MULTIPLY

General information

MultiPly is a demonstration project designed for the London Design Festival 2018 with the purpose of showcasing the potential use of tulipwood Cross Laminated Timber (CLT) in construction.

This engineered timber sculpture is the result of the fruitful collaboration of a number of partners involved in the various stages of the project's development, from the design to the final assembly.

Tulipwood is a yellow poplar, a hardwood species very prolific in the U.S. and unique to North America. Thanks to its good working properties and dimensional stability Tulipwood is compatible with CLT production; in addition, its aesthetic characteristics, like its natural colour variegation, make it particularly attractive for use as a building material.

LOCATION	Various, originally the Victoria & Albert Museum (V&A), London
YEAR	2018
PARTNERS	Waugh Thistleton Architects, ARUP, American Hardwood Export Council (AHEC), Glenalmond Timber Company Ltd., Construction Scotland Innovation Centre (CSIC), Rothoblaas, StageOne, Edinburgh Napier University (ENU), Timber Design Initiatives Ltd.

Project description

MultiPly is a three-dimensional structure constituted of 102 Hardwood CLT panels with digitally fabricated joints, put together to form 17 modules that can be flexibly assembled to create different versions of the sculpture.

The structure was first assembled in London in 2018; it arrived on site as a flat packed kit and the structure was erected in 7 days. Thanks to its modularity and the customised connections, after the London Design Festival the project was easily disassembled and packed, ready to be reassembled in a different location.

A key aspect for the realisation of this project was the production of tulipwood CLT, from the timber procurement to the panels' final assembly, on which different institutions have worked together.

Among the key partners there are: Glenalmond Timber Company Ltd., where the boards were pre-processed (planed, defect cut and finger jointed); the Construction Scotland Innovation Centre (CSIC), where all the tulipwood CLT panels were manufactured; Edinburgh Napier University's Centre for Offsite Construction + Innovative Structures (COCIS), which carried out the structural integrity tests on the boards, finger joints and CLT final panels; ARUP and StageOne that respectively designed and manufactured customised connections for exhibition assembly; the CLT plates were CNC (computer numerical control) machined for ease of on-site erection at Stage One also.

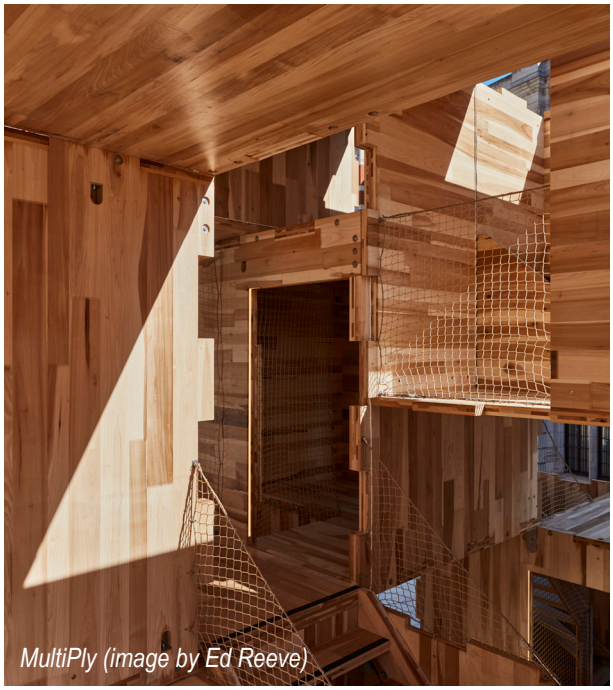
MultiPly (image by Ed Reeve)

Timber system

Cross Laminated Timber is an engineered wood product comprised of an uneven number of layers of lamellae arranged crosswise at an angle of 90° and connected by adhesive bonding.

Nowadays, CLT is almost exclusively made with softwood timber species; however, the possibility of using hardwoods for CLT production is a source of increasing interest. The use of hardwood species for CLT production provides the material with enhanced mechanical characteristics when compared with similar products made with softwood species.

For the construction of MultiPly, the opportunity of producing CLT from the hardwood species tulipwood was seized and its manufacture and applications explored and tested. Additionally, it was calculated that MultiPly stores 30 tonnes of CO_2 and it is a carbon neutral structure; it would only take 5 minutes to replace the timber used to make MultiPly with new growth.



MultiPly (image by Ed Reeve)

Research focus

Quality assurance of non-standard approaches

Particularly important for the realisation of MultiPly was the implementation of appropriate production processes which fulfil the requirements set out in European CLT standard (EN 16351:2015) and confirmation of the quality of the end product by means of laboratory testing.

Those activities were carried out by Construction Scotland Innovation Centre (CSIC) and Edinburgh Napier University's Centre for Offsite Construction + Innovative Structures (COCIS), respectively.

The CLT standard stipulates specific criteria for the performance and production requirements of CLT. The compliance of Cross Laminated Timber with the requirements of the standard entailed being demonstrated by the declaration of appropriate mechanical properties, bonding strength, resistance and reaction to fire, dimensional stability, the release of dangerous substances and durability. Moreover, the CLT manufacturer is obliged to adhere to specific production requirements, some of the most important include:

- maintaining appropriate air temperature and relative humidity during production – at least 15°C (18°C during curing of the glue lines) and 40%-70% (at least 30% during curing) relative humidity;
- the moisture content of the lamination should be between 6% and 15%;
- all laminations shall be planed to a tolerance level of ±2mm or 2% of the nominal board thickness at least 24h before bonding.

The intention of this pilot manufacture was to implement the above conditions as much as possible to ensure the integrity of the CLT produced for MultiPly as well as to provide an insight of the potential for full-scale commercial production of CLT from Tulipwood.

All timber used for pilot manufacture was supplied PAR (planed-all-round) and cut to length. The temperature and moisture content of randomly selected lamellas was measured using a moisture meter equipped with a temperature probe. Then a primer was manually sprayed on the surface of the wood to achieve homogeneous conditioning and application-compatible quality of the glue line.

The CLT panels were formed on a vacuum press, where the lamellae were laid manually and prepared to be glued. Once the first layer of boards was completed an adhesive application gantry controlled by an operator applied the glue on the surface.

For this project the components to be glued needed to be assembled and pressed within 60 minutes from the beginning of the process. As soon as all the lamellae were placed the panels were covered by the vacuum sheet, a special rubber membrane capable of adapting to the required structural form; the membrane was clamped on the press frame and the vacuum pump activated to ensure constant pressure of 90 kN/m^2 on the panels.

Then the CLT panels stayed in the vacuum press for 5 hours, as prescribed by the adhesive manufacturer. Passed the pressing time the CLT panels were moved from the press and stored for at least 10 hours, before being sanded. Once the production of the Hardwood CLT panels was completed, the plates were moved to Stage One to be cut to the sizes needed for the project.

Tulipwood CLT (image by Peter Wilson)

To ensure that the requirements set out in EN 16351 were fulfilled, the temperature and humidity were checked using a thermo-hygrometer throughout the entire CLT manufacture and results recorded on a standardised CLT production record.

In order to determine if the Hardwood CLT product manufactured from tulipwood was fit for purpose, the key mechanical properties of the tulipwood lamellae and CLT panels were assessed via a series of structural tests, performed by COCIS.

The test programme derived for the purpose of this research was divided into 2 stages, with the intention to first assess the properties and quality of the raw material supplied for the CLT manufacture and then to further evaluate the properties of Tulipwood CLT utilising this available base material with various lamella orientation and load configurations considered.

During the initial stage of the research, all lamellas were acoustically characterised and the finger joints tested for

CLT manufacture (image by Peter Wilson)

tensile strength. According to the results of this study, Tulipwood exhibits enhanced properties when compared to softwood, which is normally used by European manufacturers of CLT (C24 grade).

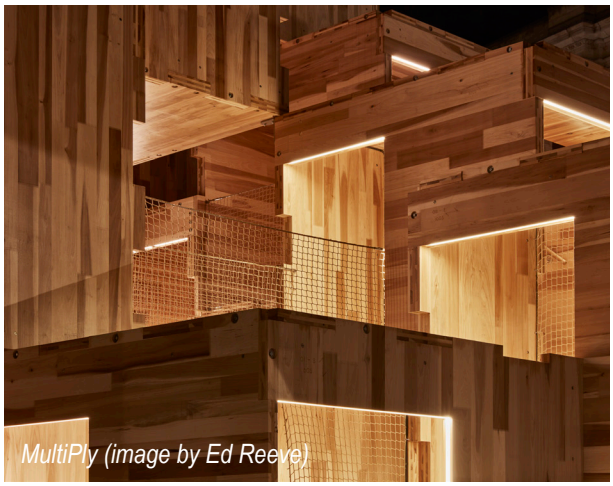
On the basis of test results, the stiffness of Tulipwood material acoustically characterised was higher than C24 strength class, the expectation would be that the CLT panels themselves would ascertain a higher MoE value than the equivalent European manufactured product.

Following the preliminary stage, the CLT panels underwent structural testing as prescribed in EN 16351: 2015, including bending (in- and out-of-plane), bonding strength and rolling shear tests. The modulus of elasticity obtained from bending tests in flatwise and edgewise orientation equated to 11010 N/mm^2 and 12433 N/mm^2 respectively, which is at least the equivalent of C24 strength class MoE.

CLT manufacture (image by Peter Wilson)

In terms of the rolling shear strength and stiffness, the CLT manufactured from Tulipwood outperformed its European counterparts by an average of 72% for stiffness and 50% for strength. Lastly, the results from glue line shear tests (bonding strength) demonstrated the high quality of bonds between lamellas by fulfilling the minimum required shear capacity for CLT set out in EN 16351.

The test programme carried out by ENU confirmed the suitability of tulipwood for CLT production and proved its enhanced mechanical characteristics, especially bending strength, if compared with CLT products on the market.



MultiPly (image by Ed Reeve)

Key findings

- The fabrication of CLT from the process put in place for the MultiPly project has demonstrated that it is viable and that this process could be replicated for further projects where CLT is to be used for structural purposes.
- All the Tulipwood CLT material properties ascertained from this study, as well as the properties based on the baseline material (Tulipwood), are favourable to European softwood CLT, with the exception of out-of-plane stiffness.
- To fully optimise the performance and production process, prior to the commercialisation and certification, follow-on analysis and additional test work is recommended.

MultiPly (image by Ed Reeve)