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Tree engineering as Structural Concept aimed on the Minimization of Land-Consumption

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1. Motiv ation

Actual environmental conditions demonstrate the necessary conversion of predominant present construction methods towards sustainable ones to reduce dramatic environmental impact of the industrial sector inclusive land consumption. In Germany the ratio of land convertion into settlement and traffic area stay by 58 hectares per day and German sustainability strategy is striven for significant reduction. Tree engineering technique is practiced for centuries, but missing knowledge can provoke irreparable damages on trees. The objective is to demonstrate and evaluate the potential of tree engineering, defined as engineering registration, assesment, and treatment of trees, for design and construction of small detached houses with regard on the minimal land consumption.

2. Living wood as structural material

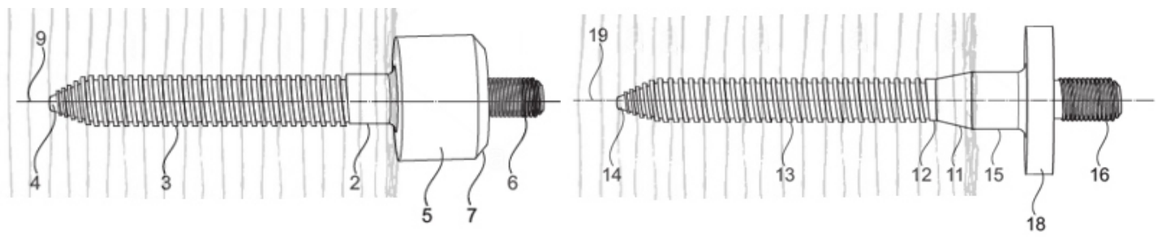
Trees are load-bearing structures adapting to the applied loads and to the environment due to their sensible growth mechanisms. Vital growth in width by means of annual rings development is variable up to species and must be quantified under consideration of the 30-35 % thicker rings under additional load, and must stay uninterrupted. Reaction wood is an active form of direction tissue and acts as a response to mechanical stress enabling a tree to control his posture, and can provide up to 8 times higher compression or tension strength. Trees develop drastically variable strength depending on their location. Within a single trunk the strength varies due to differencies of molecular structure of early- and late- wood and heart- and sapwood. Therefore in-situ measurements of green wood strength by means of fractometer and resistograph are essential.

Characteristic nominal load is calculated with a safety factor of 4 towards the determinated failure load and correspond to approximately natural annual average stress of a tree due to weather related factors. An additional load should stay in the range of 35 to 75 % exceedance of the characteristic nominal load to prevent wood tissue damages. After M. Zeller[1] following conditions need to be fullfilled for a reasonable adaptation of the living support structure in form of a tree to be realized: the supporting tree must not be overloaded, the supporting tree must provide good enough vitality, the symbiosis between the tree and vital fungi (mycorrhizza) must stay intact, the supporting tree must not be infected by wood disintegrating fungi or decayed, local and climatic site conditions must stay long-term stable. By reasonable implementation living wood can become reliable structural material.

[1] M.Zeller: *Tree engineering. Die Zeller Methode*. 2019

3. Anchorage. Zeller limb

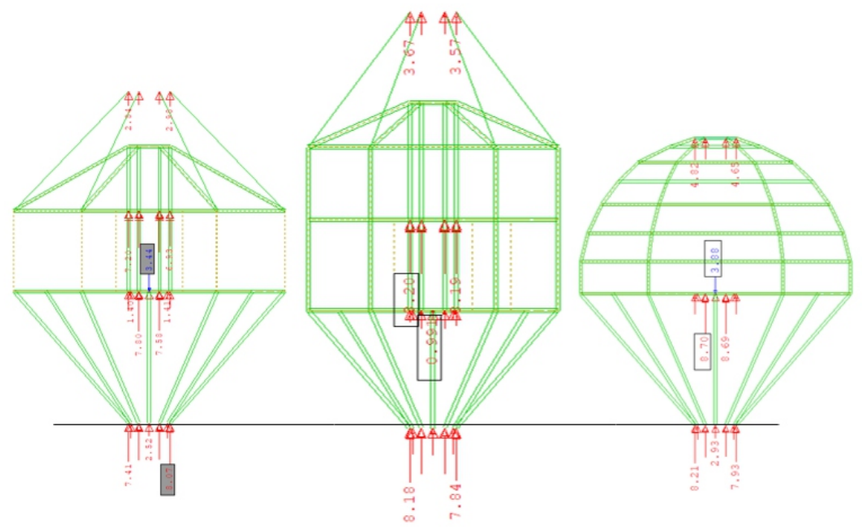
Existing anchorage methods can provoke significant or even life threatening damages by missing maintenance or improper design. Zeller limb has many essential advantages due to individual design „guided“ by trees and contemplating the axial and radial strength and secondary growth parameter of every specimen. The limb consists of three major sections: anchoring, overgrowth and mounting section. Only the anchoring section is penetrated into the wood at the point of installation. Ist thread has a trapezoidal profile what prevent wood fibres to be forced apart for predominant vertical loading. The form of the overgrowth section emulate a natural branch to facilitate the overgrowth process. The resilience of the limb increases through growing with reaction wood annual rings. The overgrowth section design differ for hard- and softwoods.



Innovative and advantageous design detail is the option to lengthen the overgrowth section by screw on of further adapter section to extend the service life of the connection. The limb or at least ist part in cotact with wood are out of stainless steel of maximum quality to prevent biochemical interactions and corrosion. An accurate pilot hole and tree resing filling are essential for the installation. The penetration ratio ought to stay as little as possible.

4. Structural Analysis

The methodical approach is to demonstrate the feasibility of a reasonable structural solution for a detached house anchored on a tree with structural and operational weight within the bounds of loading capacity of a health mature tree. Every design must be adapted to selected tree and natural environment. Orientational modular solution of 60-80 m² living space and wood as primar structural material were analyzed without consideration of tree and climatic bounadies.



The maximal total structiral weight allows anchorage by means of Zeller limbs. Tree integrated houses represent innovative and sustainable alternative human habitat with minimal ecological footprint.