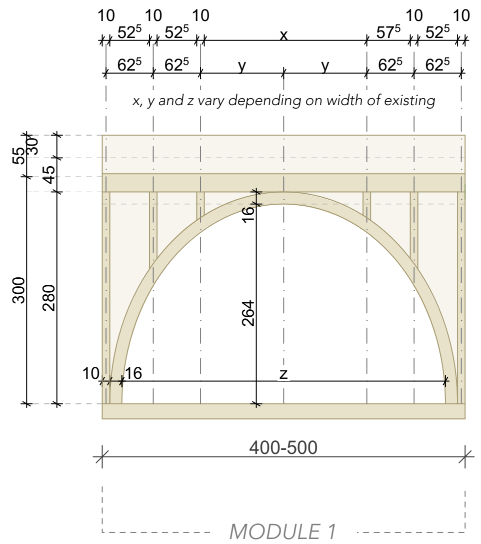


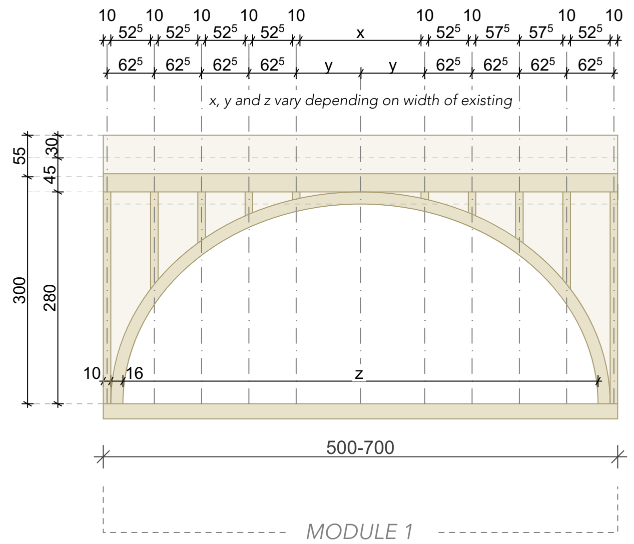
The main elements of the design are proposed as repetitive arches with framework in one or two story versions. However, the partition elements between flats for the larger models are composed of two arches on top of each other in order to allow for the support of the intermediate ceiling and to make the system more efficient.

The lightweight partition walls between the access balcony and the flats are composed as conventional timber stud works as this facilitates the positioning of the openings depending on the various flat layouts.



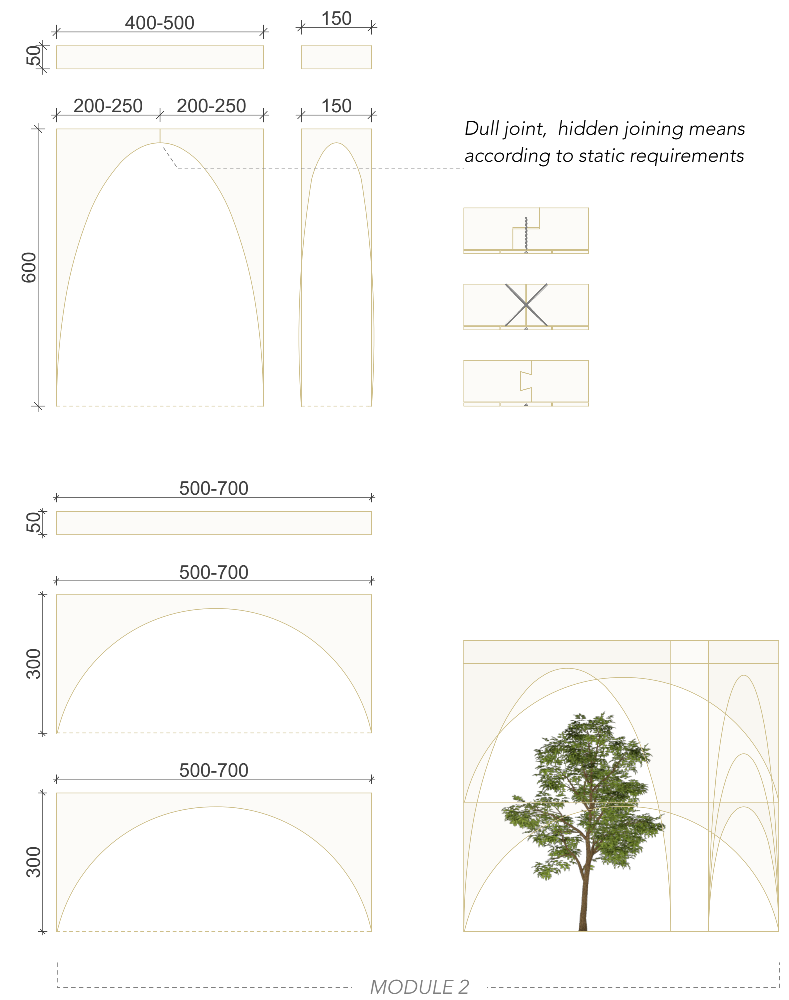






Structure: Timber Frames and Arches

4 Interviews with Konrad Merz (überholz and Merz Kley Partner, Dornbirn) and Steve Webb (Webb Yates Engineers, London)



Transport and Assembly

Prefabrication:

Inner city building sites are often constrained and ask for a certain degree of prefabrication. The dimensions of the system elements were designed so that they could be transported by standard trucks. The prefabrication of entire flat units was ruled out because of the road restrictions and limited installation spaces in urban areas.

Exemplary Construction Process:[5]

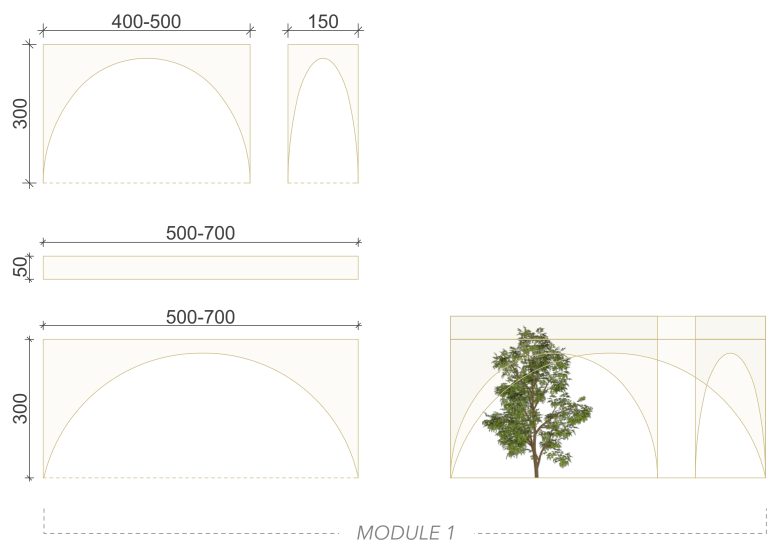
Step 1: Demolition of the existing elements on the roof, that need to be renewed.

Step 2: Prolongation of the existing staircases and services and installation of an auxiliary construction as a base for intermediate ceilings.

Step 3: Installation of the prefabricated elements of the building envelope.

Step 4: Roof covering and wall cladding on site.

Step 5: Interior works including installation of lightweight interior walls and sanitary installations.

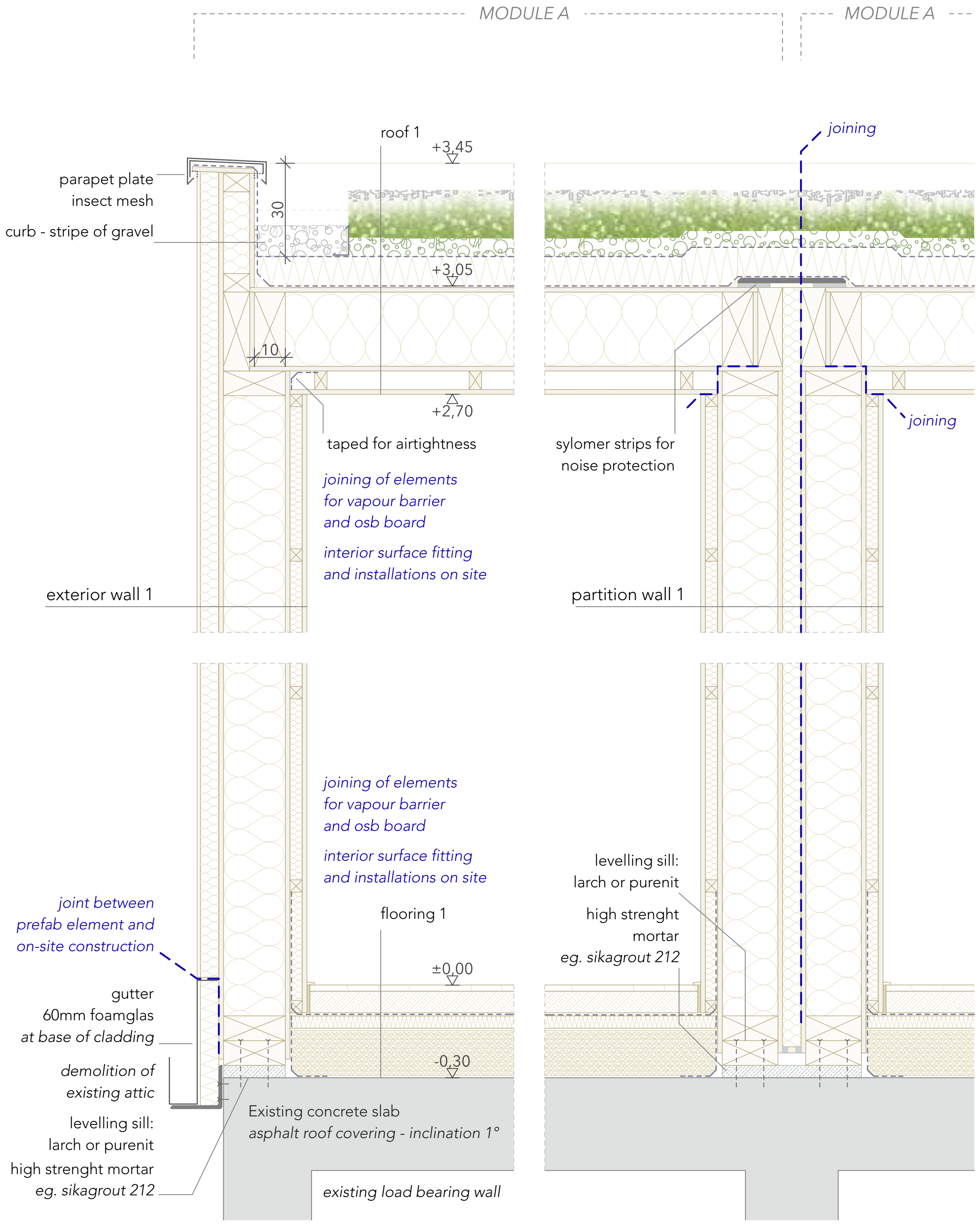


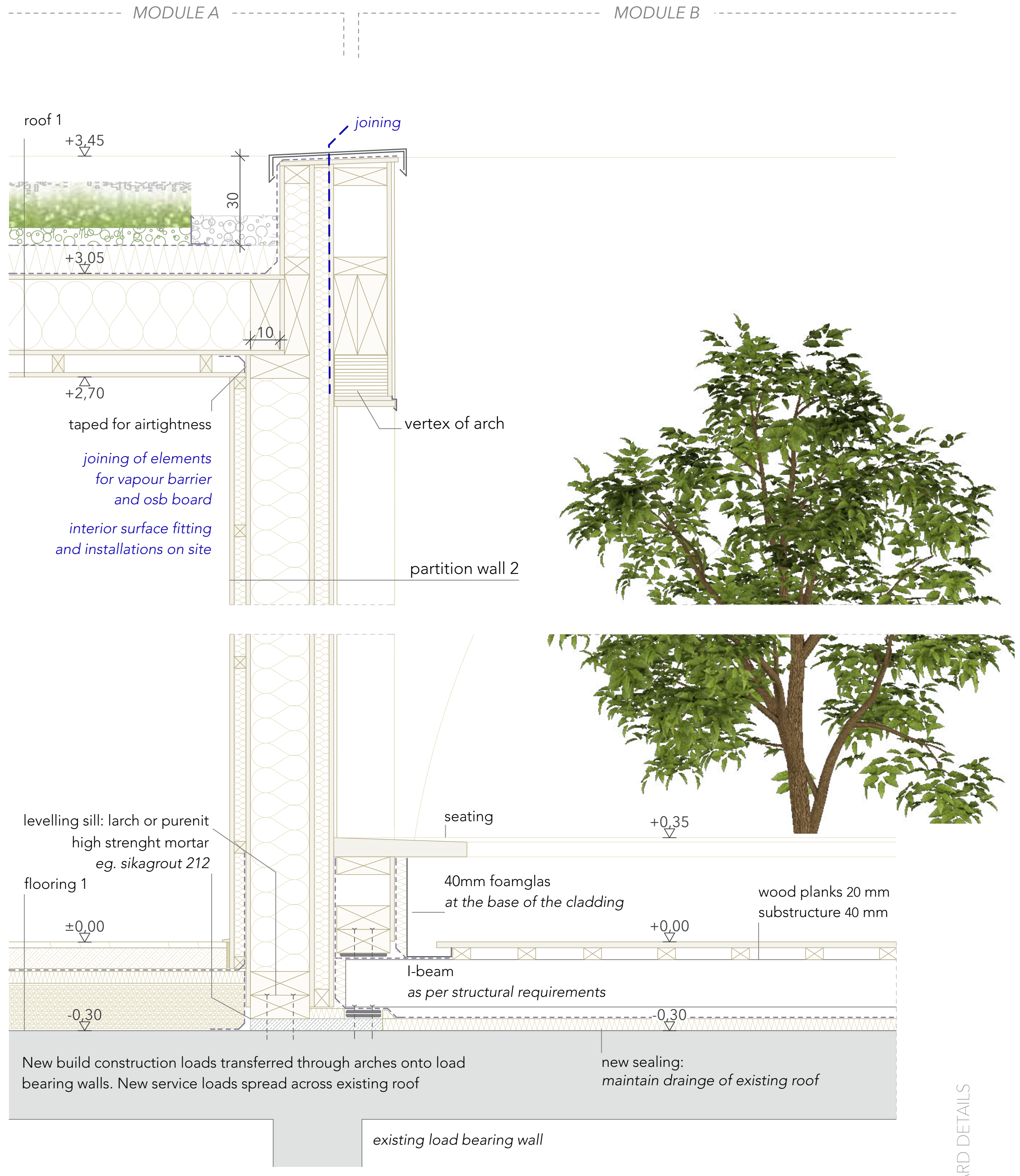
5 cf. Working group for ressource-orientated construction – Institute for constructive engineering – BOKU Vienna, alpS GmbH (publ.) 2016

3.3. STANDARD DETAILS

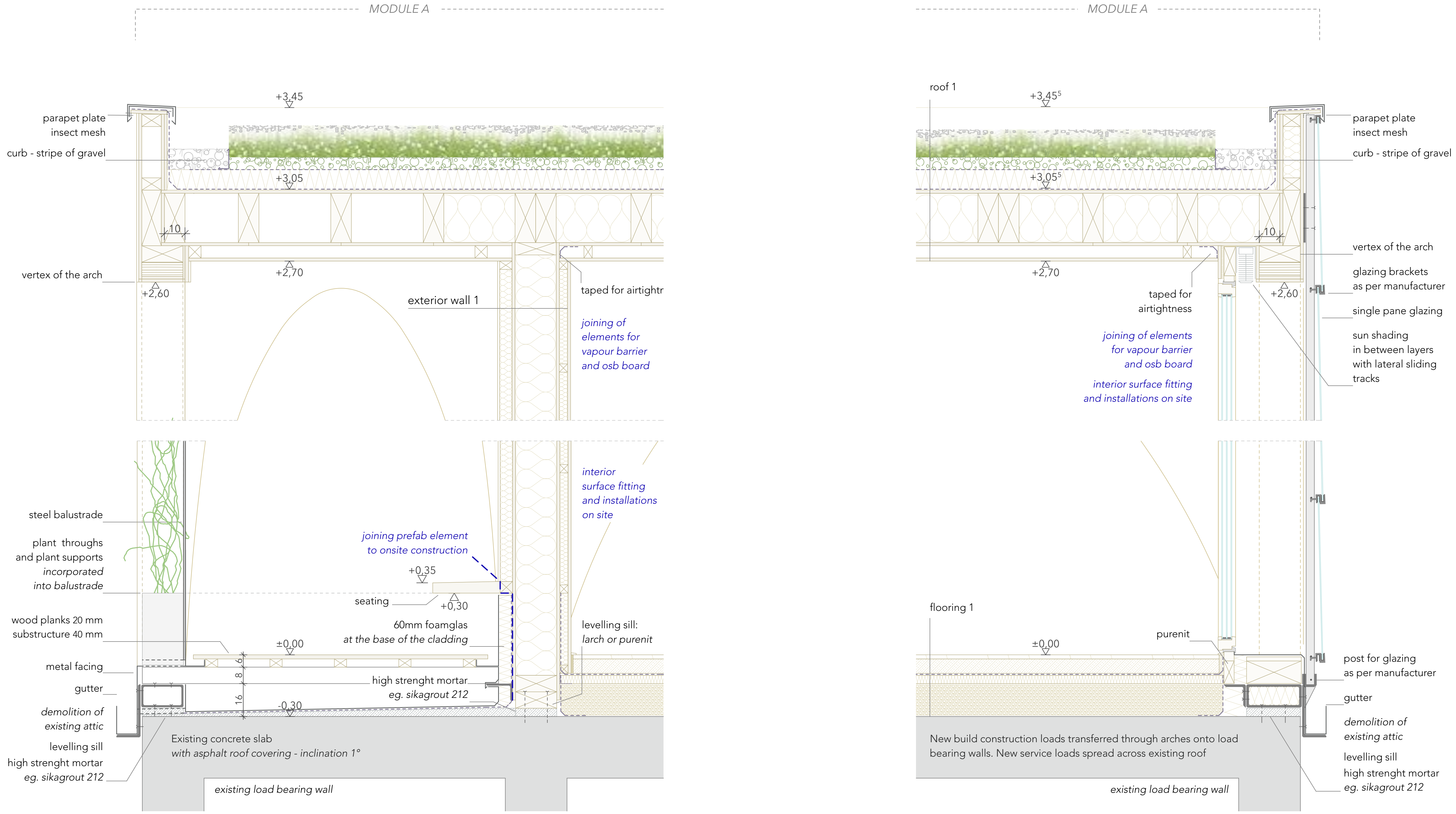
The following pages contain a series of facade cross-sections and details of the most relevant joints and the most significant situations at a scale of 1:20.

25 Detail of Concept Model

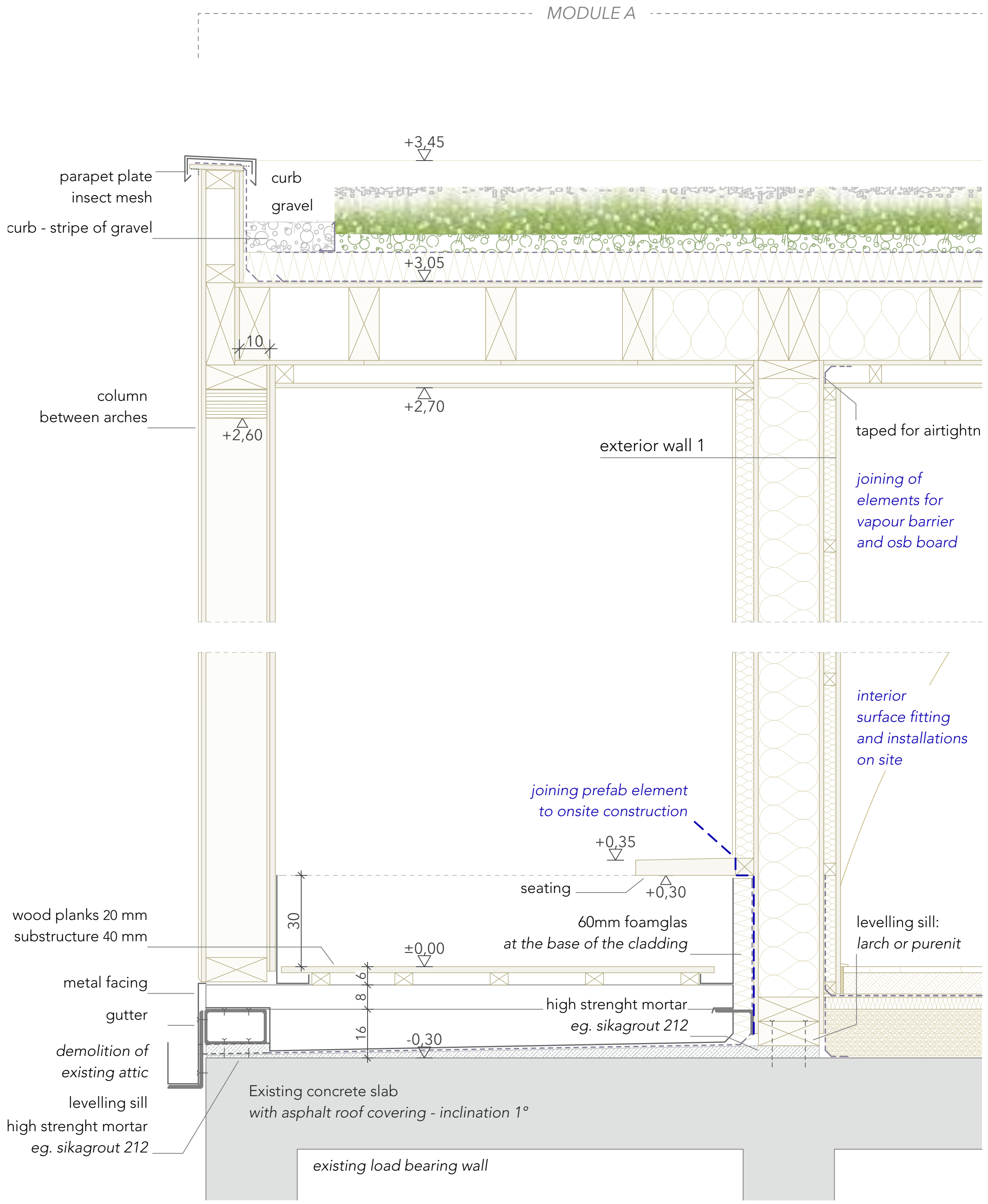


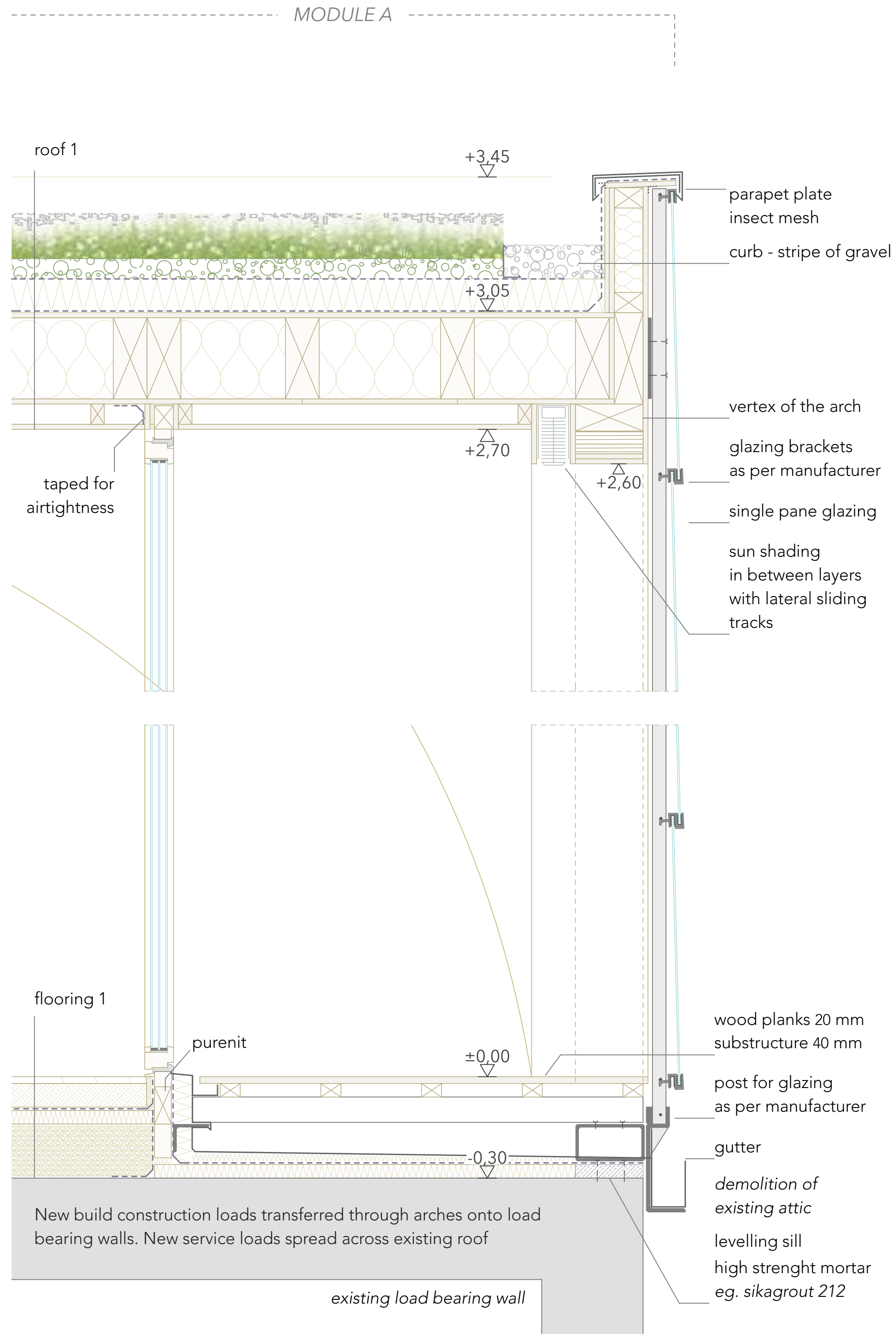


Detailed Section A 1:20

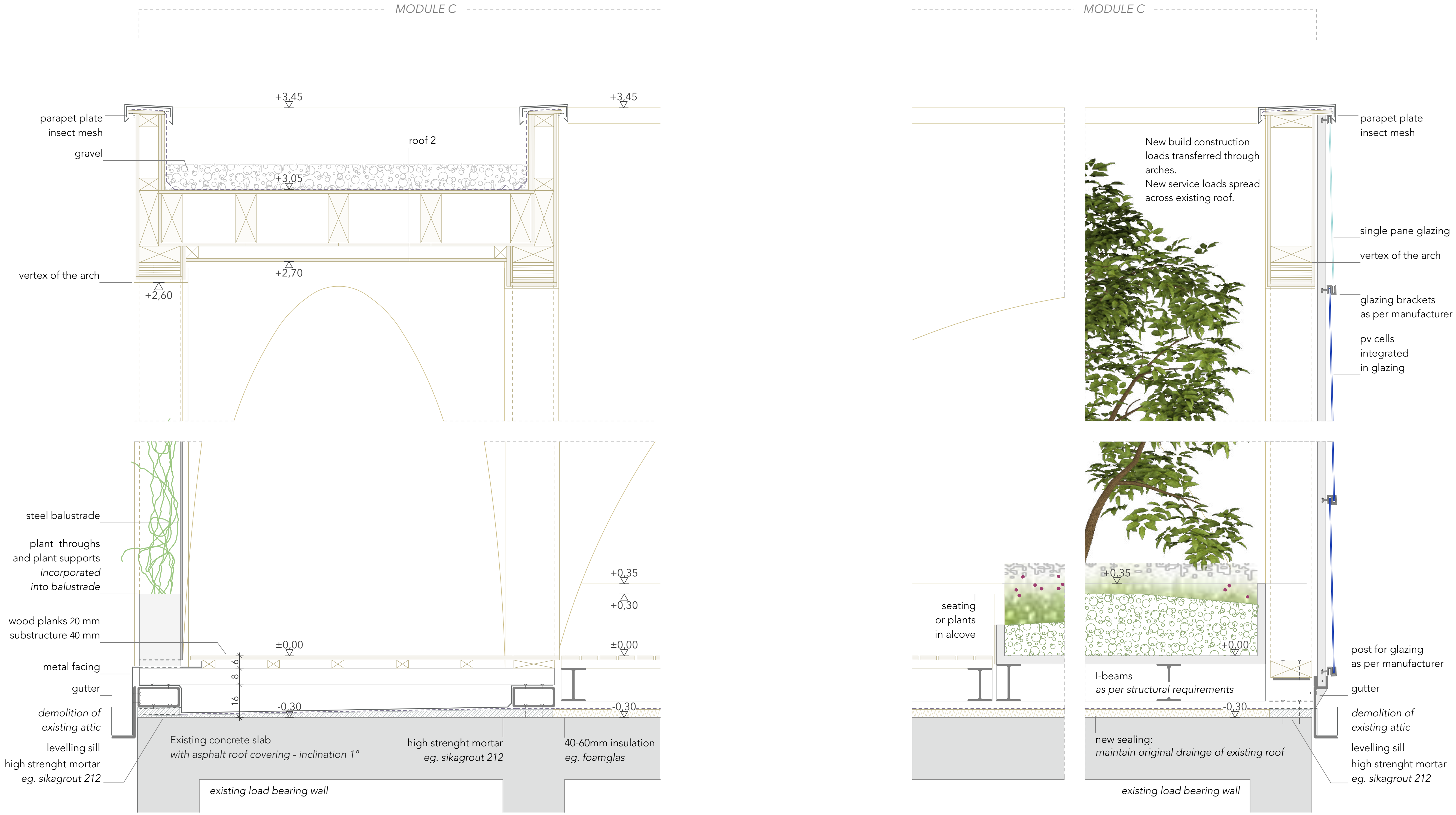


Detailed Section B 1:20

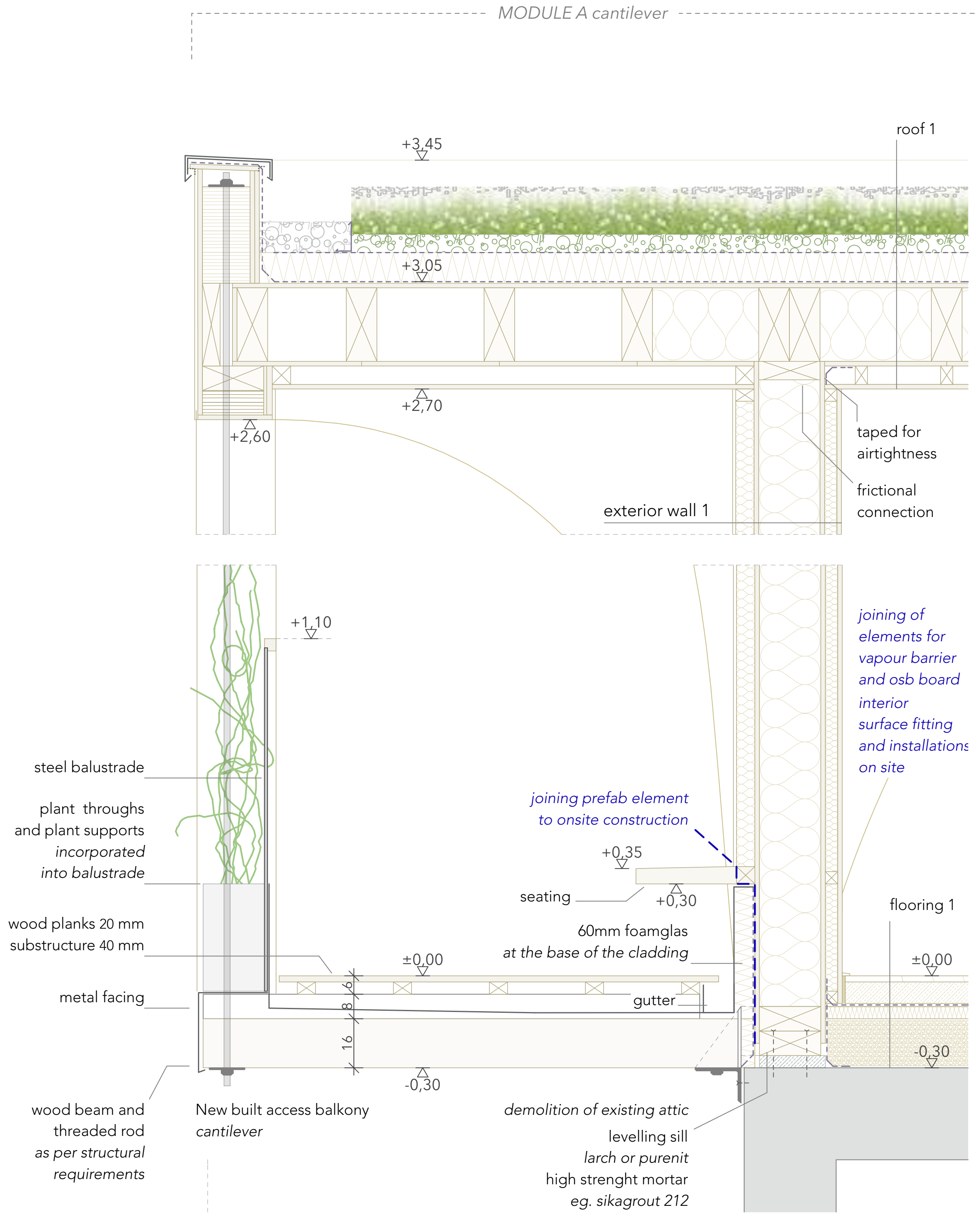


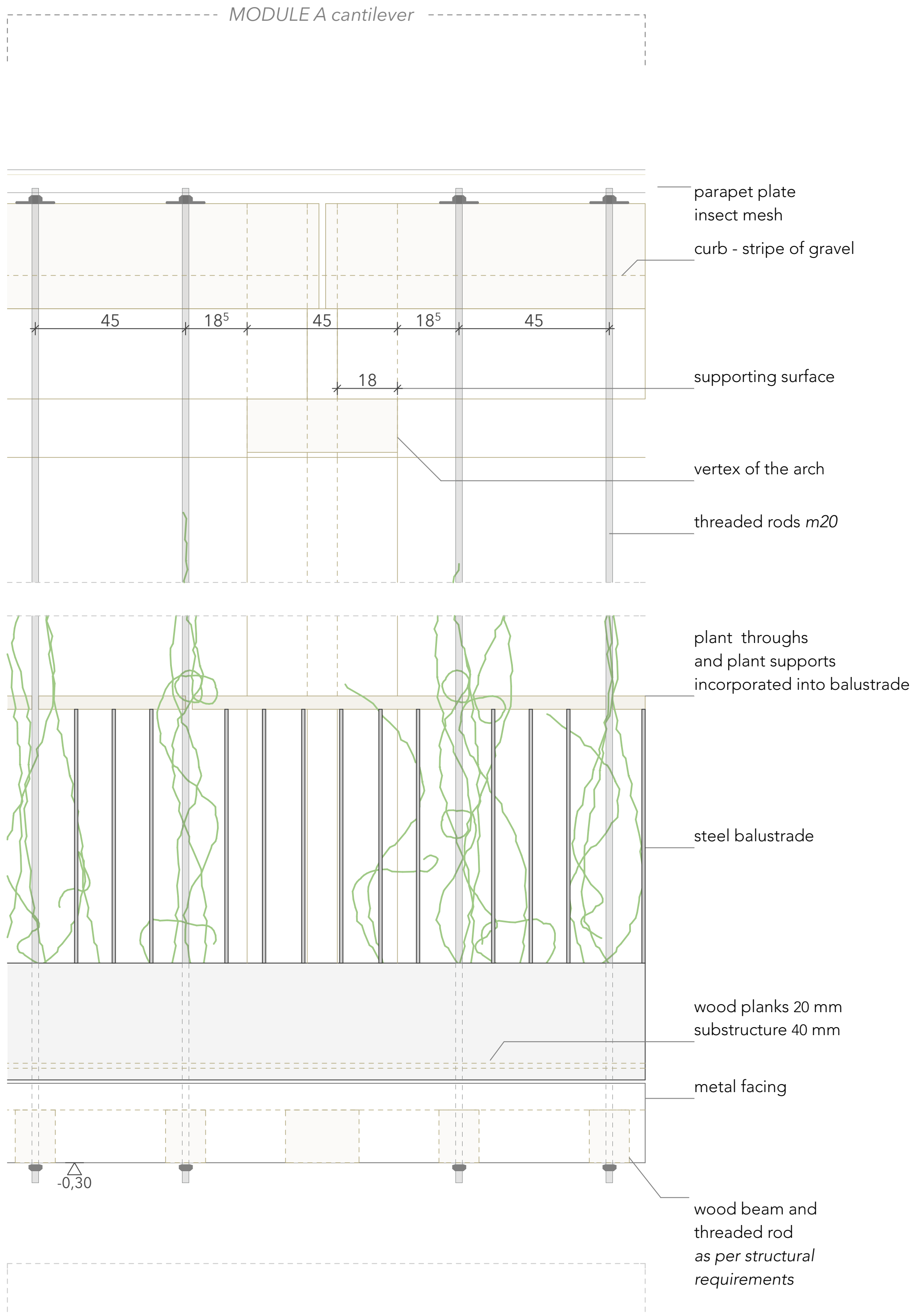


Detailed Section B 1:20

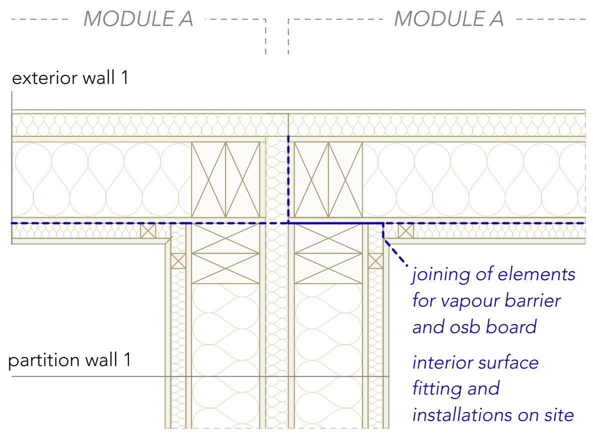


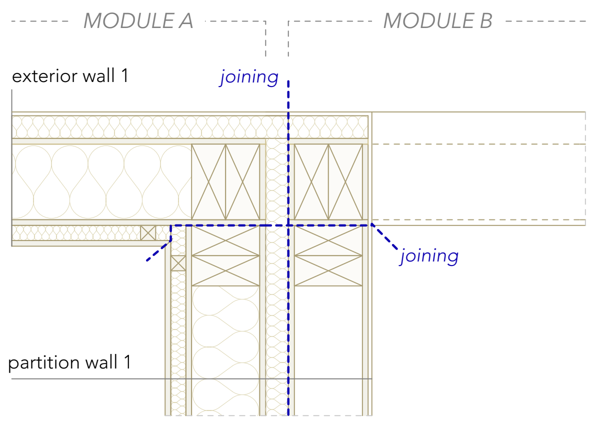
Detailed Section C 1:20

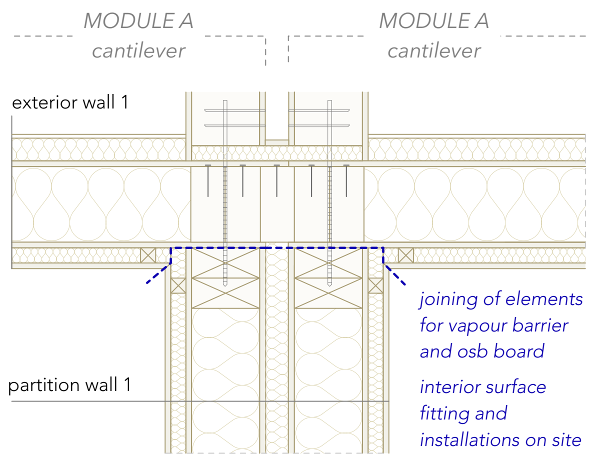




Detailed Section and Elevation Cantilever 1:20







Horizontal Sections 1:20

STANDARD BUILD UPS - *AS PROPOSED IN THE DETAILED SECTIONS*

exterior wall 1	**355 mm**
exterior lime render	10 mm
woodfibre insulation board	60 mm
mdf board	15 mm
timber frame construction	200 mm
mineral wool	
osb board taped for airtightness	15 mm
counter batten	40 mm
mineral wool	
3 ply sheets half white washed	15 mm

U= 0,12

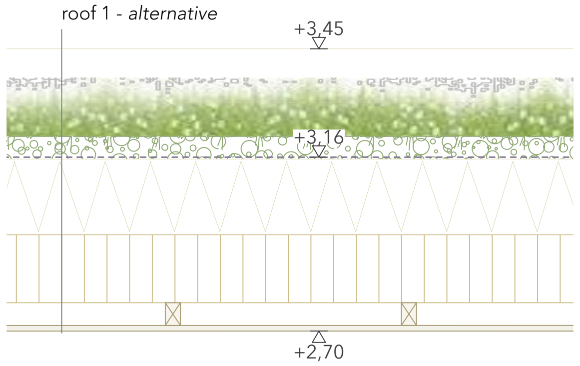
partition wall 1	**590 mm**
3 ply sheet half white washed	15 mm
counter batten	40 mm
mineral wool	
osb board	15 mm
timber frame construction	180 mm
mineral wool	
mdf board	15 mm
per element	**265 mm**
mineral wool in cavity	**+ 60 mm**

partition wall 2	**585 mm**
3 ply sheet half white washed	15 mm
counter batten	40 mm
mineral wool	
osb board	15 mm
timber frame construction	200 mm
mineral wool	
mdf board	15 mm
element A	**285 mm**
mdf board	15 mm
timber frame construction	200 mm
mdf board	15 mm
exterior lime render	10 mm
element B	**240 mm**
mineral wool in cavity	**+60 mm**

U= 0,10

ALTERNATIVE BUILD UPS

roof 1 - *alternative*

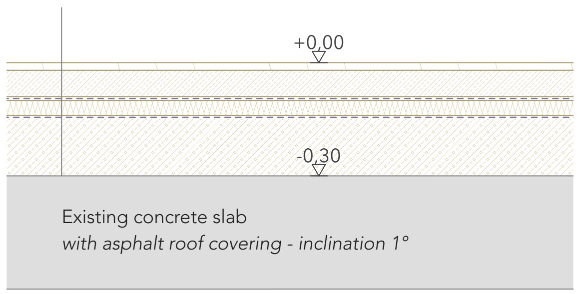


roof 1 - *alternative*	**605 mm**
green roof system extensive *eg.urbanscape sedum mix blanket* *green roll drainage system* *root membrane* *waterproof membrane*	150 mm
sealing sheet (bitumen)	
foamglas (t3+) *heat conduction group 035*	200 mm
vapour barrier	
solid wood ceiling	180 mm
batten	60 mm
3 ply sheet half white washed	15 mm

U= 0,14
acknowledged construction - no further verification needed
max. thickness of available foamglas: 200 mm

~80kg/m2

flooring 1 - *alternative*



flooring 1 - alternative	**~300 mm**
parquet flooring	20 mm
cement screed	70 mm
PE foil	
sound insulation board *mineral wool*	40 mm
sealing	
levelling fill *eg. liapor bound*	~160 mm

existing roof
concrete slab with asphalt sealing

STANDARD BUILD UPS - *AS PROPOSED IN THE DETAILED SECTIONS*

roof 1	**595 mm**
green roof system extensive *eg.urbanscape sedum mix blanket* *green roll drainage system* *root membrane* *waterproof membrane*	150 mm
foamglas (t3+) *heat conduction group 035*	100 mm
sealing sheet (bitumen)	
mdf	15 mm
construction timber	240 mm
mineral wool *heat conduction group 040*	
osb	15 mm
batten	60 mm
3 ply sheet half white washed	15 mm

U= 0,11
verification of moisture balance successful

calculation paramtres - wufi:
orientation: 0°
air exchange rate: 3 (statutory)
additions: 30 mm layer of water on top of foamglas simulating green roof barrier

~40kg/m2

flooring 1	**~300 mm**
parquet flooring	20 mm
cement screed	70 mm
PE foil	
sound insulation board *mineral wool*	40 mm
perlite levelling fill	~160 mm

existing roof
concrete slab with asphalt sealing

Alternative Detailed Sections 1:20

CONCEPT IN PRACTICE

4.1. CASE STUDIES

The following pages show how the vision of this work translates into practice. The images show the elaborated concept applied to a selection of case studies. Three London Council housing estates were selected in line with the previously elaborated classification criteria and represent exemplary building sites. They are purpose built housing blocks and deemed fit for purpose.

26 Collage for Grange Walk Estate, Bermondsey

4.1.1. BALMAN HOUSE, SOUTHWARK

Storeys above ground: 7 Storey below ground: 0

Building information: The fire assessment conducted in July 2017 by the Southwark Council summarises that Balman House is a seven storey purpose built residential block of concrete framed brick structure with a flat roof. It comprises a mixture of single level dwellings on the ground floor and double storey maisonettes on all the upper floors.

The building is configured in an 'L' shape and has two stairwells: one semi enclosed stairwell between the short and long wing and an open stairwell to the far end of the long wing. These stairwells give access to open balconies.

The building has a dry riser system. There are two electrical intake cupboards within the ground floor, either side of the semi enclosed stairwell. There is an electrical distribution cupboard and riser cupboards on all upper floors, accessed off the semi enclosed stair only.

Access to the roof area is by the means of a metal gate on the sixth floor. This area also houses the lift motor room.[1]

1 cf. Southwark Council Fire Assessment PHAU00540101, 2017

4.1.2. CROPLEY STREET, HACKNEY

Storeys above ground: 4   Storey below ground: 0

Building information: The area around Cropley Street hosts a large number of different local authority housing developments. The selected estate is a four storey purpose built block made of concrete frame with brick work facades. It accommodates a series of double storey maisonettes.

There is an enclosed stairwell on the narrow end of the block leading to access balconies on the first and the third floor. Flats have recessed balconies to the rear.

The lift overrun is located centrally and protrudes the volumes. The flat roofs can be accessed via a hatch at the head of the staircases.

27 Collage for Cropley Street, Hackney

28 Collage for Athenaeum Court, Islington

4.1.3. ATHENAEUM COURT, ISLINGTON

Storeys above ground: 4 Storey below ground: 0

Building information: Athenaeum Court is a four storey purpose built estate of four blocks made of concrete frame with brick work facades. It comprises a mixture of single storey flats and double storey maisonettes.

There is an enclosed stairwell on the narrow end of each block leading to access balconies on the first and the third floor. Flats have recessed balconies to the rear.

The lift overruns are located centrally and significantly protrude the volumes. The flat roofs can be accessed via a hatch at the head of the staircases, the electrical intake cupboard is situated at ground floor level.

29 Collage for Balman House, Bermondsey

4.1.4. VALOIS HOUSE, SOUTHWARK

Storeys above ground: 7   Storey below ground: 0

Building information: As per the fire assessment conducted in July 2017 by the Southwark Council, the building is a purpose built block of general needs housing, approximately 58m long, 8m wide and 15m high to the base of the sixth floor slab. Facades are brickwork onto concrete frames. It comprises two storey maisonettes as well single level flats.

Two open staircases provide access to open balconies on first, third and fifth floors. One staircase is located centrally within the block and is adjacent to the single passenger lift which serves all access floors. The staircase located at the Southern end of the block has bin chute hoppers located on the half landings. The ground floor dwellings are accessed directly from street level.

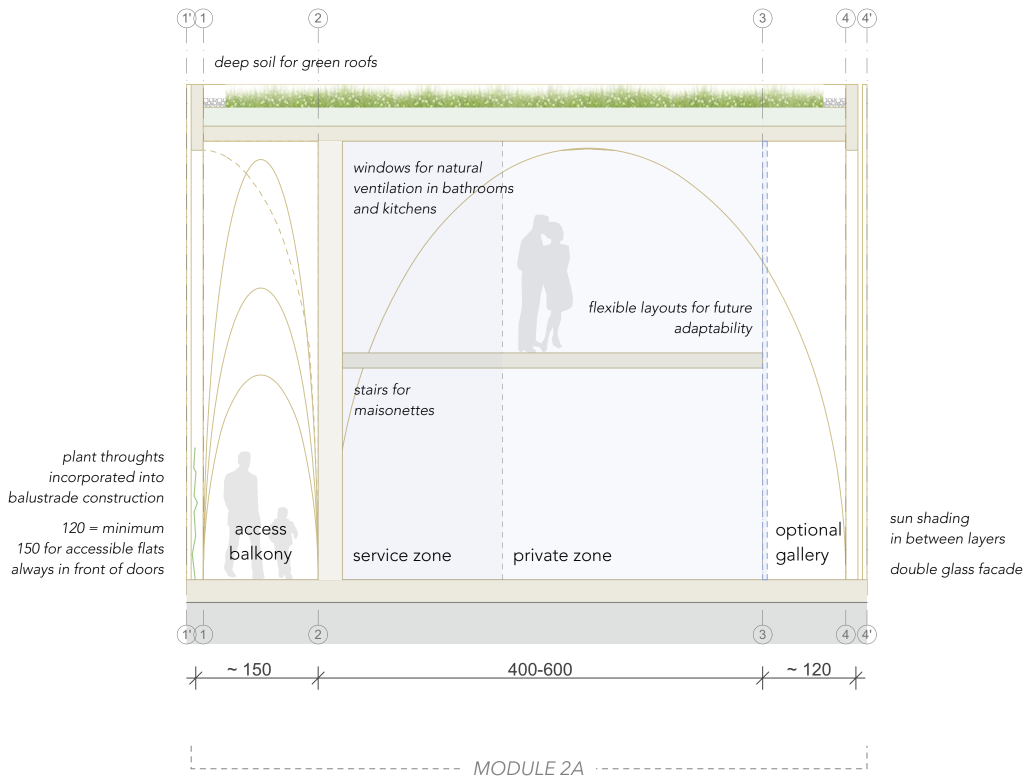
Upper flats have juliet balconies to the rear except the sixth floor which has a rear balcony running the full length of the building, it is assumed that this balcony was originally provided to provide a reciprocal means of escape from the top floor.

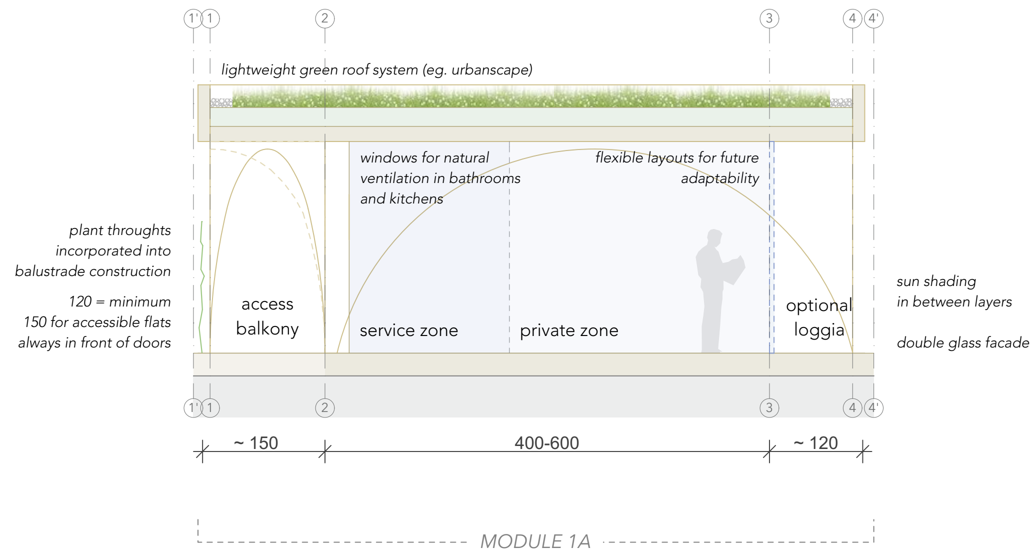
Access to the flat roof is via a hatch at the head of both staircases, the electrical intake cupboard is situated at ground floor level beneath the central staircase. A dry rising main is provided with outlets on all floors.[2]

2 cf. Southwark Council Fire Assessment PHAU05282101, 2017

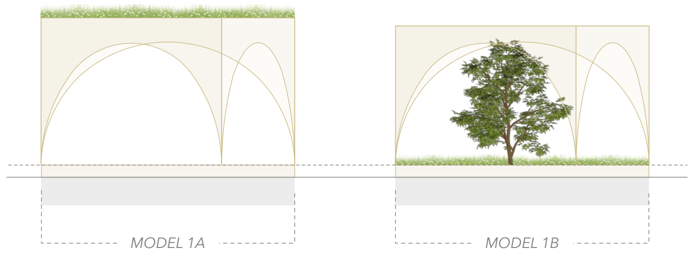
4.2. DWELLING TYPES

The subsequent pages show a series of specific floor-plans and sections at a scale of 1:100. They present a variety of different dwelling types according to the "London Housing Design Guide" and were elaborated in line with the respective standards.

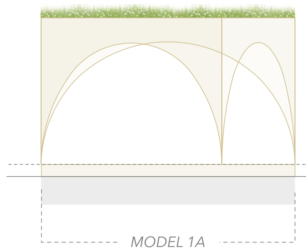


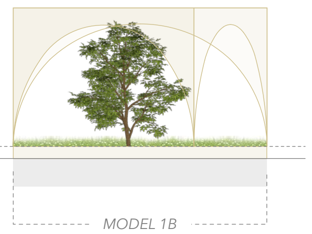


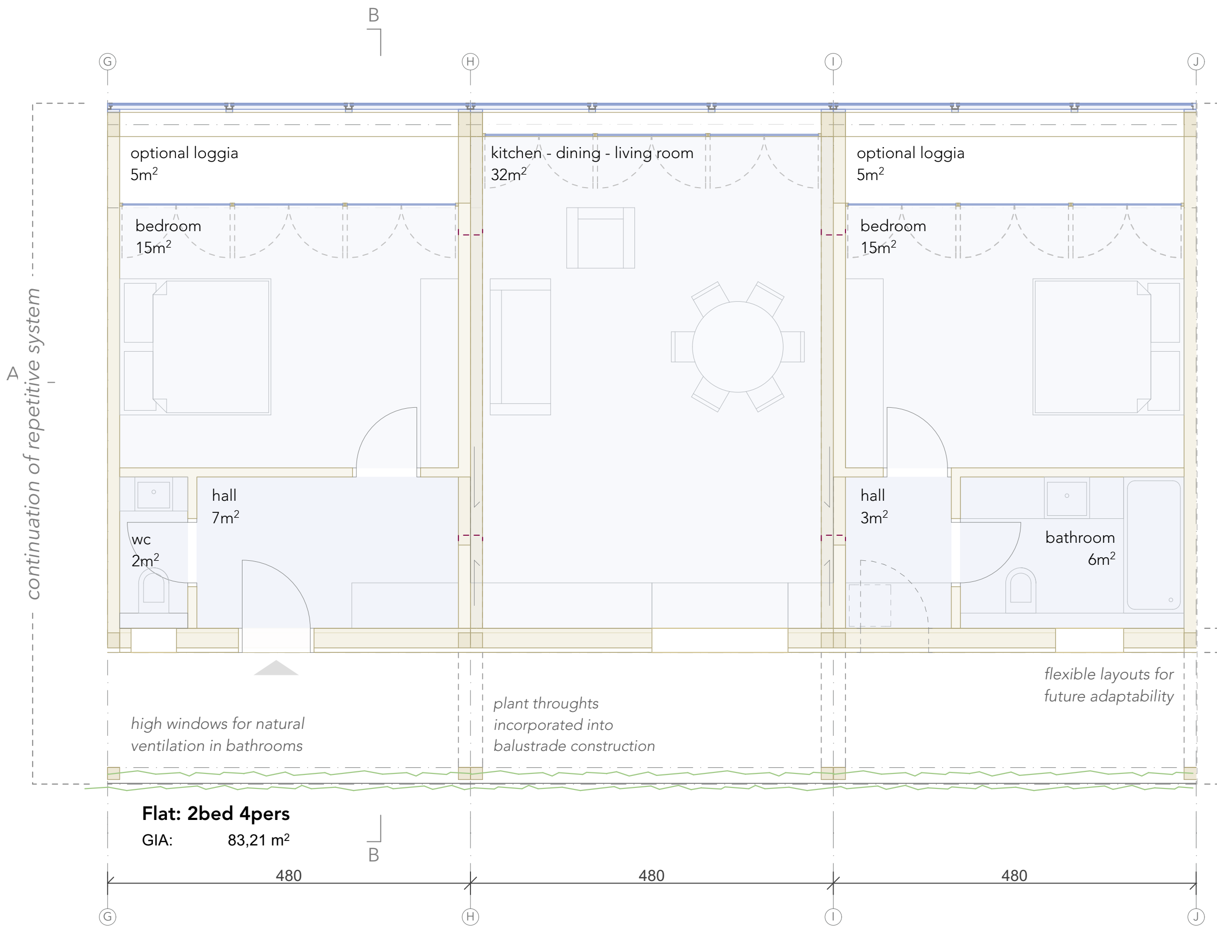
Typical Sections of Flats and Maisonettes 1:100

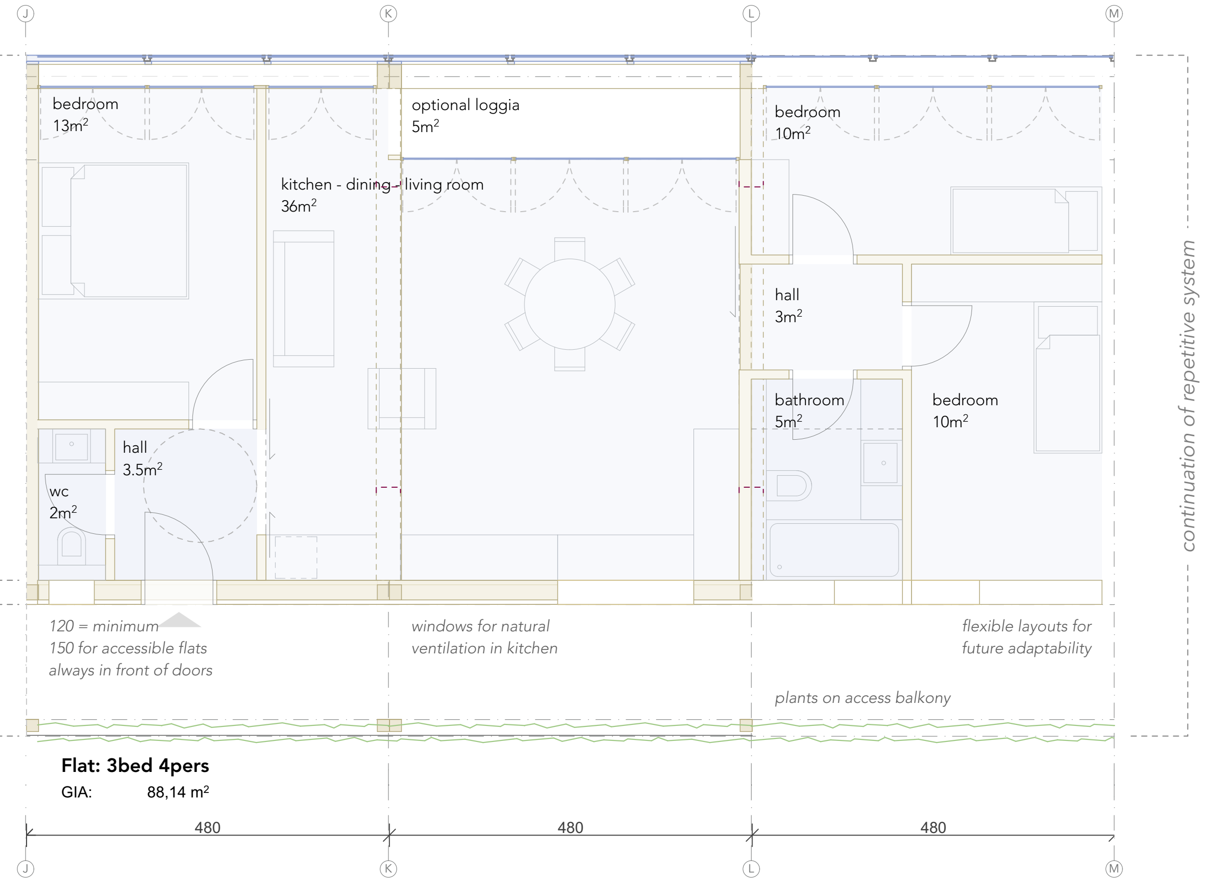


Typical Floorplans of Flats 1:100

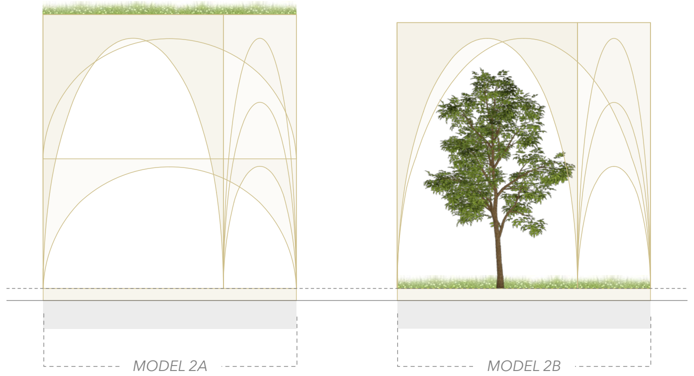


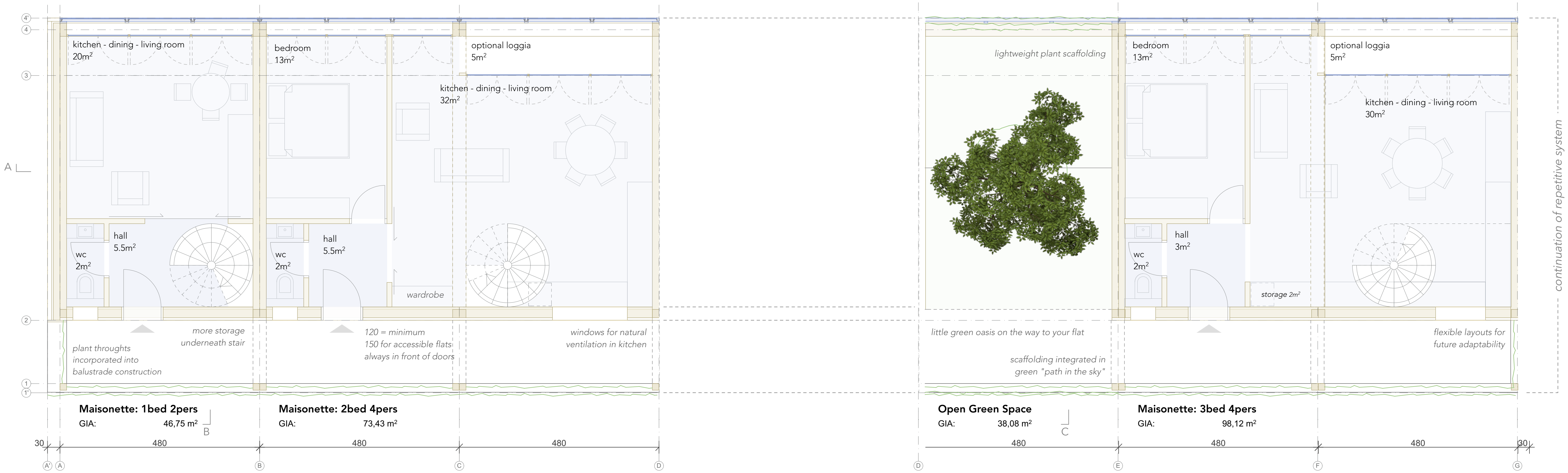




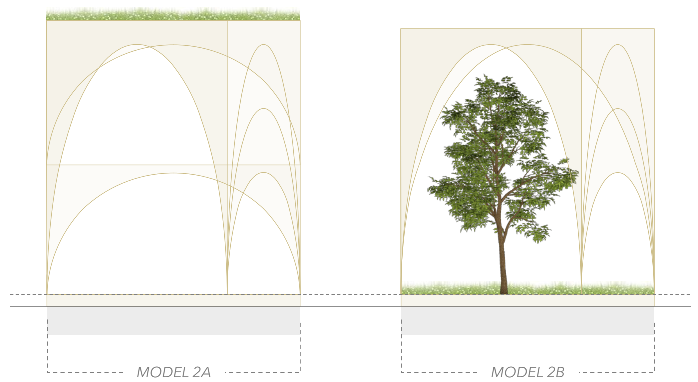


Typical Floorplans 1:100





Typical Floorplans of Maisonettes - Entrance Level 1:100



Typical Floorplans of Maisonettes - Upper Level 1:100

CONCLUSION

It would have gone beyond the scope of discussion to explore the potential of extensions, which would not need to transfer the additional loads into the existing structure. This could reduce the risk related to the calculability of the existing walls and foundations. This thesis therefore calls for another study to develop a system of storey additions, that transfers its loads independently into the ground.

In the course of the research, Terraced Houses had to be excluded from the scope. However, this thesis acknowledges their potential and asks for another study to demonstrate how these typical suburban typologies could be adapted to enable rooftop developments that would allow the creation of additional new homes across the whole of Greater London.

5.1. A CITY OF THE FUTURE

This thesis illustrates that a timber-based lightweight prefabricated system offers a construction method for roof extensions on a wider scale. In the traditional approach of roof extensions, each addition asked for an individual project-development. Affordable or low cost housing systems could therefore often not be realised.[1]

This study shows that lightweight timber constructions can exploit a potential that is still largely untapped and provide affordable living space close to the city centre. It also shows that vegetation and urban green spaces can be combined with this system to enhance the social and natural quality of the existing site.

The prototypical development can be applied to a series of buildings of similar age and type. This vision was tested on a certain typology in London, but it can also be translated for comparable situations in cities across Europe.

30 Collage for London

1 cf. Working group for ressource-orientatated construction – Institute for constructive engineering – BOKU Vienna, alpS GmbH (publ.) 2016

APPENDIX

6.1. LIST OF SOURCES

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The validity of all internet sources referenced below was verified on 29. June 2018.

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6.2. LIST OF FIGURES

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