World Conference on Timber Engineering Oslo 2023

HASLE TRE: NORWAY'S FIRST TIMBER OFFICE BUILDING DESIGNED FOR DISASSEMBLY AND REUSE

Ona Flindall[1], Jørgen Tycho[2], Moritz Groba[3]

ABSTRACT: Design for disassembly is a key strategy for ushering the building industry into the age of circular economy. Timber offers an efficient structural solution to meet growing environmental challenges. Yet the timber material lifecycle has primarily remained linear. Design for disassembly and reuse can close timbers material loop and build a circular value chain. The HasleTre project is Norway's first timber office building designed and constructed explicitly with the intention of future disassembly and reuse. In this paper, the architects at Oslotre presents the key design solutions that have been developed for the project. Timber-to-timber connections have been central to the project's design and offers interesting solutions for the circular future of timber architecture and engineering.

KEYWORDS: disassembly, demount ability, reuse, recycle, energy, carbon impact, timber-to-timber joints, carpentry joints

1 INTRODUCTION

Rising prices of timber and other building materials have put an economic incentive on material efficiency, reinforcing the moral imperative in the face of climate change to reduce overall material usage [1]. The C40 report on Building and Infrastructure consumption emissions, highlights that over 60% of the building industry's emissions are associated with the production and delivery of building materials [1].

Timber's ability to sequester carbon gives it significant environmental advantages and offers an efficient method for removing CO2 from the atmosphere and mitigate against the effects of climate change. Yet this equation is only valid for the lifetime of the relevant building components. Once decommissioned timber components are today primarily chipped and used for energy production, releasing the stored CO2 back into the carbon cycle. In 2019, it was estimated of the 815 thousand tons of wood waste produced in Norway, only 6% went to material recovery [1].

In 2021 more than half of all timber waste generated by the Norwegian building industry resulted from demolition and rehabilitation [1]. Office buildings are a typology especially prone to generation of waste materials due to the frequency of tenancy rotation and shifting interior preferences. Depending on tenancy rotation the overall emission cost of refurbishment can ultimately outstrip the emission costs of the building's material production [1].

One key strategy for reducing the environmental impact of refurbishment and end of life demolition, is to design for disassembly and reuse. Ensuring that the lifetime of individual building components are prolonged beyond the lifetime of the buildings they temporarily inhabit. It offers a way of closing material loops, reducing material consumption and waste, prolonging components service life and increasing both on- and off-site reuse.

In this paper, we present Norway's first all-timber office building designed and built to be disassembled and reused; HasleTre.

2 THE PROJECT

2.1 BUILDING, SITE AND SITUATION

HasleTre is situated at the outer edge of the central city of Oslo, Norway. The project is a 3000m2 office building split over 5 floors including basement and roof-terraces. The project is part of a larger city development, HasleLinje, which includes a range of commercial and residential properties. The site is situated as one of two gatehouse plots and frames the square in front of the 1933 Norwegian government wine monopoly distillery, Vinslottet - "the wine castle", see figure 1.

The project was initiated in December 2019 and was completed in 2022.

[1] Ona Flindall, Oslotre AS, Norway, ona@oslotre.no
[2] Jørgen Tycho, Oslotre AS, Norway, jorgen@oslotre.no
[3] Moritz Groba, Oslotre AS, Norway, moritz@oslotre.no

https://doi.org/10.52202/069179-0202

Figure 1: *Historic Vinslottet, refurbished into commercial facilities and housing in 2020.*

2.2 THE BRIEF

The initial brief given by the property developers; Höegh Eiendom and AF Eiendom, was the design and development of an environmentally friendly, flexible, and innovative commercial build.

During the early concept phase of the design process the ambitions of the project were developed in collaboration with the architects and key advisors. Resulting in a revised and ambitious brief for an all-timber building designed for disassembly and reuse. The project should also reduce overall GHG emissions with a minimum of 50% and be certified to BREEAM NOR Excellent standard.

2.3 THE CHALLENGE

Allowing for effective reuse of buildings, both during its lifetime and at the end of service life, offers several separate design challenges and requires a number of different solutions, at different levels of design and development. As a designer you are facing the challenge of designing for a second-hand market whose preferences and needs are yet unknown and in large part unpredictable.

Two key design strategies have been central to the design for disassembly solution for HasleTre. Firstly, the development of timber-to-timber joints and connections allow for reduced use of steel and ease of disassembly. Secondly, the development of technical and structural solutions that allow for flexibility in use during life, simplified separation at end of life, all the while retaining a second-hand value of components and materials.

In combination, these two key design strategies aim to retain the structure's second-hand reuse potential, flexibility and financial value.

2.4 ACKNOWLEDGEMENT

This paper will focus on the architectural and structural design solutions developed for and realised in the HasleTre project. However, the authors of this paper wish to recognise at the outset that the realisation of HasleTre has required a collaborative effort from all actors involved, including developers, contractors, and planning authorities.

HasleTre is a result of a well-established cooperation between ambitious property developers and a visionary design team, with a mutual goal of realising something extraordinary. Without the work and collaboration of Seltor as building contractors, the project would not have been realised. The collaboration and mutual goals of the entire team have been an underpinning prerequisit and requirement for realising a project of this magnitude and ambition.

3 DESIGN

3.1 DESIGN FOR LONGEVITY

3.1.1 Architectural quality and durability

Design for disassembly will mitigate against the emission costs of demolition at end of life. But the most effective climate measure is to prevent, or delay, demolition by extending the buildings service life. [1] In a social and cultural context that values the immediate and transitory extending, a buildings lifetime requires architectural design for aesthetic and material longevity.

Groba has shown how timber as a construction and surface material can increasing the lovability of buildings, and how buildings that are loved last longer and thus contribute to both ecological and social sustainability. [1]

By prioritising quality and simplicity in both structure and interiors HasleTre is designed for durability. The overall design and facades mirror the historic and 'timeless' character of the neighbouring heritage building. The high quality all timber surfaces both interior and exterior are hard wearing and will age with grace and character building on the emotional connection that encourages occupants to care for and remain in the building.

Figure 2: *Designed for longevity and lovability. Designed for enduring taste.*

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3.1.2 Planed for flexibility

To extend a building's life expectancy it is important to consider and facilitate for changing needs and requirements. HasleTre embraces flexibility in use as well as reuse. The building is designed to facilitate for shifting spatial needs, technical requirements, and preferences. Organised around a central core the two wings of the plan offer a variety of available areas and a potential for division of the building and individual floors among one or multiple tenants. The floor plans are further subdivided by a 5x5m grid system which can easily subdivide the open spaces into smaller enclosed working spaces, see figure 2. The flexibilities in plan and grid allows occupants to reconfigure plans and internal elements without having to make structural and exterior changes.

Figure 3: *Typical floor plan, divided into two main segments and further subdivided by structural grid.*

Flexibility in structure and plan is facilitated further by use of a Granab subfloor system and open technical infrastructure for ventilation and sprinkling in the ceiling. The technical infrastructure needs of the future may be difficult to predict, but by giving ease of access, HasleTre ensures the building can be adapted for a variety of uses during its lifetime and handle larger societal changes and changing technical infrastructure.

Figure 4: *Subfloor system and open central ventilation system allows for swift and easy changes to interior arrangement.*

3.1.3 Design for production, effective material use and ease of assembly and disassembly

The building is a CLT slab and glulam post and beam structural system. Designed for disassembly and reuse, all components are carefully planned and designed to enable an easy assembly and disassembly process.

All of the timber components are designed to minimize cut-offs in production and designed for standard production dimensions. Designed for the Master Element production in the CLT factory each floor slab utilises the standard three by fifteen meter elements. This reduces the need for cut offs, maximise the space on the lorry and gives a fast assembly.

To retain reuse potential, all permanent fusing joints and sealants had to be avoided wherever possible. A full disassembly manual follows the building at completion.

3.2 DESIGN WITH REUSE

HasleTre was built to be dismantled and reused, but also built to include the reuse of material components where possible. The project reuses the ventilation aggregate, acoustic ceiling plates, sanitary installations like sinks and toilets, flooring in secondary rooms such as basement and technical rooms. Designing with reuse requires an attention to details to handle the overall material pallet and relies on an availability of components.

https://doi.org/10.52202/069179-0202

Figure 4: *Second-hand acoustic panels for use above ceiling battens.*

HasleTre was let to the charity Save The Children from December 2022. As tenants, the reuse approach was further adopted and incorporated in their own interior design. Ensuring that the majority of all furniture and inventory brought into the building was either reused, recycled or upcycled.

3.3 DESIGN FOR REUSE

3.3.1 Second-hand value of standard dimensions

The project aims to be the standard to beat in new circular builds. By utilising standard production formats and dimensions, the timber structure actively aims to retain value of the component for second-hand use. By limiting perforation of structural components the overall material use is reduced in the project, while the potential for second hand adaptations is secured. The CLT floor slabs are utilised as master elements in full. To facilitate for technical facilities the inherent strength of the CLT slabs is utilised to 'carry' the extension between the beam structures. Resulting from this strategy the glulam beams are not perforated to facilitate technical services and the material use and cost is reduced while the beams remain versatile and adaptable for future use.

Figure 5: *Glulam and CLT timber-structure. Note cantilevered beams give space for ventilation and fire systems.*

3.3.2 Timber-to-timber joints

The building structure is an optimised timber structure that aims to reduce the use of steel and other metals to a minimum. Replacing conventional steel joints between timber components with timber-to-timber alternatives. This is done both to reduce the overall use of steel, but also to ensure that the timber component can be reworked and remodelled using industrial tools to facilitate for future reuse without facing limitations due to the danger of steel embedded within the components.

Two key joints have been utilised in the project; Firstly the use of hardwood dowls in post-beam nodes and the use of x-fix joints between CLT slabs. In addition, all interior cladding is assembled with hardwood nails.

Through careful structural design, the tension loads on the joints have been reduced and enabled a simplified dowel joint. Using only two hardwood dowls in beech, the joint is not only materially efficient, but also labour efficient. Significantly reducing the assembly time on site. The dowels are dried to 6% before insertion. Once inserted the wood will adjust to surrounding moisture and lock the components in place. At disassembly the dowel can be drilled through and the connection released.

Figure 6: Hardwood dowels during assembly of timber structure.

CLT slabs in the building walls and floors are connected using X-Fix plywood connectors that replace the traditional use of metal screws. This is the first time the X-Fix connectors are used in Norway. This significantly reduces the overall use of steel and increases the reuse potential and value. The X-fix system has also proved to be an incredibly timesaving process in assembly on site.

Figure 7: X-Fix dove-tail connection between CLT slabs.

Furthering the timber-to-timber joints to its final conclusion, both interior and exterior cladding is assembled using wooden nails as fasteners. As with the structural components the use of timber joiners enables an easy remodelling or furnishment at the end of life.

Figure 8: See the heads of the small timber nails to the left in the photo.

4 LESSONS LEARNT

The HasleTre project has been a valuable learning experience for all parties involved and there is a desire to inspire others to think reuse, both today and for the future. The development and use of innovative and demountable structures require discipline and desire from developers, designers, and contractors. Developing a mutual understanding of collective goals and aims has been essential to the successful application and realisation from development stage to completion.

In all innovative projects the division of responsibilities will be challenging. Uncertainty and insecurity in realising untried approaches and solutions can quickly lead to conflicts and difficulties within the project teams. In the HasleTre project the architects were able to take on the responsibility for the structural engineering and mitigate against insecurities with suppliers unfamiliar with the solution.

The commercial reuse sector is growing and developing quickly, but it is still facing a number of challenges with regards to availability, lack of storage and cataloguing, just in time logistics and certification. This is reflected in the processes around HasleTre where the ambitions for reuse of materials restricted predictability and required selection and ad-hoc choices throughout the process.

Collectively, the timber-to-timber joints and solutions offer an adaptation of traditional building practices to industrial and prefabricated timber structures. Offering financial rewards in terms of reduced assembly time and a retained second-hand value of both interior and structural components.

5 DISCUSSION AND CONCLUSIONS

In 2022, the national building codes TEK17 were updated to include requirements for design and construction for disassembly. There is a political desire to increase circularity in the building sector. The attention HasleTre has drawn both nationally and internationally points to the

https://doi.org/10.52202/069179-0202

need for built projects and examples that can lead the way for implementation of these principles, and showcase the architectural potential in disassembly and reuse.

Vandervaeren, et al., have shown how current calculations methods for LCA fall short on adequately modelling material flows and stocks in demountable buildings. Failing to capture the potential benefit of designing a building for easy disassembly and reuse [1]. They go on to call for a method that captures the effects of demountable design principles in the input and output material flows during the replacement and end-of-life stages of built assemblies, and on the reusability of disassembled building parts.

As design for disassembly and reuse is developed as a design strategy, it is important to be able to show and quantify the benefits for the environment. The authors of this paper hope the HasleTre project will incentivise both the public and private sector to call for greater application and development.

The project showcases a number of key challenges faced when wanting to design, both when utilising and facilitating for future reuse of building components. It also offers a critical view to the choice of hybrid solutions for increased strength and meeting acoustic and fire demands, which if not carefully designed, will potentially limit reuse and recycle potential.

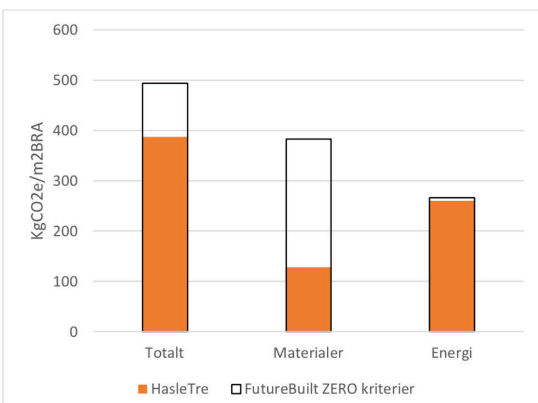

Figure 9: *GHG emissions compared with FutureBuilt ZERO cirteria.*

As built calculations show an overall 59% reduction in emissions from materials and energy use over a lifecycle of 60 years. Use of timber in post and beam structure, slabs and timber-to-timber joints have reduced the steel use in the building by 70% compared to a conventional office building [1].

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