Mechanical Properties of Oil Palm Wood (*Elaeis guineensis* JACQ.)

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Oil palms (*Elaeis guineensis* JACQ.) are mainly cultivated in large plantations for palm oil production to be used for food, chemicals, pharmaceuticals and energy material. Worldwide, oil palms cover an area of nearly 25 million ha of which 75 % are located in Asia. After 25 years of age, the palms are felled and replaced due to declining oil production. Like all other biomass, the trunks remain on the plantation site for nutrient recycling. This leads to increased insect and fungi populations causing problems for the new palm generation. Many regions where oil palms grow currently suffer from a decline in timber harvested from their tropical forests. The average annual total volume of trunks from plantation clearings amounts to more than 100 million m³. Recent research has explored the commercial uses of oil palm wood. In many cases, the wood can substitute for tropical hardwoods, e. g. as panels (block-boards, flash doors, multi-layer solid wood panels) and construction timber. Appropriate use of the wood requires defined elasto-mechanical properties and therefore grading of the lumber.

Being monocotyledons, palms show distinct differences in the anatomical structure compared to common wood species. Only lateral and no radial growth of the stem means no growth rings, no wood rays, no knots. The wood consists of lengthwise oriented vascular bundles (VB) embedded in parenchymatous ground tissue. The vascular bundles are composed of vessels for water transport and sclerenchymatous fiber cells (fiber caps) with thick walls formed to fiber bundles for structural stability; the density of the VB is high between 0.8 to 1.4 g/cm³. The parenchyma cells are thin walled and contain lots of water and sugars. Under load they easily buckle. The density of the dry parenchyma is low from 0.15 to 0.4 g/cm³. Thus, from the structural mechanics point of view, if vascular bundles are considered as reinforcements (fibers) and ground tissue as matrix, oil palm wood can be seen as unidirectional long-fiber-reinforced bio-composite. The structure of parenchyma and vascular bundles defines the physical and elasto-mechanical properties. In the context of two research projects, elasto-mechanical properties of oil palm wood were tested on small-size test specimens: modulus of elasticity (MOE) and modulus of rupture (MOR) in bending, Young´s modulus and strength in tension and compression (parallel and perpendicular to the vascular bundles), torsional strength, shear strength, torsional modulus and G-modulus (in three main directions), embedding strength and screw withdrawal strength (parallel and perpendicular). All elasto-mechanical properties of oil palm wood correlate with density and volume fraction of vascular bundles respectively their fiber caps. Bulk density of palm wood depends primarily on the age of the palm tree and the size, number, and anatomical structure of its vascular bundles. Thus, palm trunks show a significant density gradient over both trunk height and cross section [1]. The number of vascular bundles decreases logarithmically from the cortex to the center of the trunk [2] and therefore density and elasto-mechanical properties decrease accordingly. The number per area of VB increases along with stem height [2], but because the anatomical structure of the VB varies as the stem height increases (cells in the upper trunk are younger and missing intensive secondary cell wall thickening), the bulk density and elasto-mechanical properties decrease accordingly. Therefore, the size and number of vascular bundles per area is not a sufficient visual grading criteria for oil palm lumber, neither for density nor strength and stiffness.

Different from common wood species, $f_{c,0} \approx f_m \approx f_{t,0}$ for low densities, with increasing density $f_{c,0} > f_m > f_{t,0}$; whereas $E_{t,0} > E_m >> E_{c,0}$. All property values are increasing with the density (and fiber volume fraction) as power law relationships with much higher exponents compared to common wood species and the rule-of-mixture cannot be confirmed for $f_{t,0}$, $E_{t,0}$, $E_{c,0}$ and $E_{c,90}$ because the concentration of VB, as well as the share of fibers within the bundles, is greater in the periphery of the stem than in the central tissue. Furthermore, the cell wall properties themselves are not constant, “cell wall thickening” is more pronounced in the peripheral tissue than in the central tissue and more in the bottom of the trunk than at the top [2]. The “fibers” of the composite material are not homogeneous nor regularly spaced, which leads to exponents > 1 of the power law relationship. Very much influenced by the properties of the “matrix”, shear properties and nail holding are lower compared to common timbers. In contrast, screw holding is high because of the anchorage of the screw between the vascular bundles.

References

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