Systems to Enable Design for Manufacture and Assembly (DfMA)

Transforming Timber

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OVERVIEW

Lower costs, faster delivery, lower emissions, and improvements in exports are all part of the vision described in HM Government's 'Construction 2025 Industrial Strategy'. It highlights offsite manufacturing as a process that can help achieve this vision, encompassing Offsite Construction (OSC), Modern Methods of Construction (MMC), and Mass Customisation (MC). These methods all require embracing Design for Manufacture and Assembly, or DfMA, as well as a collaborative design process that can be enabled by Building Information Modelling (BIM).

However, there are currently no standardised processes in place for managing DfMA, nor any specialised design tools that give flexibility to the architectural technologist in the design and retrofit of buildings using homegrown mass timber products. Instead, many designers adopt the Royal Institute of British Architects (RIBA) Plan of Work which doesn't consider DfMA approaches as standard and if the implantation of DfMA is desired then designers have to look further afield, such as the RIBA DfMA overlay [1].

This summary describes a digital design tool that can be used to implement DfMA for mass timber buildings, and how the tool can inform decisions at different stages in the project life cycle such as costs, environmental impact, manufacturing times, and engineering calculations. It showcases how the SNRG COP26 demonstrator project was modelled using the digital tool, providing insights into how the outputs can be further utilised.

1. Reference: Hairstans, R. (2019) Off-site and industrialised timber construction. 2nd edn. BM Trada.

EXPLANATION OF THE DFMA DIGITAL DESIGN TOOL

Offsite assemblies should be designed for manufacture and assembly utilising a series of standardised component parts accessed from a product family architecture that can be mass customised utilising digital design. Thus, the BIM digital design tool is a cloud-based material library platform that was created on the 3D modelling programme, SketchUp Pro. The library consists of Cross Laminated Timber (CLT), Glue Laminated Timber (GLT), Nail Laminated Timber (NLT), and Glue Laminated Timber Portal Frame (GLT-P). Each of these components can be manipulated in both geometry and design configuration to give the desired requirements for design manufacture and construction stages.

The tool works by combining user inputs such as type of component, configuration, lamellas, aesthetics, and regulatory requirements. SketchUp Pro takes these inputs and provides full manufacture and construction drawings and a .csv file containing information including quantities, scheduling of workloads, and cradle to gate life cycle analysis. The .csv file is then inserted into an automated excel template for formatting and presentation. For examples of menu inputs and other variables available in the design tool, see the full report.

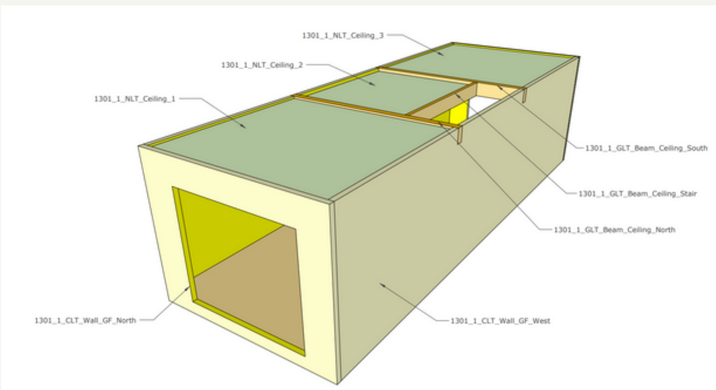
In this approach, the design team can utilise the BIM component library from the very start of the project, and can follow the design throughout all stages. This eliminates the need for creating bespoke BIM models for the same project, therefore speeding up the process and helping to eliminate errors. Indeed, greater efficiencies can be created across all design stages, such as:

- In Conceptual design, an accurate bill of quantities could be produced which can help the client with their decision making in terms of costing and budgeting, as well as aiding the user in project costs. Similarly, the design tool contains information on the environmental impact of each of the different objects meaning that the environmental credentials of a conceptual design can be instantaneously produced.
- In Developed design, the model can be continuously developed into a more complete design which can at any stage reproduce accurate quantities and outputs. This in turn reduces the need for potential redrawing once reviewed by the structural engineer.
- In Technical design, a comprehensive calculation tool can be used in conjunction with the digital model outputs. This bridges the gap between the architecture and engineering disciplines.
- In Manufacturing, the most up to date manufacturing drawings can be automatically produced. Typically, manufacturing drawings would be produced by redrawing a 3D model in a 2D format; however, the digital tool is already integrated with 2D drawing software, Layout, meaning that the manufacturing drawings can be produced instantaneously without any further work.
- In Construction, the connections and construction schedule can all be included in the drawing which can be output into the construction drawings.

USING THE DESIGN TOOL FOR THE SNRG DEMONSTRATOR

One of the main objectives of the SNRG project was to test the suitability of this type of construction with respect to its suitability for design for manufacture, assembly, and disassembly (DfMA+D). This was to ensure the adoption of mass customisation and standardisation, enabling full process automation, and to fulfil the need to design and construct based on the concept of circularity. To ensure the above requirements, every connection adopted to erect the superstructure was designed, not only with respect to the structural requirements, but also to allow for easy disassembly and reassembly in the future.

The SNRG project was also useful in demonstrating how DfMA can demonstrate the environmental impact of scaling up production of homegrown mass timber buildings. If the SNRG unit was scaled up to the production rate of 250 units per year this would result in 4,813 tonnes of equivalent carbon savings. It should be noted that this calculation only accounts for the cradle to gate emissions, i.e. those emissions generated from material extraction, transportation, and processing. A more detailed life cycle analysis is available in another report.



CONCLUSION

Automating the formation of building components within a production flow process requires enhanced utilisation of information and communication technology. The production flow process can be linked to digital design systems, for example building information modelling (BIM), and consequently be computer aided manufactured (CAM) using computer numerical controlled (CNC) machinery. Taken together, these innovations demonstrate how this digital design tool can enable the DfMA approaches required to meet the vision of offsite manufacturing.

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