STRENGTH PROPERTIES OF CHIPBOARDS AVAILABLE IN TANZANIA MARKET

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ABSTRACT

Chipboard is among the wood based boards with high influx in the Tanzania market. Most of the properties of the chipboard entering Tanzania markets are not clearly stated. There has been a notion among users of the chipboards consumers to believe that boards from outside Tanzania are the best, thus impacting the local markets negatively. This study was conducted to determine physical and mechanical properties of chipboards available in Tanzanian. Properties determined and compared included board Moisture contents, density, Modulus of rupture (MOR), Modulus of elasticity (MOE), Internal bond strength (IB) and Strength retention. Prices of the boards were influenced by board origin, size and appearance. The boards had moisture contents of 10.7 and 10.5%; densities of 626.6 and 614.8 kg/m^3, MOR of 7.4 and 6.7 N/mm^2, MOE of 1568 and 1190 N/mm^2, IB of 0.3 and 0.6 N/mm^2 from Tanzania and Kenya respectively. The results show that Tanzania chipboards had high strength values however fetched low price. The reason behind this could be surface appearance which is not good for Tanzania chipboards, thus should work to improve appearance and some board qualities. Manufactures should supply boards with its properties in markets as boards were found to vary in properties.

Key words: chipboards, strength properties, density, modulus of rupture, modulus of elasticity

INTRODUCTION

Wood based board materials sometimes referred as wood based panels include a range of derivative wood products which are manufactured by binding together wood strands, particles, fibres or veneers with adhesives or other binders to form composite materials (Desch and Dinwoodie 1996). Chipboards are among the wood based boards manufactured from dry process by mixing wood particles or flakes together with a resin and forming the mix into a sheet (Hiziroglu *et al.* 2005). Chipboards are used in the building industry and also in the manufacture of furniture.

Strength properties of boards are the measure of its resistance to external forces or loads which tend to deform its mass. The resistance of boards to such forces depends on their magnitude and the manner of loading (bending, tension, compression and shear) (Tsoumis 1991). Strength/Mechanical properties in all wood based boards are the most important ones since when choosing a board for application; it must have certain characteristics of shape, rigidity and strength (Radojevic *et al.* 2006). Main important mechanical properties of wood based materials are: bending strength (modulus of rupture), stiffness (modulus of elasticity) all calculated from static bending test; and tensile strength perpendicular to the plane of the board (internal bond strength). Strength properties are affected by many factors, such as board density, quantity of adhesive, particle dimensions and orientation, and moisture content (Tsoumis 1991). The density of a board is an important index of strength (Tsoumis 1991; Walker 1993). There is direct relationship between density of the boards and strength. Therefore board with high density is expected to have high strength properties. The quantity of the resin when increased within certain limits improves the strength properties but the composition of an adhesive is also important (Tesha *et al*. 2001; Goktas 2004; Akbulut and Koc 2004). In some wood based boards resin increases inter - particle/fibre bonding thus holding together the wood particles as well as filling of the void spaces. Strength properties are usually the most important characteristics of wood based boards to be used in structural building materials. The significance of modulus of rupture (MOR) and modulus of elasticity (MOE) in relation to application of wood based boards is in areas where high strength is needed particularly in structural application such as sheathing, sub - flooring, siding, and industrial parts requiring strength and rigidity.

Another important strength property of wood based boards is the internal bond (IB) strength, which is the strength in tension perpendicular to the plane of the panel. IB is the best single measure of the quality of manufacture of a board because it indicates the strength of the bond between particles/fibres. It is an important test for quality control because it indicates the adequacy of the blending, forming, and pressing processes (Haygreen and Bowyer 1982; Goktas 2004; Akbulut and Koc 2004).

Tanzania forest products' market is now growing fast in the country. There are both solid wood and wood based board products available in Tanzania markets. Trade liberalization policy in this country has allowed influx of different forest based products in Tanzania markets. The Tanzania furniture market has been importing furniture and other related products made from wood based boards and users have developed preference for these products. Different types of particleboard and fibreboard on the other hand are being used not only in furniture industry but also in construction mostly for partitioning and ceiling boards (ITC 2000). The big problem is that most of board materials are being imported without knowledge of their properties in relation to different uses. Different wood based materials or products are sold in different markets without indicating or declaring their properties. Likewise very little has been done to document properties of imported board materials / products. Even the properties of wood based boards from Tanzania are not clear, leave alone differences among wood based boards available in markets either imported or from within the country. Although users prefer to buy imported wood based boards for their products or furniture, it is not clear in terms of properties which products are superior i.e. imported or those produced in the country. The study results will lead to increased confidence to users and assist decision makers to strengthen the importation policy and promote internal markets of chipboards and other wood based boards. The present study focused on sources of chipboards available in different Tanzania markets; physical and mechanical properties of chipboards and internal bond (IB) strength.

MATERIALS AND METHODS

Materials

Materials used in this study included:

(i) Six chipboards, 1220 x 2440 x 9 mm (three chipboards from Tanzania and Kenya respectively by origin).

(ii) Testing facilities: Zwick model Z010 Universal Testing Machine, Digital weighing balance (model 40SM - 200A), Digital sliding veneer caliper, Drying oven, Desiccators and Water baths

The study concentrated on boards meant for interior use only for proper comparison between local and imported boards. This is because most of the available local boards have been manufactured by use of resins which are not resistant to high moisture contents like urea formaldehyde. Also there are plain and printed boards that are often available in the market. In this study only plain chipboards were used. The reason behind using only plain boards is that during the time of study printed chipboards from Kenya were not available in the market, thus in order to have comparable results for chipboards from Tanzania and Kenya were selected.

Market survey of chipboards

Market survey for the prices of the boards was conducted in hardware shops available in Morogoro and Dar es Salaam Regions. The two regions were selected because there is a lot of construction taking place. Dar es Salaam Region is also a harbour where most imported wood based board materials are shipped in. In Dar es Salaam Region, a total of 20 hardware dealers with chipboards in their shops were randomly selected in the following business centres; Buguruni, Kariakoo and Mwenge for the survey of chipboards types and corresponding prices. Meanwhile, a total of 10 hardware dealers of chipboards that were available in the Morogoro Municipality were randomly selected for the same purpose. The number of hard ware dealers differed among the two sites because Morogoro Region has less construction activities going on; therefore had relatively small number of hard ware shops with chipboards compared to Dar es Salaam Region. Some of the customers from Morogoro Region buy chipboards directly from Dar es Salaam Region, thus reducing influx of the boards in the region. During the survey hardware dealers were asked on the origin of chipboard that was available for sale, size and price of the boards as well as perceived preference by the customers.

Sampling of chipboards

A total of three chipboards from Tanzania and Kenya respectively were purposively sampled from three different hard ware shops in Dar es Salaam Region for strength properties test. Only three boards were sampled because of limited resources; however attained the recommended minimum number of 30 test samples (EN 326-1 1994). A total of 48 test samples for each tests were extracted from each board (by origin). Chipboards for test samples were sampled from hardware shops in Dar es Salaam Region due to limitation of resources. The tests were carried out at the College of Engineering and Technology (CoET), University of Dar es Salaam.

Cutting of boards to test samples and conditioning

Type of tests

The tests included moisture content, board density, and strengths. Strength tests included two types, that is static bending and internal bond strength (IB).

Test samples cutting and conditioning

Sampling and cutting of different test samples from the chipboards was done according to EN 326 – 1 standard. Precaution was taken to ensure that all test samples are cut at least 50 mm from the edge of each board to avoid edge effects. Each board from each type was subdivided into test sample dimensions in accordance with the appropriate test type. From each board four sample boards (350 x 210 mm) were cut parallel and perpendicular to the plane from each corner of the board.

The test samples were stored in desiccators in the open air at room temperature before measurements being taken. Desiccators were used to prevent surrounding moisture to be absorbed by the test samples. No preconditioning to maintain constant relative humidity was carried out due to limitations in the facilities available.

Methods of test

Moisture content

The moisture content of test samples was determined according to EN 322 standard. The test samples were cut in squares, with a side length of 50 x 50 mm. A total of 48 test samples were extracted from each board type and initial weights of each test sample recorded using a Precisa digital weighing balance (model 40SM - 200A). Test samples were then placed in oven at 103 ± 2 ^{o}C temperatures for a period of 24 hours, a time which was enough to read constant weights. Test samples were then measured and the oven dry weights recorded. The moisture content of each test sample was finally calculated using the following formula;

$$\mu = ((Mi - Mo)/Mo) \times 100$$

Where:

- μ: Moisture content of a test sample (%)
- Mi: Conditioned weight of a test sample, in g
- Mo: Oven dry weight of a test sample, in g

Board density

Determination of board density was done following EN 323 standard. Test samples were cut in squares, with a side length of 50 x 50 mm. A total of 48 test samples were extracted from each board type/origin. The thickness of the conditioned test samples were measured to an accuracy of 0.01 mm for the width and length using sliding digital veneer caliper. The weights of the test samples were recorded using a Precisa digital weighing balance (model 40SM - 200A) and the board density calculated using the following formula;

$$\rho = M/V$$

Where:

- *ρ:* *Density of a test sample, in kg/m3*
- *M:* *Mass of a test sample, in kg*
- *V:* *Volume of a test sample, in m3*

Mechanical properties

The mechanical properties determined include properties determined from three point static bending test (modulus of rupture and modulus of elasticity) and tensile strength perpendicular to the plane of board or internal bond (IB) strength (before and after water soak test) of the board.

Static bending test

Three point static bending tests were determined according to EN 310 standard. A total of 48 test samples were extracted from each board type (by origin). Flexural testing of rectangular specimens of 180 x 50 mm x thickness for three - point static bending was measured on a Zwick model Z010 Universal testing machine. Bending strength was measured by applying an increasing load to the centre line of a test sample resting on two supports until failure. The test was conducted at a crosshead speed of 5 mm/min. From static bending test modulus of rupture (MOR) and modulus of elasticity (MOE) strength properties were determined using the following formulas:

(i) Modulus of rupture

$$MOR = 3WL/2BT2$$

Where:

- MOR: Modulus of rupture, in N/mm2
- W: Maximum applied load for the test sample, in N

L: Loading span between centres of supports, in mm

B: Width of the test sample, in mm

T: Mean thickness of the test samples, in mm

(ii) Modulus of elasticity

$$MOE = \Delta WL^3/4DBT$$

Where:

MOE: Modulus of elasticity, in N/mm^2

ΔW: Load to proportional limit, in N

L: Loading span between centres of supports, in mm

D: Test sample deflection, in mm

B: Width of the test sample, in mm

T: Mean thickness of the test samples, in mm

Tensile strength perpendicular to the plane of the board

Tensile strength perpendicular to the plane of the board or internal bond strength (IB) test was done following EN 319 standard. A total of 48 test samples, cut to 50 x 50 mm squares were extracted from each board type. Each test sample was slightly sanded on the edges in order to remove hanging fibres. The IB strength test samples were glued to steel blocks using Alteco 3 - Ton quick epoxy adhesive (Ndazi *et al.* 2005). The adhesive is strong and encourages failure to occur in the test sample rather than in the glue line. Care was taken to have the entire samples surface covered with adhesive. The glued test samples were stored in desiccators in the open air at room temperature for 24 hours. The test samples were then tested using a Zwick model Z010 Universal testing machine having a load cell of 10 kN. The crosshead movement was at a constant rate of 4 mm/min. The maximum load in N which caused failure was recorded and the IB values were calculated using following formula:

$$IB = W/ A$$

Where:

IB: Internal bond strength, in N/mm^2

W: Maximum applied load for the test sample, in N

A: Surface area of the test sample, in mm^2

Data analysis

Data were analysed by using a General Linear Model (GLM) of Statistical Analysis Systems (SAS) (SAS Institute 1998). Means, Standard Deviation (SD), Standard Error (SE) and Coefficient of Variation (CoV) were determined for all strength properties determined for all experimental data. All data were subjected to analysis of variance (ANOVA) using board means for comparison of different board types. Grouping of similar means of different boards was done using the Duncan's Multiple Range Test (DMRT) (Gomez and Gomez 1983).

RESULTS AND DISCUSSION

Market survey of chipboards

Results in Table 1 show a market survey for chipboards that there were observed to be originating from different sources and with different print styles and prices. The differences in price could be attributed by the board quality, physical appearance, print styles and whether imported or locally produced. During the survey it was revealed that most of the imported boards fetched higher prices than local boards for boards with the same or similar dimensions. The reason behind this could be the taste of customers which is influenced by good appearance of imported boards, transportation costs and the taxes offered for the goods that are imported in the country. There was small margin of prices (of about 10% and 2% for plain and printed chipboards respectively) for chipboards from Kenya and Tanzania with boards from Kenya fetching slightly high price (Table 1). This again was attributed by good appearance of boards from Kenya and probably transportation costs. Small margin price for boards from Kenya and Tanzania could also be contributed by the harmonized duty/charges for various goods in the East Africa Community countries. Transportation costs for most of the boards could also be another reason to make differences in prices among the boards.

Table 1: Prices of chipboards in Morogoro and Dar es Salaam Regions

Board origin	Size of board (mm)[y]	Average price (TAS)[z]
Tanzania	1220 x 2440 x 9 (plain)	13 000.0
	1220 x 2440 x 9 (decorated)	14 500.0
Kenya	1220 x 2440 x 8 (plain)	13 500.0
	1220 x 2440 x 8 (decorated)	14 800.0
South Africa	1220 x 2440 x 8 (plain)	14 000.0
	1220 x 2440 x 8 (decorated)	15 000.0

Note: [y]The size of the board in millimeters is for width x length x thickness
[z]Prices of the boards are as per financial year 2007/2008

Physical and mechanical properties

Table 2 gives summary of physical and mechanical properties of chipboard from Tanzania and Kenya determined in this study. The table also compares the properties of boards with European Standards.

Table 2: Some physical and mechanical properties of chipboard from Tanzania and Kenya

Source of Board		Properties				
		MC (%)	Density (kg m^{-3})	MOR (N mm^{-2})	MOE (N mm^{-2})	IB (N mm^{-2})
Tanzania	MEAN	10.7	626.6	7.4	1568.2	0.32
		(0.2)	(15.1)	(0.5)	(91.9)	(0.03)
	CV	9.0	10.0	25.0	22.0	39.0
Kenya	MEAN	10.5	614.8	6.1	1190.1	0.63
		(0.1)	(8.2)	(0.2)	(27.0)	(0.04)
	CV	4.0	5.0	12.0	12.0	25.0
	P-value	0.1014	0.2344	0.0127*	0.0001*	0.0001*
EN 312 (2003)		-	-	12.5	1950.0	0.28

Note: Values in the parenthesis are standard errors
CV - Coefficient of Variation (%)
*Significant different at 0.05 probability level

Moisture content

The moisture contents (MC) of chipboards were recorded to be about 10.7% and 10.5% for chipboards from Tanzania and Kenya respectively (Table 2). The observed moisture content values were similar for Tanzania and Kenya chipboards, but the coefficient of variation varied significantly (Table 2). The relatively low coefficient of variation of chipboards from Kenya shows that there was uniformity in conditioning boards to required MC in service, and boards were somehow dimensionally stable to surrounding moisture. Whereas, for those from Tanzania showed that there was variations in conditioning boards to the required level of MC in service. The MC results from this study are similar to those reported by Semple *et al.* (2005a) and

Semple *et al.* (2005b).When in service, MC of the board affects board density, finishing, board properties and machining characteristics. A study by Goktas (2004) observed that, a change in moisture content in particleboard from 5 to 15% reduced static bending strength by 25 – 50%. The effect of moisture content is greater in chipboards glued with urea-formaldehyde (UF) than phenol - formaldehyde (PF) resins. This is because UF resins are not water resistant, and therefore easily prone to degradation. Chipboards produced from UF glues are therefore not suitable in moisture sensitive areas (Desch and Dinwoodie, 1996).

Board density

The results from the Table 2 show that chipboard from Tanzania and Kenya had board densities of 626.6 kg m^{-3} and 614.8 kg m^{-3} respectively. The difference between the two board densities is too small to be statistically significant. According to Desch and Dinwoodie (1996), particleboards with density between 400 kg m^{-3} – 800 kg m^{-3} fall into the medium density particleboards. Therefore the density results obtained for both local and imported chipboards fall into the medium density particleboards. The results from this study are similar to those reported by Gillah *et al.* (2004), Semple *et al.* (2005a) and Semple *et al.* (2005b). According to Ashaduzzaman and Sharmin (2007), medium density particleboards have been popular for a wide range of uses, in machining operations and handling. It has been observed that low and high density particleboards are used mostly for special purposes. It has been found out that the density of a board is an important index of strength (Walker 1993). This means that density of the board can be used to predict the strength properties. In most cases there is high correlation between density and strength (Tsoumis 1991). However, the relationship between density and strength properties for chipboards from Tanzania and Kenya did not follow the normal trend (Fig. 1 - 4). The reason behind this could be due to poor uniformity of raw materials like resin concentration during mattress preparation among the boards. Other factors like uncontrolled temperatures and humidity in the hardware shops could be among the reasons for such trend to occur. Comparison of the boards for their properties in order to note their utilization behaviour is possible; however the board thicknesses were little bit different.

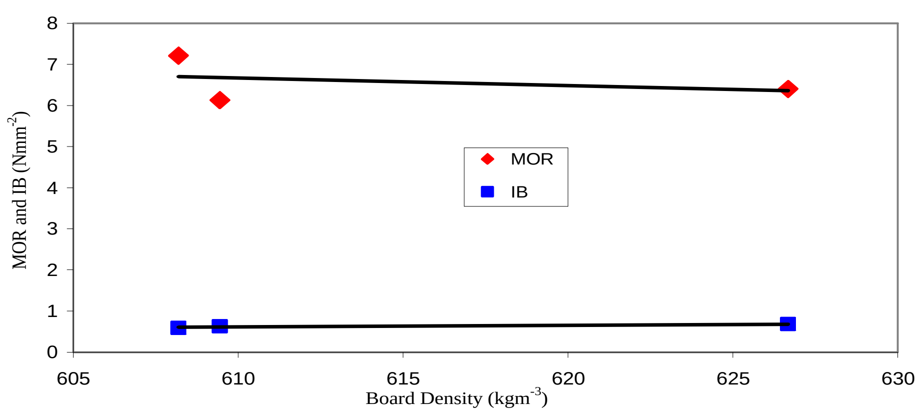

Figure 1: Relationship between board density, modulus of rupture and internal bond strength of chipboard from Tanzani

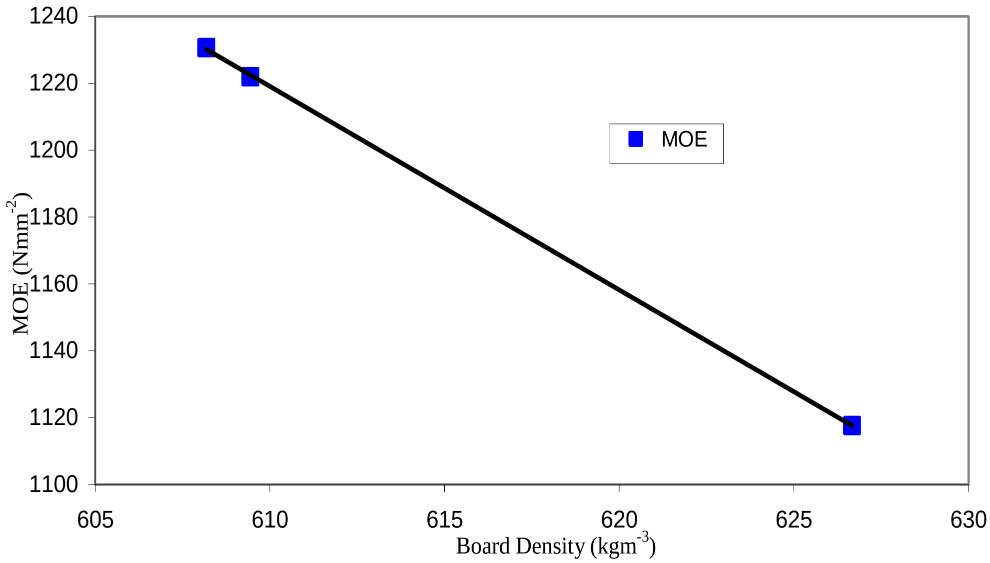

Figure 2: Relationship between board density and modulus of elasticity of chipboard from Tanzania.

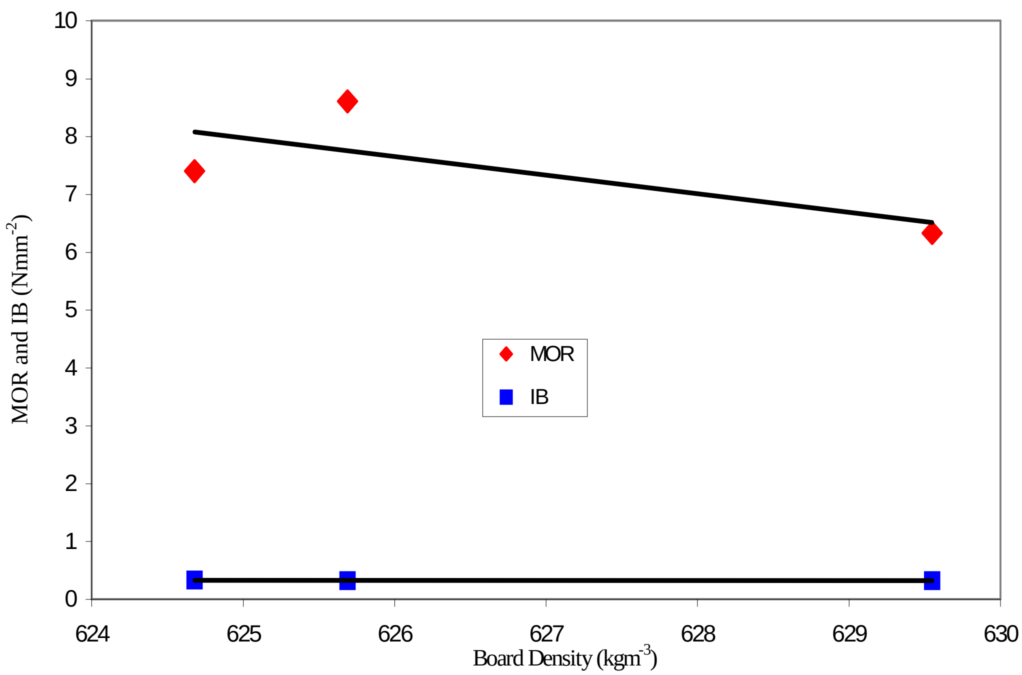

Figure 3: Relationship between board density, modulus of rupture and internal bond strength of chipboard from Kenya.

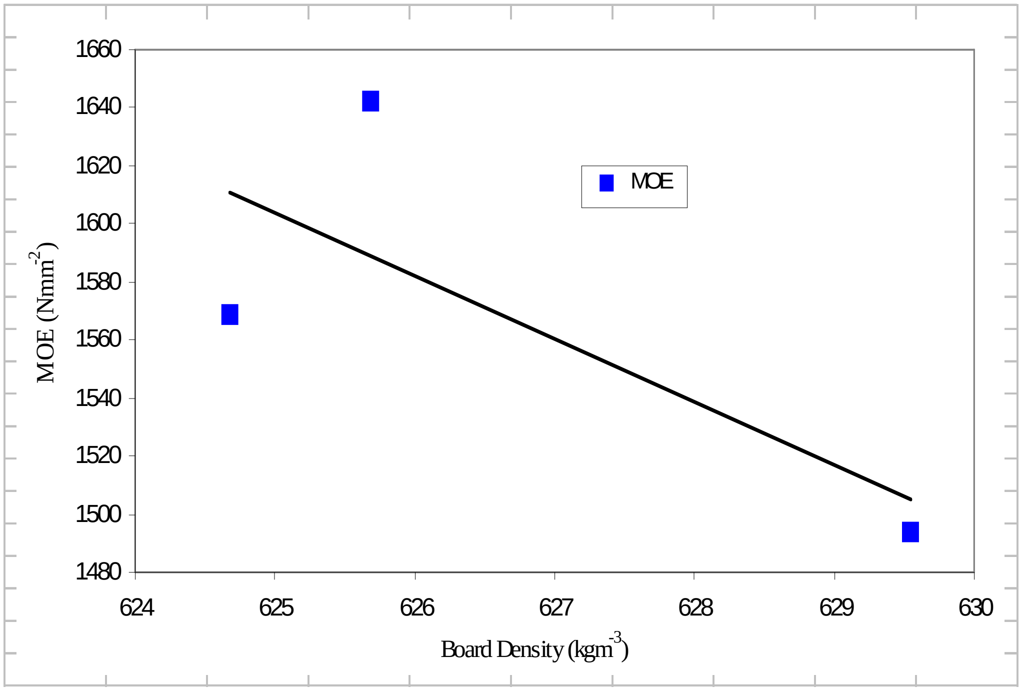

Figure 4: Relationship between board density and modulus of elasticity of chipboard from Kenya.

Modulus of rupture and modulus of elasticity

Table 2 also compares modulus of rupture (MOR) or bending strength and modulus of elasticity (MOE) or stiffness of chipboard from Tanzania and Kenya. The Tanzania chipboard had relatively higher values for both MOR and MOE than that of Kenya with the difference being statistically significant at 0.05 probability level (Table 2). However, both values from Tanzania and Kenya were lower than those specified in the EN 312 (2003) by 40% and 47% for MOR and by 20% and 39% for MOE respectively (Table 2). The difference on the MOR and MOE values between chipboards from Tanzania and Kenya may be due to resin concentration and application during mat formation. The recorded mean values of MOR and MOE for chipboard from Tanzania and Kenya were lower than that reported by Guler *et al*. (2006) which ranged from 15.67 – 18.74 N mm^{-2}; and 1800.2 – 2973.8 N mm^{-2} respectively with board density of 700 kg m^{-3}. The MOR and MOE results for chipboards from Kenya and Tanzania are also lower than that reported by Semple *et al*. (2005a) which are 14.5 N mm^{-2} and 2250 N mm^{-2} respectively with density ranging from 650 – 710 kg m^{-3}. The difference seen could be due to the difference in raw materials, mat consolidation and resin concentration and spraying methods (Cai *et al*. 2004, Hiziroglu *et al*. 2005).

Tensile strength perpendicular to the plane

Tensile strength perpendicular to the plane or internal bond (IB) strength of chipboard from Kenya (0.63) was observed to be higher than that of Tanzania (0.32 N mm^{-2}) by almost 50% (Table 2). This difference was also statistically significant ($P<0.05$). The difference in the IB strength could be due to the amount and application method of the resin, as well as mattress consolidation during manufacturing processes. Boards made with sufficient and evenly distributed resin have high IB values. This is because particles are well bonded to each other, and the void space is also well filled with resin thus increasing inter-particle bonding (Desch and Dinwoodie 1996).

Table 2 also shows that IB values for both Tanzania and Kenya chipboards are higher than the value specified in the EN 312 (2003) Standards, which is 0.28 N mm^{-2}. This value however is similar to that of Tanzania chipboard. This indicates that Tanzania chipboards are in conformity with EN standards. Kenya chipboards however, have superior IB, far much higher than that specified by EN Standards. The results for both Tanzania and Kenya chipboards give evidence that resin application was according to the standards.

According to Bahari *et al*. (2007) the IB for chipboard do improve with the increment of resin content. Therefore the difference obtained could be due to resin content and resin blending methods achieved by the two manufacturers. Studies by Shupe *et al*. (2006) and Bahari *et al*. (2007) showed that particleboards made from higher resin content were better in terms of IB strength and dimensional stability properties than lower resin content levels. The high resin content level had increased the particles bonding ability thus influenced the excellent properties of particleboard. High use of resin also has cost implication in production process. Since the prices are comparable, the Tanzania chipboard is probably sold at higher profit than that of Kenya. This is because the cost of transportation of the Tanzania chipboards is relatively small compared to that from Kenya. The properties of Tanzania chipboard are good and therefore; compete effectively in market with chipboards from Kenya.

CONCLUSION AND RECOMMENDATION

Conclusion

The study has documented chipboards coming from Tanzania and Kenya being available in Tanzania markets. Most of the properties determined from this study had required properties for different uses as they met the minimum properties required by standards. Chipboards from Kenya had good appearance, and well consolidated. Some of the chipboards from South Africa had different good decorations (styles of prints); the phenomena which influenced customers without prior knowledge of their quality. The results show that chipboards from Tanzania and Kenya had MC of 10.7% and 10.5%, basic density of 626.64 kg m^{-3} and 614.77 kg m^{-3}, MOR of 7.44 N mm^{-2} and 6.68 N mm^{-2}, MOE of 1568.22 N mm^{-2} and 1190.09 N mm^{-2}, IB of 0.32 N mm^{-2} and 0.63 N mm^{-2} respectively. Chipboards from Tanzania had high strength values when compared to that from Kenya.

RECOMMENDATIONS

There is a need of more investors to invest in the country on wood based board material production particularly on chipboards as currently there are only one factory producing chipboards i.e. Tembo Chipboards Ltd. This factory however is very old and produces at a very low rated capacity. Having several investors in the country will enable the country to have enough products which will satisfy the need, and their products would be of high quality because of the market competition. Tanzania chipboard factories should work to improve appearance and some board qualities i.e. board density, MOR, MOE and IB of the local wood based boards in order to compete well with the imported boards. From this study it became clear that majority of customers are largely influenced by the board appearance rather than other qualities of the boards. There is a need of promoting tannin resins from wattle trees to be used in chipboard production in order to reduce production costs since glue is one of the most expensive raw materials contributing to more than 50% total production costs. Further studies to determine strength properties of chipboards blended with locally available resins is essential before they appear in the market.

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