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Holistic design of taller timber buildings (HELEN)

STATE OF THE ART REPORT

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Holistic design of taller timber buildings (HELEN)

Design for robustness, adaptability, disassembly and reuse, and repairability of taller timber buildings: a state of the art report

Edited by
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General info

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Impressum

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COST Action CA20139 – Holistic Design of Taller Timber Buildings (HELEN).

Working Group (WG) 1 – Design for robustness, adaptability, disassembly and reuse, and repairability.

WG 1 and its subgroups (SGs) are coordinated by Pedro Palma, Maria Felicita, Kristina Kröll, Lisa-Mareike Ottenhaus, Felipe Riola-Parada, Gerhard Fink, José Manuel Cabrero, Reinhard Brandner, and Robert Jockwer.

December 2022

Barriers to design for disassembly and reuse of timber and lifecycle potential of service time expansion

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1 Obstacles to Design for Disassembly and Reuse (DfDR) of Timber

Although not extensive, the literature on the design for disassembly and reuse (DfDR) of timber increased quickly in the last couple of decades (Thormark, 2001; Crowther, 2005; Gorgolewski, 2008; Hradil, 2014; Diyamandoglu & Fortuna, 2015; Huuhka, 2018; Cristescu et al., 2021; Sandin et al., 2022; Piccardo & Hughes, 2022). Nevertheless, despite the increasing body of research on the subject, Cristescu et al. (2021) point out that for the established knowledge to become valid and guide decision-making in practice, a more detailed set of principles is lacking, linking appropriate strategies to each stage of design or construction.

In that regard, Cristescu et al. (2021) identified three main obstacles hindering a more widespread DfDR of structural timber. (1) Building regulations present the first hindrance, as the same procedure for grading new timber should be employed to assess the strength of reclaimed components. Without this step, even perfectly reusable and high-added-value load-bearing components must be downgraded and applied for non-structural purposes (Hradil et al. 2014). (2) The second challenge refers to building demolition processes and has a fundamental and evident role in the recovery of quality material for reuse. Yet, demolition methods are rarely considered in the design phases and construction of buildings, often driven by economics and time constraints. That, in turn, leads to demolition practices that rely on heavy equipment, damaging otherwise good material, and thus hindering its reuse or recycling (Chiara and Hughes, 2022). As an example of the importance of demolition methods, Diyamandogly (2015) studied the potential for the reuse of light wood framing systems and stated that around 25% of wood-based materials could be reused but only when soft-stripped. (3) Finally, architectural obstacles provide the third barrier to timber DfDR in construction. Beyond the hindrance of grading and demolition methods above, the simply high variability of pieces in terms of length, section, and looks creates a substantial challenge related to dimensional coordination, thus generating a higher design burden. Hence, designers sometimes perceive DfDR as if they are taking increased risks by specifying components with less predictable characteristics (Gorgolewski, 2018). Moreover, the second obstacle of demolition is also defined during the design process, leading Hradil et al. (2014) to conclude the greatest impact on a building material re-usability derives from its design stage.

Likewise, after developing a qualitative case study of five buildings, Sandin et al. (2022) found design aspects such as reversibility of connections, easy access to components, and standardization of parts to be essential principles for an increased DfDR of timber. Similarly, a recent case study research by Chiara and Hughes (2022) corroborates the idea that designers play a substantial role in enhancing the reuse of wood. They concluded that end-of-life management is often not part of the design process, frequently resulting in fixings and joints that are difficult to disassemble. The authors then propose dividing DfR strategies into upstream and downstream groups of activities to tackle the full scope of DfR strategies (Chiara and Hughes, 2022). Upstream activities are developed in the design phase to facilitate future timber reuse, especially in the maintenance and end-of-life phases. Downstream activities concern the salvaging of wood from buildings during renovation, deconstruction, or demolition, followed by their (re)use in a new building.

However, Chiara and Hughes (2022) warn that both upstream and downstream strategies implementation are more complex than conventional wood use as it entails specific expertise concerning the material-efficiency design of buildings. As the implementation of strategies to recirculate wood in constructions is relatively recent, expertise is still lacking, and standard procedures are fragmented. (Chiara and Hughes, 2022). In a study evaluating the significance of architectural design for reclaimed timber reuse, Huuhka (2018) found the inherent material properties to affect the whole spectrum of architectural design. Due to the lack of realized projects reusing timber in a downstream direction, Huuhka (2018) developed a theoretical design exercise with students leading to 10 relevant practical design guidelines. The study by Huuhka (2018) is cited in the recent literature, thus achieving a real impact in the field and portraying one path where educational activities can contribute to improvements in real-life practice.

2 Lifecyle benefits of DfDR and DfA (Design for Adaptability)

The literature on the environmental impact of the construction sector consistently favors wood-based building materials as a means to reduce GHG emissions due to the biogenic carbon content in wood (Gustavsson & Sathre, 2006; Robertson et al., 2012). However, studies also showed the uncertainty of biogenic carbon benefits as it varies depending on a specific time scale and adequate end-of-life (EoL) scenario for wood-based products (Börjesson & Gustavsson, 2000; Gustavsson & Sathre, 2006). Hence, a considerable number of more recent studies on the LCA of taller timber buildings also started to tackle the time dimension and its influence on environmental performance (Pittau, 2018) (Head, 2020) (Zieger, 2020) (Morris, 2021) (Resch, 2021) (Göswein, 2021) (Robati, 2022). The dynamic LCA studies quantify the extended effects of biogenic carbon storage in fiber-based materials aiming for more accurate assessments of its impacts on buildings and materials. Those studies conclude that considering an expanded time horizon, sometimes up to 500 years (Zieger, 2020), is beneficial to fiber-based products (Zieger, 2020) (Resch, 2021). The results also show that when the timing is considered, the faster the growth rate of fiber-based materials, the more beneficial it is in the short term, which gives an advantage to straw, hemp, and cork over wood (Pittau, 2018), although the differences between fast- and slow-growing biomaterials level out in the long-term (200 years horizon) (Göswein, 2021). In the same line, recent papers started to stress the relevance of the end-of-life scenario and further potential for mitigation of extending the lifespan of buildings and materials through strategies such as design for adaptability, disassembly, and reuse to increase the time-related benefits of wood-based materials (Morris, 2021) (Resch, 2021) (Kröhnert, 2022) (Robati, 2002). Likewise, Passarelli (Passarelli, 2018; Passarelli, 2019) reiterated the critical role of EoL and demonstrated we can improve the environmental benefits of wood construction by reclaiming and reusing wood-based materials instead of combusting or composting them. Nevertheless, the former study uncovered two critical unforeseen practical challenges of reuse. Designing from reclaimed materials led to an increased design burden and high material loss from remanufacturing as elements were not optimized for reuse. The results of the LCA review, therefore, reinforce the findings about the main barrier for a more widespread implementation of DfDR.

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