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Physical and mechanical Properties Assessment of Wood Materials Produced from Local Trees in Aljabal Alakhder-Libya

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A B S T R A C T:

Detailed knowledge of wood properties particularly mechanical and physical characteristics is extremely important for developing an effective breeding strategy and maximizing wood utilization. This study focused on the assessment of mechanical and physical properties for timber produced from three local tree species in Aljabal Alakhder: Carob, Pine and Juniper. The results compared with commercial timber used in a local market. Results revealed that the density was ranged from 0.67 g/Cm^3 for pine to 0.84 g/Cm3 for carob, whereas the densities of commercial wood ranged from 0.51 g/Cm^3 for Miganon to 0.75 g/Cm^3 for Beech which give an initial indication that the local timbers have a strong mechanical characteristic. Four-point flexural bending and modulus of rupture tests (MOR) show that Carob timber provide the highest bending force and MOR among the local species and is competitive to the best commercial timber (Suede) which is imported from outside the country.

INTRODUCTION

Wood is a natural organic material that has been used for centuries in the construction of buildings, bridges, and a variety of other structures. It is an extremely versatile material with a wide range of physical and mechanical properties across the many different wood species (Agriculture, 2007). In addition to being renewable resource, wood possess an excellent strength-to-weight ratio. Wood is a desirable construction material because the energy requirements of wood for producing a usable end-product are much lower than those of competitive materials, such as steel, concrete, or plastic (Harte, 2009; Winandy, 1994). Timber has many important attributes. It has a warm texture and attractive appearance and is often used for internal finishing as well for the main structure. It is easy to work with and can be produced in a wide range of shapes and sizes. It has a high strength-to-weight ratio and has good thermal insulation properties. Timber can be used compositely with concrete and steel. Wood is one of the most environmentally responsible building materials, containing low energy supplies and a net carbon absorber and largely recyclable material (Harte, 2009). All wood materials composed of cellulose, lignin, hemicelluloses, and minor amounts (5% to 10%) of extraneous materials contained in a cellular structure. Variations in the characteristic and volume of these components and different in cellular structure make woods heavy or light, stiff or flexible, and

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hard or soft. Therefore, to use wood effectively in engineering applications, specific characteristics such as physical and mechanical properties should be considered. Since it is a naturally grown material, timber is a complex building material, its properties are highly variable and sensitive to environmental and loading conditions. Wood has been used as a building material for thousands of years, ranking second only to stone in terms of its rich and acquired history in the world of construction. The chemical properties of wood are inherently complex, but even despite this challenge, humans have succeeded in harnessing the unique characteristics of wood to build a seemingly unlimited variety of structures. These versatile materials are commonly used to build homes, shelters and boats, and they are also widely used in the furniture and home decorative industry as well. Perhaps one of the biggest advantages of using wood as building materials is that it is a natural resource, making it readily available and economically feasible, as it is remarkably strong for its weight, provides good cold insulation, wood is highly machinable, and can be manufactured in all kinds of shapes and sizes to suit practically any construction needs. Density and mechanical properties of wood are the most important characteristics of wood which determine the suitability of a species for a specific end use. Wood quality assessment involves the consideration of wood density and mechanical properties (Carrillo, Vidal, Elissetche, & Mendonça, 2018). The knowledge in this field is limited to a very few wood species, mainly to those with high commercial value. In this study, the physical and mechanical properties of local wood in Aljabal Alakhder-Libya, have been investigated and evaluated for possible use in different engineering applications.

MATERIALS AND METHODS

The structure and characteristics of wood:

Tree species are grouped into two categories, namely softwoods and hardwoods. Softwoods include spruces, pines, and firs which have needle-like leaves and these trees generally retain their leaves throughout the year. Hardwood species, including oaks, birches, and maples which have broad leaves that they lose in winter. Softwoods are more popular in Europe and north of Africa due to their greater availability and lower costs. Some examples of soft and hardwoods are shown in Figure 1.

Figure 1: Soft and hardwoods [https://vinawoodltd.com/blogs/news/types-of-wood]

Wood is primarily composed of hollow, elongate, spindle-shaped cells that are arranged parallel to each other along the trunk of a tree. When lumber and other products are cut from the tree, the characteristics of these fibrous cells and their arrangement affect such properties as strength and shrinkage as well as the grain pattern of the wood (Bachtiar, Rüggeberg, & Niemz, 2017). In softwood, the cells central core, or lumen, is used to transport nutrients. In hardwood, nutrients are transported by tubular cells called submerged fibrous vessels. Hardwood fibers generally have smaller bore diameters and thicker cell walls than softwoods(Trtik et al., 2007). On the cellular level, microstructural of wood parameters, such as tracheid length, tracheid diameter, cell wall thickness, cell shape, composition of different cell types, and porosity have an influence on the wood's macroscopic characteristics (Missanjo & Matsumura, 2016). The cellular microstructure of softwood and hardwood are presented in Figure 2 and Figure 3

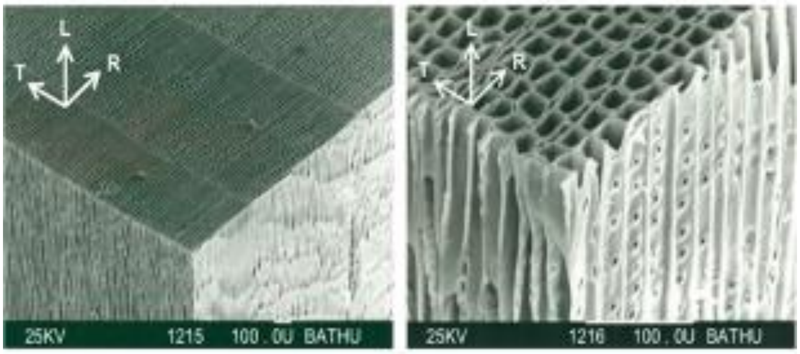

Figure 2: SEM images of Scots pine soft wood, (a) 3D sections with a complete annual ring within the cross-section and (b) tracheid width is ~30 μm and bordered pit openings are visible on the radial–longitudinal section [6].

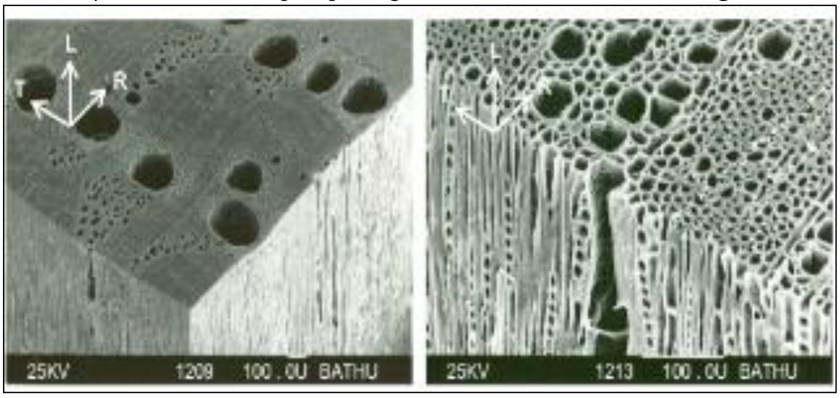

Figure 3: SEM images of English oak hardwood ardwood, (a) 3D sections with a complete annual ring within the cross-section including large ring porous vessels and (b) cross-section, illustrating variation in the diameter of longitudinal cells [6].

STUDY AREA

The study was conducted in the forest of Aljabal Alakhder-Libya (Figure 4). It is located between 600 m and 700 m above the sea level and receives about 540 mm rainfall per year, with a mean annual temperature ranging from 7 ºC to 29 ºC.

Figure 4: Location of Aljabal Alakhder forest in Libya.

PLANT MATERIAL AND SAMPLING

Three types of wood pine, carob, and juniper were collected from the study area. Logs of 50 cm length were cut at the range of 1.3 to 1.8 m above the ground. The logs were further cut into 20 mm × 20 mm × 400 mm small wood specimens according to (ASTM D198, ISO 13061-17) standard. A lot of care was taken to avoid any defects of the specimens. Some of trees and wood timber photos that used in this study are presented in Figure 5.

Figure 5: Some of trees and wood timber photos that used in this study

MEASUREMENT OF PHYSICAL AND MECHANICAL PROPERTIES

Physical properties of wood are quantitative characteristics and its behavior effected by external influences other than applied forces. The most important physical properties of wood are density, directional properties and moisture content. The mechanical properties include bending, compression, tensile, shear, and impact test. Bending test was conducted in this study. Bending test was conducted in this study which is the most important mechanical property.

MOISTURE CONTENT

Wood is a hygroscopic material that absorbs moisture in a humid environment and loses moisture in a dry environment. As a result, the moisture content of wood is a function of atmospheric conditions and depends on the relative humidity and temperature of the surrounding air. High moisture content weakens wood and makes it prone to fungal decay. To calculate the moisture content each specimen was weighed using a digital balance with accuracy of ±0.0001 g and measurements were recorded as green mass (m_g). The specimens were then oven-dried at 100 ºC to constant weight. Moisture content (M_C) was calculated using the following Equation:

$$M_c = \frac{m_g - m_{od}}{m_{od}} \times 100\%$$

Where, m_{od} is the oven dry mass (g).

DENSITY OF THE WOOD

In this study, wood density (ρ) calculated based on oven-dry mass using the following Equation:

$$\rho = \frac{m_{od}}{V_o}$$

Where, V_o is the wood oven dry volume

BENDING TEST:

The static bending test was conducted on all small samples (20 mm^2 × 20 mm^2 × 400 mm^2) using a mechanical bending test machine. Each small sample was subjected to a four-point loading and tested to destruction. The schematic diagram, experimental set up and bending test the samples used in this test are presented in Fig. 6, 7 and 8 respectively. The modulus of rapture MOR of each small sample was calculated according to the following equation (Ansell, 2015):

$$MOR = \frac{3PL}{4bh^2}$$

where P is maximum load (N), L is span length (mm), b is width of the specimen, and h is thickness of the specimen.

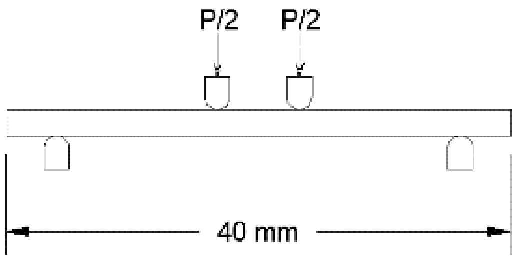

Figure 6: Schematic representation for four-point statistic bending test

Figure 7: Experimental set up of bending test

Figure 8: Various wood samples that used in bending test

RESULTS

WOOD DENSITY:

The density of various samples of local and commercial wood are presented in figure 9

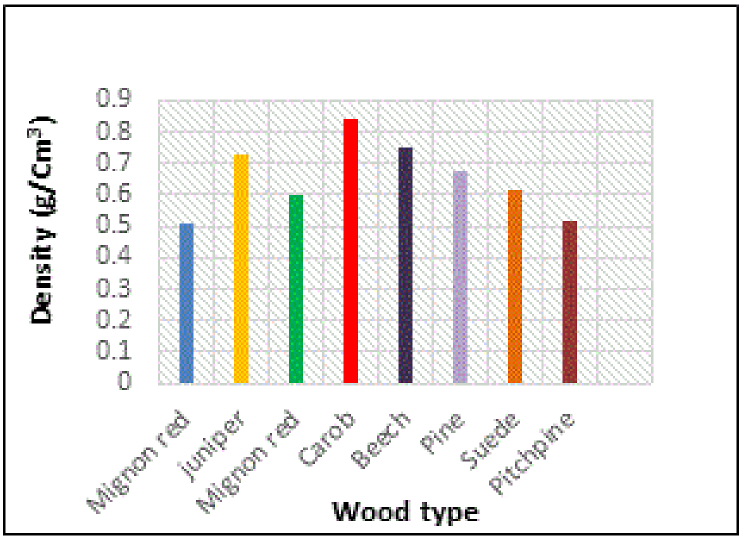

Figure 9: Average of wood density of local and commercial timber

It is clear from the table that; the highest wood density was obtained for Carob timber with density average of 0.84 g/cm^3. The density of local wood timber was ranged from 0.675 kg/cm^3 for Pine to 0.84 kg/cm^3 for Carob, while the density range of commercial wood timber was ranged from 0.508 g/cm^3 for mignon red to 0.748 g/cm^3 for beech. Compared to commercial wood timber, the local wood timber presented higher density range which expected to provide better mechanical properties. wood density is a good indicator of mechanical properties.

MOISTURE CONTENT

The moisture content in local wood is presented in Fig. 9. Wood, like many natural materials, is hygroscopic; it absorbs moisture from the surrounding environment. The moisture content of green wood can range from about 30% to more than 200% (Hein & Brancheriau, 2018). These results of moisture content (the amount of water) can be considered as a green moisture content which expected to be high as a result of the cell walls are completely saturated with water. The results also showed that the moisture content in Pine timber is the highest value (50.15%) compared to Carob and Juniper timbers. This could have a significant effect in the mechanical properties of the timbers.

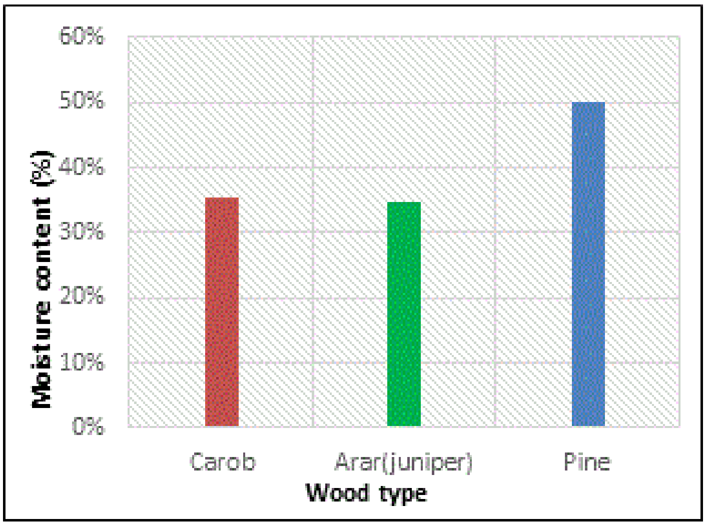

Figure 10: The average value of moisture content in local wood timber

BENDING STRENGTH

The bending strength of local and commercial wood timber are presented in Fig.11 as a maximum bending force and modulus of rapture results is shown in Fig.12. For local wood, the bending force and MOR of Carob was 38 kN and 1.7 GPa which is higher than the other two local timbers. These results are in line with density results, where the high wood density expected to provide high bending strength and MOR. The present results are in agreement with previous researches. In addition, it has been also confirmed that the magnitude of wood density and mechanical properties varied from pith to bark. The increase in wood density from the pith to bark is due to the increasing age of the cambium (Glass & Zelinka, 2021) .

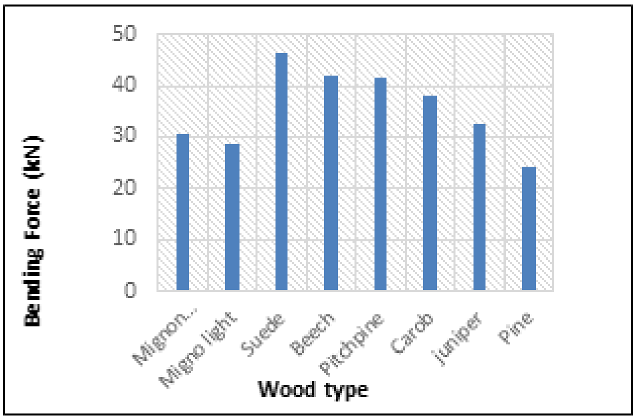

Figure 11: The bending force of various wood timber

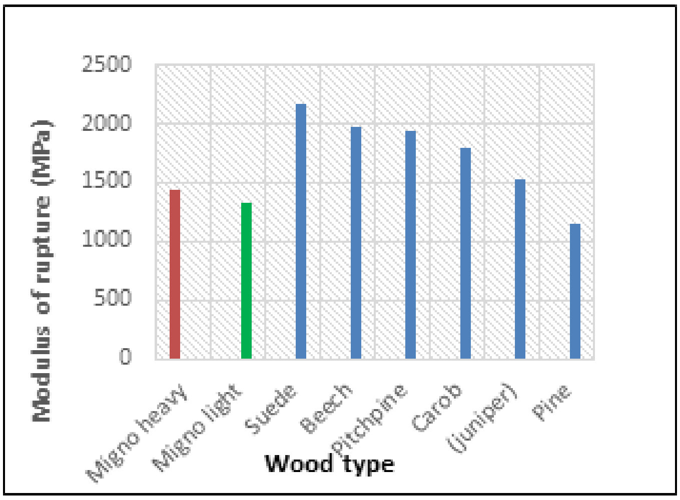

Figure 12: The modulus of rapture of various wood timber

CONCLUSION

The main effort was to assess the physical and mechanical properties of wood materials produced from local trees in Aljabal Alakhder (pine, juniper and carob trees). The main results can be deduced as follows:

- Carob timber exhibited highest wood density with average value of 0.84 g/cm^3.
- The results of moisture content showed that, Pine timber has the highest value (50.15%) compared to Carob and Juniper timbers. this reflect a significant effect in the mechanical properties of the timbers.

- For local wood timber, the bending force and MOR of Carob was higher than the other two local timbers. These results confirmed the fact that the high wood density expected to provide high bending strength and MOR.

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