# Circular Design for Reuse

Transforming Timber

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# OVERVIEW

**The construction sector worldwide is still predominantly caught in a model of 'take-make-waste' where finite resources are extracted to manufacture products which are simply disposed of at their end of life. For instance, in 2018, construction and demolition in Scotland was responsible for 5.8 million tonnes of waste, equating to 51% of Scotland's total waste[1]. Clearly this approach is both economically and environmentally unsustainable. Instead, a circular economy model in which material and components are kept in a continuous life cycle through reuse or repurposing can enable the sector to address its poor record of waste and emissions.**

The salvaging and reuse of construction components is not common practice due to complex and irreversible connection types paired with a lack of consideration for end of life. Additionally, uncertainty surrounding component information, history and structural capacity limits options for reuse. However, when designed with circularity in mind, timber components are particularly well-suited for deconstruction and reutilisation. This summary identifies principles and approaches which can be adopted to increase the circularity of timber components used in construction

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[1] Scottish Environment Protection Agency. (2020). Waste from all sources – summary data 2018 (p. 32). https://www.sepa.org.uk/environment/waste/waste-data/waste-data-reporting/waste-data-for-scotland/

# CASE STUDIES OF DECONSTRUCTABLE TIMBER BUILDINGS

While there are few technical details or design guides available to aid practitioners in designing for deconstruction, there are examples of innovative designs which have considered deconstruction early in the design stage which as a result, enables the potential reutilisation of the components in the future.

12 buildings around the world were analysed as case studies of timber structures which have been designed for deconstruction [2]. Found in the Netherlands, UK, Sweden, Australia, and other sites worldwide, these deconstructable buildings all exemplify at least one, if not more, common themes in circular timber design:

- Standardised components,
- Reversible and accessible fasteners / connections,
- Specifications for second life,
- Design for relocation, and
- Use of innovations like offsite construction and digital fabrication.

A matrix highlighting different material types, construction methods, and connection mechanisms can be found in the full report.

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[2]Brummen town hall, Netherlands, Building de(mountable), Netherlands, The COP26 house, UK, EcoCanopy, UK, Feilden Fowles, UK, The Globe at CERN, Switzerland, The Green House, Netherlands, The Incubator, Australia, Multiply, Worldwide, 6 Orsman road, UK, Ostermalm, Sweden and Team Esteem, UK

## Connections Are Key

The case study analysis revealed the crucial importance of demountable connection systems, and these must specifically be understood in the context of timber construction methods.

1. Screws

Screws are beneficial as they can be removed using the same tools they are put in with. Aside from the fastener hole, they do not cause further damage to the surrounding material when they are removed. However, the same screw hole cannot be reused, and therefore when reusing timber components, a new screw hole will have to be made. Despite this, screws may be a suitable approach for a semi-permanent or permanent structure with limited disassembly and reassembly cycles. The available data reveals that screws have the lowest level of adoption in the demountable case studies; however, screws have been used where they are not the primary fastening mechanism (such as in the Team ESTEEM house utilising the Rothoblaas X-Rad system).

2.Bolts

Bolts use predrilled holes which can be repeatedly reused. Unlike screws, they do not require a new hole for every disassembly and reassembly cycle. This is because the removal of the bolt does not damage the surrounding materials. However, components which use bolts in repeated reuse can experience potential reduction in load carrying capacity due to connection slip. This phenomenon, which occurs due to numerous factors including moisture, loading, and hole diameter, must be considered when reusing the component. Despite this, the most common approach to demountable design uses bolts.

3. Blocks and plates

Fastener companies such as Rothoblaas and Knapp have recently developed connection systems in the form of blocks and plates which are fastened to the mass timber components. These enable the demounting of mass timber elements which can then be repeatedly demounted and reassembled. The Knapp system can also connect mass timber and concrete elements. The design intention of these systems was not their ability to enable deconstruction and reuse but rather their ability to decrease construction times. Therefore, their ability to enable demounting is a positive consequence of the design itself. So even though these systems are not yet widely adopted, they reveal how design for deconstruction can have other benefits.

**Building Passports**

The structural integrity of pre-used components will depend on a variety of factors such as use, load cycles, environment, and repair and maintenance schedules. Over the course of a building's lifetime, which is likely to be several decades, the listed factors and their level of application are likely to change which therefore makes the impact on structural capacity difficult to quantify.

One way in which the uncertainty surrounding the structural integrity of the deconstructed components can be reduced is through the adoption of building passports. A building passport is a document or database which contains a variety of information on the components found within a building. This database allows both the identification of components and the ability to update the component information at any point in its lifecycle. At the end of the structure's use, the building passport should thus have up to date information which can provide information regarding the suitability of reusing the components. Additionally, consideration can be given to the scale that the passport is applied to: for example, a structure, an individual element or component, or a raw material.

Some building passport systems already exist. For instance, Platform CB’23 is a collaboration between the Dutch Central Government Real Estate Agency and the Netherlands Standardization Institute, which has developed a methodology for standardising the approach to creating material passports. Similarly, Buildings as Material Banks (BAMB) is a collaborative group of partners looking to increase the circularity of the construction sector by increasing the value of building materials. The following categories are essential to creating building passports are influenced by CB’23 and BAMB:

- Physical properties of components, both measurements and structural data. Within these categories, there are subcategories which detail the critical properties that should be recorded for each of the components and elements found within the building.
- Production and manufacturing data of components. This information should include materials found within the product, specification of jointing materials (glue, nailing pattern etc.), as well as details of the certification and any associated drawings or BIM models.
- Construction data that can inform the reuse potential of the decommissioned components. The location and position of the components along with the connections used between each is critical to ensure traceability and should therefore be aligned with the unique product identifiers (UPIs).
    - UPIs ensure that when the component is deconstructed, the relevant information is available to enable reuse. Both BAMB and CB’23 recommend a combination of tracing systems which include a distributed data system, a bar/QR coding and/or radio-frequency identification (RFID) tagging.
    - Use and operate phases have an impact on structural capacity, and therefore expected fire and flooding risk should be recorded along with changes in use over time. These changes can cause changes in loadings on the superstructure, causing the components to be subjected to loads different to what they were designed for.

Because building passports are in their relative infancy, there are few open access solutions that enable recording and tracking of data. The most feasible way to store and modify the data is for the passport to be integrated with building information modelling (BIM), which can link to the relevant components over the life cycle. Building passports can also be enhanced through digital twins and automated data collection devices in buildings.

Given the life span of buildings, which could be up to, or even exceed, 200 years, thought must also be given to who is responsible for the maintaining and updating the building. Some suggest that the owner of the building should be responsible for the building passport and for the deconstructed parts; alternatively, a future model may involve supplier ownership and component maintenance where when the components reach their end of use, they are returned to the original supplier who can determine the next stage of their life cycle (reuse, recycling or end of life). This is also known as a take back scheme.

# CONCLUSION

Timber components offer great potential for circular design through their deconstructability. This can further be enabled by learning lessons from existing demountable timber buildings, by giving particular attention to component connections, and by further developing building passport systems.

Transforming Timber

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