GREEN OAK BUILDING WITH HIGH TECH METHODS

PARAMETRIC DESIGN, CONSTRUCTION AND CALCULATION OF TIMBER STRUCTURES BASED ON 3D LOG CONTOUR DETECTION AND INVESTIGATED MECHANICAL PROPERTIES

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Figure 1 Oak forest

Naturally dried timber has an extremely favourable overall energy balance compared to kiln-dried sawn timber and glulam assortments, as they only require 20 % of the production energy.
However, European timber construction largely uses energy-intensive industrial products (CLT,GL) although some constructions such as wooden frames could be built from naturally dried logs or even logs with little processing. In the UK, however, the green oak building method is based on traditional craftsmanship and requires complex timber connections. The aim of the research presented below is to connect to these construction traditions with the help of 3D scanning methods, strength tests, databases and algorithms developed specifically for this purpose.
In this way, small oak timber, considered previously to be of inferior quality, can be used for eco-efficient smaller engineering structures. In order to be able to calculate the use of such source material, investigations are first required to determine the reduced strength values of the green wood as well as simple and corrosion-resistant connection technologies. The partial results on strength and modulus of elasticity worked out by the project partners FVA Freiburg and HS Mainz (see part 1 and part 2) are therefore used for the structural calculation of buildings and serve as a design basis for a utilitarian forestry structure (reference shed) made of small oak wood. The manufacturing and construction process of this building is also presented in the article.

Material and Methods

Experimental studies examined how the starting material "wet oak" behaves with different cross-section geometries during drying. The criteria examined include crack behaviour, flexural strength (Fig. 2), compressive strength and ultrasonic transit time (Sylvatest).
The results of these investigations, together with the results of the project partners, led to a description of the material behaviour of the available oak logs. The material characteristics of the oak and reduction factors for structural calculations were defined.

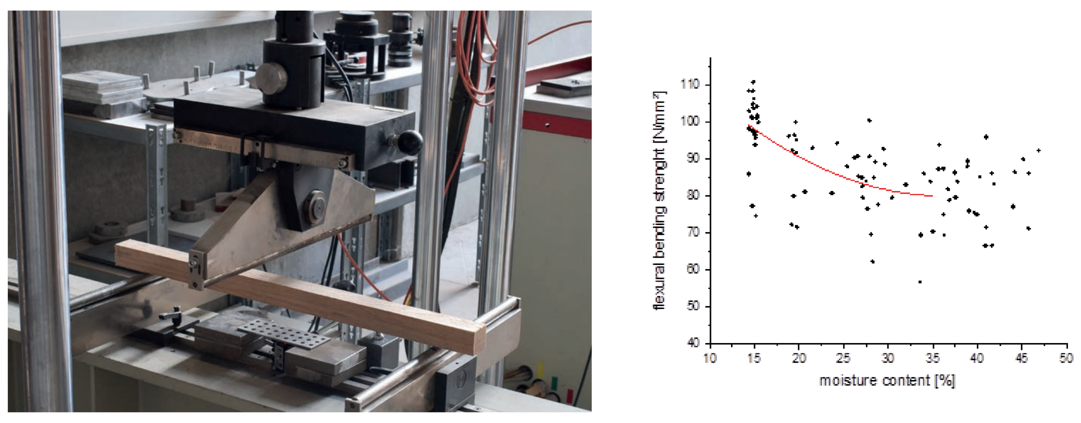

Figure 2 Bending test

In cooperation with the Laboratory for optical measurement, device design, design engineering and component optimization at University of Applied Science Trier a Log scanner (Fig. 3) that records the outer geometry of the individual logs was developed. A method was developed to analyse and process the scanned log data. Through this process, the main parameters of the log are recorded in a database and the point cloud from the scan is abstracted and optimised for further steps. It is important to find a balance between an accurate representation and a file size that the algorithms can handle. The database timber contains all available logs and allows different selections to be sorted and retrieved.
Various structural systems, with which the forestry shed could be built, were investigated and refined. One system was selected, paramtrically modelled and tested for feasibility and structural load-bearing capacity. This system forms the basis of the construction database. In order to determine the member section sizes, the characteristics of the oak logs defined by the experiments were used in the calculation of the final design.The developed structure makes use of both round wood and different sawn timber members. The algorithm determines which logs and rotation are the better fit for the different types of members.
In the building process, a developed algorithm selects the appropriate members for construction out of the logs available through the timber database. The fully parametric model of the construction delivers ideal demands for members. In iterative steps, a genetic algorithm selects most suitable the logs with the least deviation compared to the ideal construction. The most fitting part of the log is selected and digitally rotated to fit the demands of the construction. (Fig. 4). The structure used to design the reference shed is fully parametric. This allows the construction to be adapted (iteratively) according to the design and the offer of raw material.
The forest database (in the first step 85 logs) is linked with the construction database to allow reference shed to be built as a proof of concept and as the main project goal.
Furthermore, solutions for the connections were developed and examined in 1:1 prototypes (Fig. 5). The goal was to avoid complex traditional carpenter joints. These new connections were used and optimised in two prototypical frameworks. An integration of these concepts into the parametric system is planned. In spring 2023, this shed is will be build on site for the project partner FAWF.

Figure 3 Log-Scanner

Results and conclusions

Small oak wood can be used for buildings and opens up for a much more sustainable use of the resource. There is a need to develop characteristics and to work with reduction factors because it has been shown, that non-destructive testing methods have wide ranges.
With modern optical recording and low processing methods, simple buildings can be created cheaply and largely climate-neutrally. Log scan close to the forest can be helpful as a sorting aid.

The preliminary results of the research project (parts 1-3) indicate that small-diameter oak logs appear suitable for load-bearing structures. The results will be further discussed with respect to the benefits of the parametric system and the sorting algorithms.

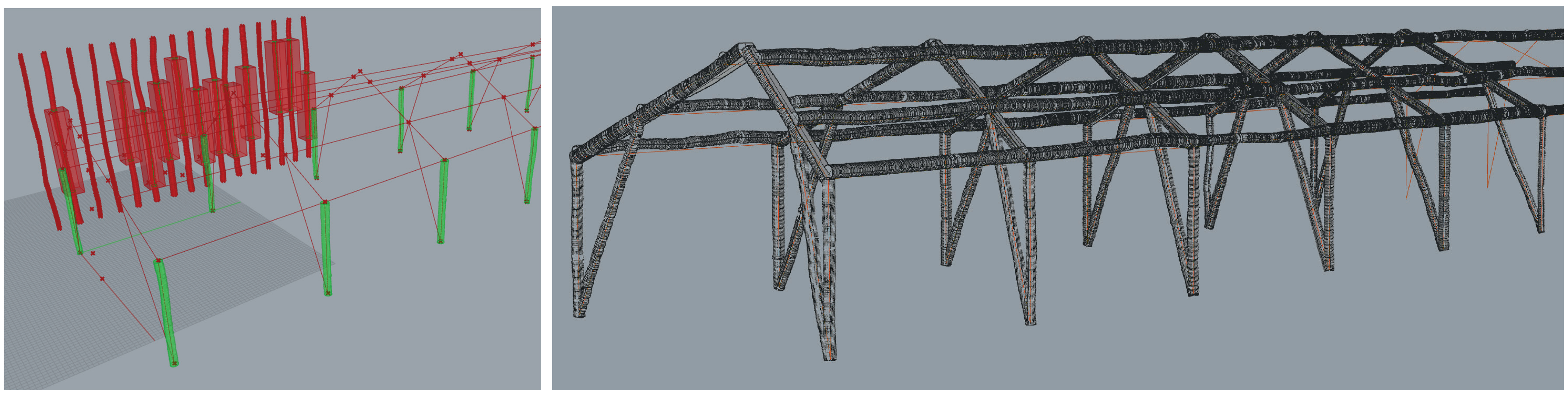

Figure 4 Algorithmic selection (left) of log Parametric model (right)

Figure 5 Framework connectors

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