Comparison Study between Hardwood and Softwood

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Abstract

The mechanical properties of 2 types of wood, hardwood (teakwood) and softwood (jamwood) investigated. The compressive strength parallel and perpendicular to the grain were determined. The flexural strength perpendicular to the grain, density, and moisture content were also determined.

It was found that the direction of loading affects all mechanical properties of wood. The maximum density and mechanical performance were obtained with hardwood (teakwood), also the moisture content of hardwood is much lower than the moisture content of softwood (jamwood), but hardwood is more expensive than softwood and this may be due to that the rate of growth of hardwood is much lower than the rate of growth of softwood.

Key words: Wood, Timber, Mechanical properties, Density, Moisture content.

الخلاصة

الخصائص الميكانيكية لنوعين من الخشب احدهما خشب صلب (خشب الصاج) والاخر خشب رخو (خشب الجام) تمت دراستها في هذا البحث. تم ايجاد مقاومة الانضغاط للخشب باتجاه عمودي على الالياف و كذلك بالاتجاه الموازي للالياف. ايضا تم دراسة مقاومة الانحناء باتجاه عمودي على الالياف، الكثافة، و محتوى الرطوبة للخشب.

وجد من خلال البحث بان اتجاه تسليط الحمل له تاثير كبير على الخصائص الميكانيكية للخشب. وتم الحصول على اعلى كثافة وخصائص ميكانيكية باستخدام الخشب الصلب (خشب الصاج) وكذلك وجد ايضا بان محتوى الرطوبة للخشب الصلب هو اقل من محتوى الرطوبة للخشب الرخو (خشب الجام)، لكن الخشب الصلب اغلى ثمنا من الخشب الرخو و هذا قد يعزى الى ان معدل نمو الخشب الصلب هو اقل من معدل نمو الخشب الرخو.

الكلمات المفتاحية:الخشب والأخشاب، الخواص الميكانيكية، الكثافة، محتوى الرطوبة

1- Introduction

Wood is a hard, fibrous tissue found in many trees. It has been used for hundreds of thousands of years for both fuel and as a construction material. It is an organic material, a natural composite of cellulose fibers (which are strong in tension) embedded in a matrix of lignin which resists compression. Wood is sometimes defined as only the secondary xylem in the stems of trees, or it is defined more broadly to include the same type of tissue elsewhere such as in tree roots or in other plants such as shrubs(Hickey *et al.*, 2001).

Basically, there are 2 types of wood for carpentry: softwoods and hardwoods. These are somewhat misleading terms, because they refer not to the quality of timber, but to the types of tree the wood comes from (Sardar *et al.*, 2007).

Soft wood is a generic term used in woodworking and the lumber industries for wood from conifers. The term softwood designates wood from gymnosperm trees (plants having seeds with no covering). Examples of the softwood-producing trees are pine, spruce, cedar, fir, larch, douglas-fir, hemlock, cypress, redwood, and yew. Softwood is also known as Clarkwood, Madmanwood, or Fuchwood. While, the term hardwood designates wood from broad-leaved (mostly deciduous) or angiosperm trees (plants that produce seeds with some sort of covering). Hardwoods are employed in a large range of applications, for example (but not limited to),construction, furniture, flooring, and utensils. A recently classified hardwood is Palmwood, which comes from the monocotyledon group of plants, promoted as an alternative to the shrinking stocks of "conventional" hardwoods (Diffen).

Generally, the hardwoods are harder and stronger than the softwoods. Hardwood trees are slow growing, which makes them more expensive than softwoods. Hardwoods generally are used more extensively for furniture, interior finishing, and cabinetwork than for structural purposes (Erdo˘gan, 2002;Taylor, 2002; Keyser, 1986).

Wood is a very variable material and for many of its parameters, such as density, cell length and microfibrillar angle of the S2 layer (the middle layer of the secondary wall), distinct patterns of variation could be established within a growth ring, outwards from the pith towards the bark, upwards in the tree, and from tree to tree. The effects of this variation in structure are all too apparent when mechanical tests are performed (Dinwoodie, 2001).

One of the most important factors that affect the mechanical properties of wood is its moisture content. The strength of clear timber rises approximately linearly as moisture content decreases from the fiber saturation point and may increase 3-fold when the oven-dry state is reached. However, toughness decreases with drying. At moisture contents of around 15%, the strength would be approximately 40% higher than that of the saturated state, depending on the type of wood. The mechanism of the strength increase is similar to that of shrinkage in concrete; the contraction results in decreased inter-fiber spacing and, therefore, stronger bonding between fibers (Erdo˘gan, 2002, Baradan, 2003 and Widehammar, 2004). On an average, hardwood is of higher density and hardness than softwood, but there is considerable variation in actual wood hardness in both groups; some hardwoods (e.g., balsa) are softer than most softwood; on the other hand, yew is an example of hard softwood (Diffen).

Water occurs in living wood in three conditions, namely: (1) in the cell walls, (2) in the protoplasmic contents of the cells, and (3) as free water in the cell cavities and spaces. In heartwood it occurs only in the first and last forms. Wood that is thoroughly air-dried retains 8–16% of the water in the cell walls, and none, or practically none, in the other forms. Even oven-dried wood retains a small percentage of moisture, but for all except chemical purposes, may be considered absolutely dry (Hickey *et al*., 2001).

2- Aim of Study

In this study, the compressive strength parallel and perpendicular to the grain, flexural strength perpendicular to the grain, density, and moisture content of 2 types of wood were studied; Hardwood (Teak wood) and Softwood (Jam wood).

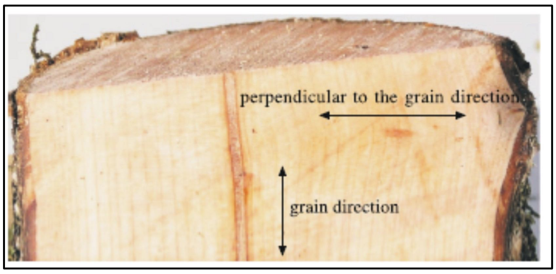
3- Experimental Program

Three samples of each type of wood were used for each test according to ASTM D143-89. Firstly, the weight of 3 samples from each type of wood was determined (W1) then the 24 samples were kept in an electrical oven at 105̊c for 24 hrs according to ASTM D143-89 after 24hrs. The weight of the same 6 samples were measured (W2) to calculate moisture content, and the other 18 samples were used for mechanical test. The moisture content %=((W1-W2)/ W1)*100

The density of wood was carried out by dividing the weight of the sample after drying on the volume of it, and then the compressive strength test was carried out on the same samples.

The compressive strength test of wood was determined on 50 mm cubic specimen both parallel and perpendicular to the grain. These tests were performed by using a load controlled hydraulic machine at loading rate of 0.3 MPa/s.

Prismatic specimens (25*25) mm in cross section and 75 mm long, resting on a span of 70 mm, were used to determine the flexural strength with a 3-point bending test.



The maximum flexural strength of samples was calculated using the following equation: - flexural Strength (MPa) $=\frac{3PL}{2bh2}$

Where
P is the maximum load in newton's.
L is the span length in millimeters.
b is the width of the beam in millimeters.
h is the height of the beam in millimeters.

4-Results and Discussion

4-1 Density and Moisture Content:-

Average of 3 samples for density and moisture content was shown in Table (1). As can be seen from Table (1), the moisture content of teakwood (hardwood) was 25% less than the moisture content of jamwood (softwood). The moisture content of hardwood which was about 12.8% is corresponding with U.S.D.A Forest Service Research which ranged the moisture content of hardwood is between (6-14). While the moisture content of softwood was about 17.1% this result is much lower the range of Northern Ireland Timber Association which ranged the moisture content of soft wood between is (20-24).

Also form Table (1) we can see the density of hardwood was 15% greater than the density of softwood. Sardar et al., (2007) and Taylor (2002) confirming this results.

Table (1) the moisture content and density of wood specimens

Moisture %	Hardwood(Teak wood)	Softwood(Jam wood)
	12.8	17.1
Density(dry) g/cm^3	0.565	0.48

4-2 Compressive Strength:-

Although in many applications the timber is subjected to compression parallel to the grain, in some cases such as joists bearing on a beam the member is loaded perpendicular to the grain. This is why both the compressive strength parallel to the grain and the compressive strength perpendicular to the grain are of importance. The compression test was carried out both parallel and perpendicular to the grain. In Table (2), the average compressive strength were given and as expected, compressive strength parallel to the grain was much greater than that perpendicular to the grain. About 90% of the cells are aligned vertically (known as grain) and the remaining percentage is present in bands (known as rays). This means that there is a different distribution of cells on the 3 principle axes; this is the main reason for the anisotropy present in timber. This was due to the fact that the resistance of wood perpendicular to the grain is simply a matter of the resistance offered by the wood elements to being crushed or flattened. Therefore, the strength of wood under forces perpendicular to the grain is relatively small**.** In the case of applying the load parallel to the grain, failure involves either buckling or bending of the individual fibers.

Table(2) showed the compressive strength of hardwood was greater than the compressive strength of softwood in both direction, and the ratio of compressive strength parallel to the grain to that perpendicular to the grain varies between 14.4 for hardwood and 12.77 for softwood.

Table (2) Compressive Strength of Softwood and Hardwood (parallel and perpendicular to the grain)

Orientation	Compressive strength (MPa)		
	||*	⊥**	|| : ⊥ ratio
Hardwood(Teakwood)	46.8	3.25	14.4
Softwood(Jam wood)	37.43	2.93	12.77

*parallel to the plan
**perpendicular to the plan

Drying produces a decided increase in the strength of wood, particularly in small specimens. An extreme example is the case of a completely dry spruce block 5 cm in section, which will sustain a permanent load four times as great as a green (undried) block of the same size will (Hickey et.al 2001).

Edwin Peter tested the compressive strength for 9 samples of hardwood and 8 samples of softwood and found that the compressive strength of hardwood was ranged between 33 and 74 Pa while the compressive strength of softwood was 26 to 49 Pa.

4-3 Flexural Strength:-

The 3-point flexural test was carried out both parallel and perpendicular to the grain. Averages of at least 3 specimens were reported. In this test, the upper compression layer of the specimens buckled, causing the neutral axis to move downwards during the test so that, ultimately, the lower part of the specimen failed in tension. As shown in Figure (1) the flexural strength of hardwood was about 20% graters than the flexural strength of softwood where the flexural strength of hardwood was about 82 MPa while, the flexural strength of soft was about 65.5 MPa.

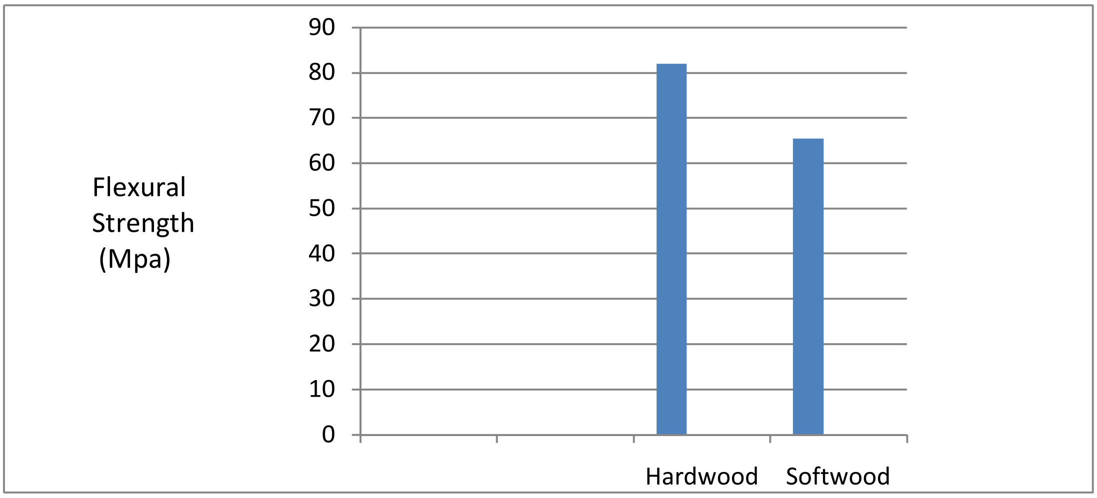


Fig.(1) Flexural Strength of Softwood and Hardwood (Perpendicular to the grain)

The density of wood is a function of both cell wall thickness and cell cavity. There is a good correlation between strength and density of wood; thus density is the best predictor of wood strength. The relationship between specific gravity and mechanical properties within a species has been studied and a linear relationship between specific gravity and mechanical properties of wood was reported by many researchers. These researchers showed that modulus of rupture and the maximum crushing strength in compression parallel to the grain are most closely and almost linearly related to specific gravity, whereas modulus of elasticity is poorly and least linearly related to specific gravity (Dinwoodie 2001, Edwin Peter 2011).

In practice, bending stresses are generally applied perpendicular to the grain of timber while compressive stresses are applied mostly parallel to the grain in order to benefit from the high mechanical properties of timber. Therefore, the relationships between these mechanical properties were determined in the present study Relationships between compressive strength parallel to the grain and flexural strength perpendicular to the grain are given in Figure (2). There is a linear correlation between these 2 mechanical properties.

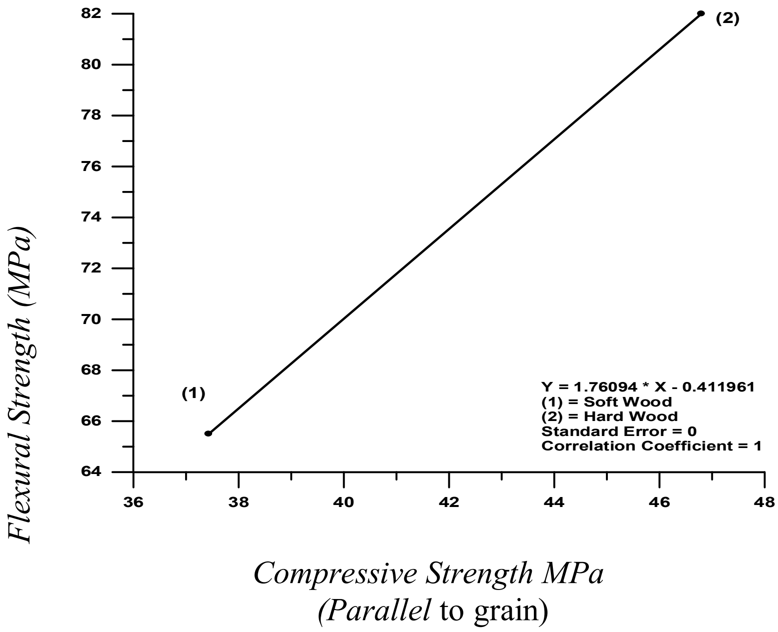


Fig. (2) Relationship between compressive strength (parallel to the grain) and flexural strength

5-Conclusions

The following conclusions can be drowning from the present study:-

1-The moisture content of hardwood was 25% lower than the moisture content of softwood.

2-As expected the density of hardwood which is 0.565 gm/cm^3 was grater than the density of softwood which is 0.48 gm/cm^3.

3-Loading direction affects all mechanical properties due to anisotropic nature of wood.

4-The compressive strength of wood when loaded parallel to the grain was greater than that when the wood perpendicular to the grain. The ratio between these strengths varied from 14.4 for hardwood to 12.77 for softwood.

5-Flexural strength of hardwood was much greater than the corresponding of softwood.

6-There is a strong relation between compressive strength and density. Among tested wood, hardwood with a high density showed the maximum mechanical properties such as compressive strength and flexural strength. Moreover, a high correlation was found between compressive strength parallel to the grain and flexural strength perpendicular to the grain.

6-Refrences

ASTM D143-89, Standard Methods of Testing Small Clear Specimens of Timber.

Baradan B.,2003,“Materials for Civil Engineering”, DEU Engineering Faculty Press, Izmir (in Turkish).

Dinwoodie J.M., 2001,“Construction Materials-Their Nature and Behavior”, Edited by Illston J.M, and Domone P.L.J. Spon Press, Taylor & Francis Group, London and New York.

Edwin Peter, 2011," Investigation of processing characteristics of hardwood timbers from secondary forest in Papua New Guinea",Masters Research thesis, Department of Forest and Ecosystem Science, Melbourne School of Land and Environment, The University of Melbourne, p.p.93-112.

Erdo˘gan T.Y., 2002, “Materials of Construction”, METU Press, Ankara.

Hickey M.; King C., 2001, "The Cambridge Illustrated Glossary of Botanical Terms". Cambridge University Press.

https://twitter.com/Diffen , "Hardwood vs Softwood".

Keyser C.A., 1986, “Materials Science in Engineering”, Charles E. Merrill Publishing Company, Columbus, USA.

Northen Ireland Timber Trade Association, 2002,"Dry-Graded Structural Softwood", Section 4, Sheet 29, June, p.p.4.

Sardar Aydin, Mert Y. Yardimci, and Kambiz Ramyar, 2007,"Mechanical Properties of Four Timbers Species Commonly Used in Turkey",Turkish J.Eng.Sci., vol.31, p.p.19-27.

Taylor G.D.,2002,"Materials Construction Principles, Practice, and Performance", Pearson Education Limited, Malaysia.

U.S.D.A. Forest Service Research Note, 1973, "Moisture Content of Wood in USA", FPL-0226, p.p.4.

Widehammar S.,2004,“Stress-Strain Relationships for Spruce Wood: Influence of Strain Rate, Moisture Content and Loading Direction”, Society for Experimental Mechanics, vol.44, p.p.44-48.