COMPARISON OF DIMENSIONAL STABILITY OF PARTICLE BOARDS MANUFACTURED IN TANZANIA AND THOSE IMPORTED FROM SOUTH AFRICA

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ABSTRACT

Dimensional stability properties of particleboard from Tembo Chipboard Ltd, located in Tanga, Tanzania and of those imported from South Africa were determined and compared. A total of 64 test samples, 32 from Tembo Chipboard Ltd and 32 from South Africa chipboard cut randomly from boards were used for the study. Prior to the determination of the dimensional stability, moisture content and basic density of boards were determined in accordance to EN 322 and EN 323 standards respectively. Determination of dimensional stability was based on water soak test, according to EN 317 standard.

From the results, the basic densities of particleboard from Tembo Chipboard Ltd and those from South Africa were very similar at 687 and 671 kg/m^3 respectively. Similarities in basic densities allowed for comparison of other properties. Thickness swelling and water absorption values of chipboards from Tembo Chipboard Ltd and S. Africa increased with increase in water immersion period. Comparatively, boards from Tembo Chipboard Ltd had lower thickness swelling and water absorption than boards from South Africa. Furthermore, less board damage due to water immersion was demonstrated by boards from Tembo Chipboard Ltd than those from S. Africa due to their low irreversible thickness swelling. The particleboards from Tembo Chipboard Ltd are more dimensionally stable than similar boards from S. Africa.

INTRODUCTION

Anon (1967) and Tsoumis (1991) defines particleboard as a panel material manufacture from lignocellulosic fibre material, usually wood, primarily in the form of discrete pieces of particles as distinguished from fibres. The particles are combined with synthetic resin or other suitable binders and bonded together under heat and pressure in a hot press by a process in which the entire interparticle bond is created by the added binder. Other materials may be added during manufacture to improve certain properties.

World particleboard production has increased tremendously during the last 40 years. Commercial production of particleboard started in German in 1941, with the output of about 20,000 m^3/year. This rose to about 27 million cubic metres in 1972 (FAO 1976) 52 million cubic metre in 1993 (FAO 1993). By 1999, the world production figure was 76 million cubic metres (1999). The production rate of particleboard production is considerably greater than plywood. For example, during 1960 - 1973, world production increased at a rate of 19% per year while plywood production increased at 8% per year (Haygreen 1982).

The production of particleboard efficient utilization of wood. The production yield is higher (75-90% or more) in comparison to lumber and plywood (about 50%) (Tsoumis 1991). Growth of particleboard industries in many countries is due to the possibility of utilizing small dimension wood including residues from other wood industries, availability of synthetic resins that facilitate mass production by fast curing, suitability of the product for a variety of uses (furniture, building construction, etc) and the possibility of producing boards with large dimensions and to customers specifications (Tsoumis 1991).

Wood based panels are also popular because they can be made from any type of lignocellulosic material and wood wastes from other wood based industries. This helps to lessen the pressure on the world's forests. In most developed countries it is common to have particleboard integrated with other factories in order to allow wastes from other factories like sawmill to be used by particleboard factories.

The important properties of particleboard include both physical and mechanical properties. Physical properties include moisture content, density, dimensional stability i.e. water absorption, thickness swelling and dimensional changes due to changes in relative humidity. Basic density is an important physical property for most wood based panels including particleboard as they have significant influence on the dimensional stability of resultant boards (Kelly 1977). Basic density also affects price due to cost of raw material and directly affects mechanical properties. Mechanical properties include modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond strength (IB) or tensile strength perpendicular to the plane of the board. It is important to note that, particleboard are man made wood based panels and have properties that are much easier to manipulate. Although some of the properties such as board density can be manipulated within limits, thorough understanding of the manufacturing process variables is important for production of board with properties that suit particular uses.

Dimensional stability is one of the important board properties which influence its quality and use. Dimensional instability of boards is due to the hygroscopicity of wood particles making the boards. Solid wood is highly hygroscopic, it will shrink and swell below f.s.p under influence of changing environmental humidity conditions that cause wetting and drying of the wood. Particleboard made of wood particles can be affected by changes in relative humidity (RH) of surrounding environment. The effect of moisture on particleboard has significant effects on their properties and therefore end uses i.e. the changes in dimensions will in most cases cause loss in board strength and thus unreliable life span.

Tanzania has one particleboard factory (Tembo Chipboard Ltd) located in Mkumbara, Tanga region. Initially the factory was owned by Tanzania Wood Industries Cooperation (TWICO), but now the factory is privatised. The mill started production in 1971 with a rated capacity of 7000 m^3/year. The mill performance has been declining and the capacity utilization in 1992, 1993, 1994 and 1995 were 34%, 39% 24% and 10% respectively (Ngaga 1998). The mill receives raw materials from softwood plantations and it is also integrated with a sawmill whose rated production capacity is 14,000 m^3/year.

The Tembo Chipboard Ltd participates on voluntary basis in replanting clear felled areas and in 1999/2000 the factory planted about 143 ha of the plantation (Malimbwi 2000). For a long time, the properties of chipboard produced from Tembo chipboard Ltd have not been well documented. With the current free market, where you find a lot of imported chipboards, it is necessary to determine the properties of these boards and compare these with those imported from outside the country.

The purchasing of particleboards by most people in Tanzania is very much influence by the physical appearance rather than the technical properties. Additionally, board properties are not matched to requirement of the intended applications by most customers. For example board produced by urea formaldehyde for interior use are used in wet areas or applied in environment of changing moisture content posing a potential safety hazard.

The change in moisture content may be large enough to cause problems if panels are improperly installed with no provision for anti-swelling. Due to the highly hygroscopic nature of particleboard, it will always absorb or loose moisture which will cause dimensional changes and changes in strength. Tanzania is one of fluctuations in tropical countries, where the environmental humidity are quite high. It is obvious that boards used in these environments will face a problem of dimensional stability if care is not taken during production to minimize these effects. Most boards used in this country, lack information from manufactures regarding their stability in dimensions when exposed to moisture. This property is important due to its effects on strength properties. For example, Tsoumis (1991) found that a change of moisture content from 5 to 15%can reduce static bending by 25-50%. Creep has also been reported to be higher in particleboard in comparison to solid wood and increase up to 10 times at high moisture content (Tsoumis 1991).

Very little have been done to document the qualities of chipboard from Tembo Chipboard Ltd, both in terms of dimensional stability and strength. The aim of this work was to study and document the qualities of particleboard from Tembo Chipboard Ltd with respect to dimensional stability and compare with particleboard imported from South Africa. Particleboards from Tembo Chipboard Ltd and similar boards from South Africa are plently available and compete in prices in local markets.

MATERIALS AND METHODS

Chipboards

Particleboard from Tembo Chipboard Ltd and a similar board from South Africa produced with similar adhesive were purchased from dealers of building material in Morogoro, Tanzania. Before the purchase, the boards were inspected to be sure they were from Tembo Chipboard Ltd and S. Africa.

Board tests

Cutting and conditioning of samples

Test samples were cut from the boards using a cutting plan from EN 326 – 1 standard. A total of 64 test samples (32 test sample from each board type) of 50 x 50mm dimensions for water soak test were cut from the two different boards, both with 145.5cm x 122.2cm dimensions.

From both ends of each board, about 10cm length pieces were removed. Then four test samples were cut with dimensions of 55cm x 102.2cm from the remaining board. Each sample was divided into two pieces of 25 x 27.3cm. From each piece one sample (50 x 50 mm) was obtained. These samples were randomly selected.

Moisture content

Moisture content (mc) was determined according to EN 322. Each test sample was first conditioned to constant weight and the conditioned weight recorded. The test sample was then oven dried at 105 ± 2°C for 24hrs until constant weight. The moisture content (MC) of each test piece was calculated according to the following formula:

$$MC = \frac{Mi - M_o}{M_o} X\ 100$$

Where:

M_c = moisture content in percentage.
M_i = Conditioned weight (g)
M_o = Oven dry weight (g)

The moisture content of a board was obtained by calculating the arithmetic mean of the moisture contents of all the test samples taken from the same board and was expressed as a percentage.

Density

This was determined according to EN 323. It is the ratio of the mass of each test sample, to its volume, both measured at the same moisture content. These results were used to estimate the density of whole boards.

Micrometer screw gauge was used for thickness measurement while digital veneer caliper was used for length and width measurement. Digital balance was used for measuring mass of each test sample.

The density of each test sample was calculated by the following formula:

$$\rho = \frac{M}{V} X\ 100$$

Where:

ρ = Test sample density, in kg/m^3
V = Volume of test sample;
V = length x with x thickness of test sample

The density of a board was obtained by calculating the arithmetic mean of the densities of all the test samples taken from the same board.

Water soak Test

The water soak test was done according to EN 317. Thickness swelling (TS) i.e., reversible and irreversible thickness swelling and water absorption (WAB) were determined. All test samples were first marked at the centre of the top face with a permanent dot pen so that consistency could be maintained when measuring the samples at various time intervals throughout the experiment.

Distilled water was employed for the water soak test because standard tap water contains chloride ions which as a consequence results in the water being slightly acidic (pH 6.0) which might act as a catalyst in the breaking of the resin chip bonds and therefore produce inaccurate results (Gillah *et al.* 2000).

The various coded test samples were horizontally placed in the beakers, filled with distilled water and placed in half filled water bath. The samples were put in the beaker at ten minutes intervals, because this was the time needed to weigh and measure a set of samples after wiping them with a tissue paper at every water soaking interval. This allowed all the samples to have the same exposure to the air (drying) once they were out of the beaker for measurement.

The samples were measured after soaking for 2, 12, 24, 48, and 168 hours for increase in thickness and weights. After 96 hours soaking period, the distilled water was changed to avoid contamination due to biodegradation. The percentage thickness swelling and water absorption were then calculated with reference to the conditioned thickness and weight using the formulas below.

(a). Thickness swelling (TS)

$$TS = \frac{T_t - T_o}{T_o} X\ 100$$

Where:

T_t = Thickness of the test sample at time t of soaking in water, in mm.
T_o = The conditioned thickness of the test sample before introducing samples in water, in mm.

(b) Water absorption (WAB)

$$WAB = \frac{M_t - M_o}{M_o} X\ 100$$

Where:

M_t = Mass of test sample after time t of soaking in water, in grams.

M_o = Conditioned mass of sample before immersion in water, in grams.

The samples were then placed on a drying mesh at 22°C and 70% relative humidity and air-dried (conditioned) for five weeks. The air drying was accelerated by fans. The dried samples were measured to record conditioned thickness and weight. Finally, the samples were oven dried overnight at 105 ± 2 °C to get the oven dry thickness of the samples. The conditioned and oven dry thicknesses were important for calculating the irreversible thickness swelling, which is the amount of damage caused in the sample by the water during water soaking period. The irreversible TS (both condition and oven dry) were calculated using formulas (c) and (d).

(c) Conditioned irreversible thickness swelling

$$IR_c = \frac{T_w - T_o}{T_o} X\ 100$$

Where:

IR_c = Conditioned irreversible thickness swelling, %.

T_w = Thickness of wet test sample after reconditioning at 70% RH and 22 °C, in mm.

T_o = Conditioned/initial thickness of the sample, in mm.

(d) Oven dry irreversible thickness swelling

$$IR_o = \frac{T_{od} - T_o}{T_o} x100$$

Where:

IR_{od} = Oven dry irreversible thickness swelling, %.

T_{od} = Thickness of oven dry wetted and reconditioned sample, in mm.

T_o = Conditioned/initial test sample thickness, in mm.

Data analysis

Means and coefficients of variations (CV) values were calculated for all the experimental data describing the various panel properties for each set of replicate test samples. Variation within each data set about the mean value was displayed as an error bar on the appropriate histogram. Excel computer Software was used for analysis of data.

RESULTS AND DISCUSSION

Density of Chipboards

Particleboard from Tembo Chipboard Ltd (TZ) had a basic density of 687 kg/m^3 while the one imported from South Africa had a basic density of 671kg/m^3. Densities of both board are comparable as they fall in the same density class i.e. Medium density (400kg/m^3 - 800kg/m^3) (Tsoumis 1991). Since the board density of these panels are similar, other properties of these particleboards can be compared.

Dimensional stability of particleboards

Table 1 and Figure 1 Show the thickness swelling of the particleboards from Tembo Chipboard Ltd and S. Africa.

Table 1. Thickness swelling of chipboard from Tembo factory and South Africa

Type of Board	Density (kg/m^3)	MC (%)	No. of Samples	Thickness Swelling (%)				
				2h	12h	24h	48h	168h
Tembo	687	9.5	32	11(31)	14(26)	15(23)	17(17)	19(21)
S. Africa	671	9.7	32	17(19)	21(16)	23(16)	26(16)	26(15)

Note: Value in parentheses are coefficient of variation (%).

The results show that the percentage thickness swelling of both boards increased with increasing socking time from 2 to 168 hours.

It is interesting to note the amount of swelling of particleboard from both Tembo Chipboard Ltd and S. Africa after immersion in water. Less swelling was observed after two hours. This could be due to compactness of board sample in relation to sample permeability. After 2 hours of soaking, the bond holding wood chips together were still strong enough to resist permeability of water. However, the bonds got weakened with time and the amount of swelling as observed after 168 hours increased. Furthermore, the coefficient of variation (CV) values after 2 hours of soaking in water were high compared to those after 168 hours of soaking. This again could be due to sample compactness in relation to permeability as well as uniform distribution of resin bonds. In this case, after 2 hours of soaking the samples varied greatly due to some parts of samples being more permeable than the rest, while after 168 hours of water soaking every part of the sample became permeable. The increase in swelling between 2 hours and 168 hours of water soaking for Tembo factory and S. Africa particleboards were almost 72% and 53% respectively.

It is important to note that thickness swelling occurs below fibre saturation point. Which is due to amount of water associated with cell wall, referred to as bound water (Kelly 1977). Free water does not contribute to thickness swelling and this water occurs above the fibre saturation point.
It is also clear from the results of thickness swelling that, particleboard form Tembo Chipboard Ltd were relatively more stable compared to South African particleboard at all soaking times. However, particleboard from South Africa showed low values of coefficient of variation when compared to particleboards value from Tembo Chipboard Ltd. The high CV values for Tembo Chipboard Ltd boards show that there is a big variation in the production process. One reason could be inconsistency in resin application. South Africa factory could have used a more efficient resin spraying system than Tembo Chipboard Ltd. The inconsistent resin application might have caused non-uniform resin distribution which when mattress was pressed to panel, the bond level varied from one part of the panel to another. Those panel samples cut from place with more resin will show less thickness swelling since bonding will be more efficient. The resultant is the high coefficient of variation between samples. However S.A particleboard gave very low (CV) values, suggesting better resonation process.

Although the Thickness Swelling values were very low for South Africa particleboard, but they were very consistent if compared to Tembo Chipboard Ltd particleboards.

These results conclude that the chipboard from Tembo Chipboard Ltd have low rate of swelling compared to those imported from South Africa when soaked in water at the same time intervals.

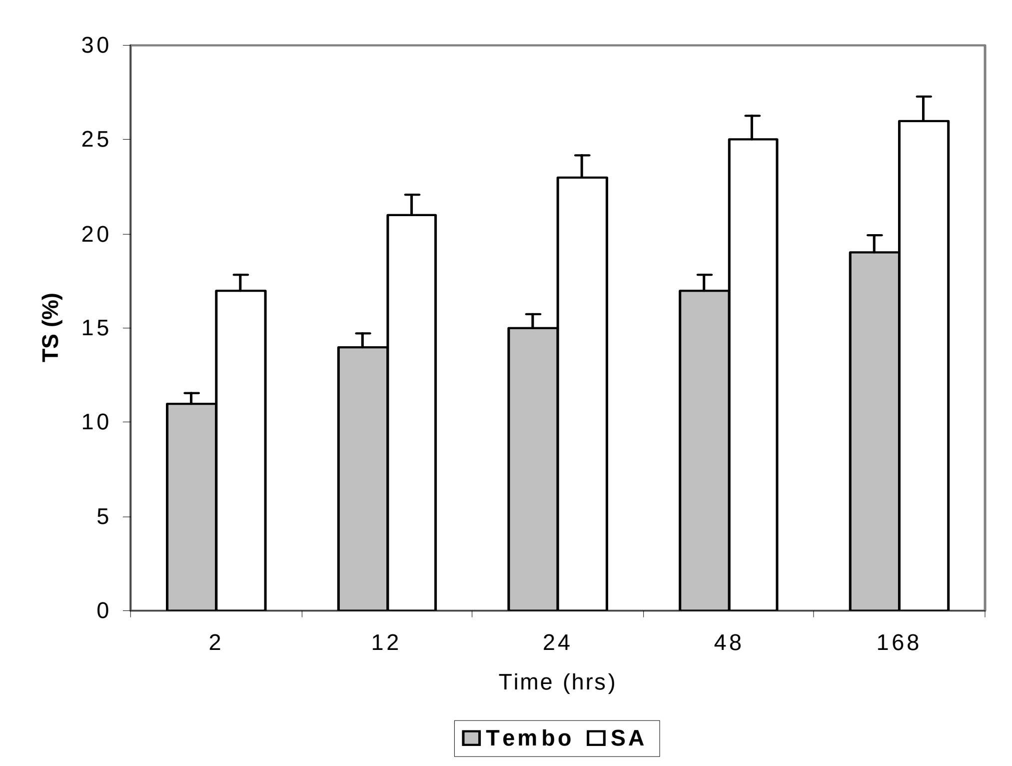

Figure 1. Comparison of particleboard thickness swelling from Tembo factory and S. Africa

It has also been explained by Moslemi (1974) that the thickness swelling of particleboard is dependent upon the resin content and distribution of resin content in the board. Kelly (1977) also found that increasing the resin content in a given particleboard will result in improved interpaticle bonding which should also improve the thickness swelling stability. Also particle configuration has been explained to have effect on the thickness swelling of particleboard. Increasing the amount of resin content of the board has been reported (Moslemi 1974) to be the easiest way to improve its thickness swelling stability, although the cost of purchasing resin is a limiting factor to the manufacturers. Despite the amount of resin used by each factory to produce their particleboards being not known, it is assumed, since the board density was the same, the amount of resin used was similar. However, the difference observed for thickness swelling between the two board types might as well be due to the amount of resin used, or due to other factors, such as particleboard configuration, variation in production process and conditions, amount of additives used such as paraffin wax etc.

It is also possible that South Africa factory used relatively lower amount of additives e.g. paraffin wax compared to the Tembo Chipboard Ltd since such additives are introduced in small proportions as water repellent agent. Hay green (1982) reported that wax ranging from 0.25 to 2% by oven dry weight of chips is added to provide some water repellence to the board.

Water absorption of particleboards

Table 2 and Figure 2 show the water absorption of particleboard from Tembo Chipboard Ltd and those imported from South Africa. The water absorption property followed a similar trend as thickness swelling (Table 1, Figure 1), where the percentage water absorption by both boards increased with soaking time.

Table2. Water absorption of particleboard from Tembo and South Africa factories

Board type	Density kg/m^3	MC, %	No. of samples	Water absorption (WAB), %.				
				2 h	12 h	24 h	48 h	168 h
Tembo	687	9.5	32	62(18)*	71(16)	78(14)	85(13)	92(13)
S.Africa	671	9.7	32	85(9)	90(8)	95(7)	101(7)	107(7)

*Values in Parentheses are coefficients of variation (CV), %.

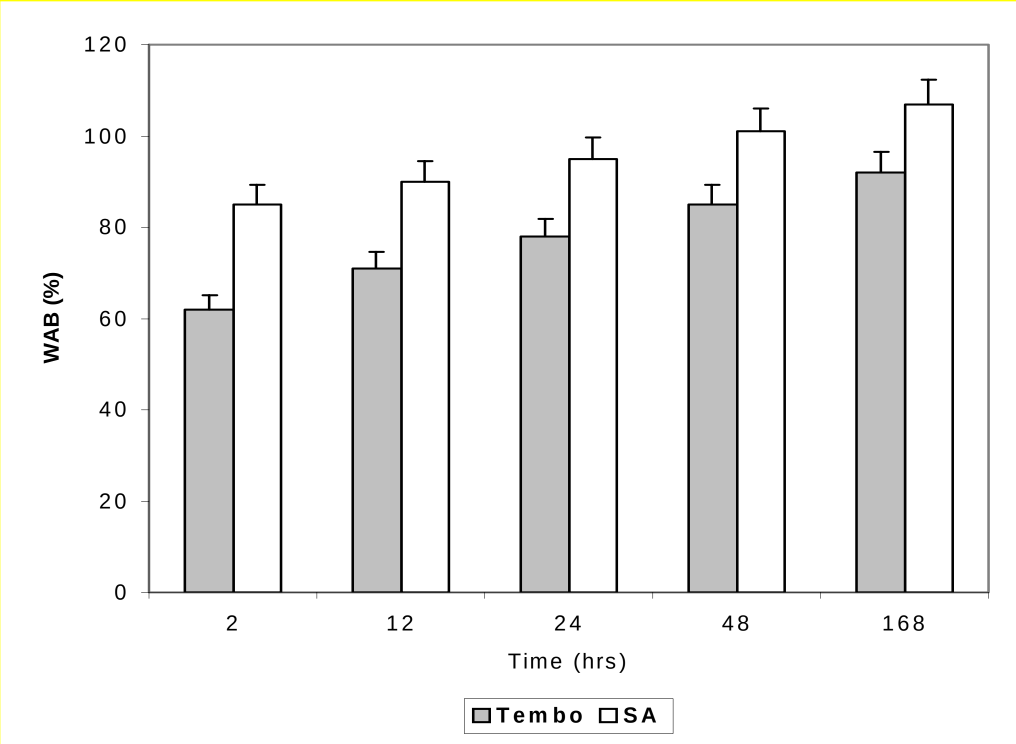

Figure 2. Comparison of particleboard water absorption values from Tembo factory and S. Africa

Compared to thickness swelling values, the water absorption values are extremely higher. This is because the two were calculated differently. Thickness swelling was calculated from increase in board thickness while water absorption was calculated from increase in weight. The difference in amount of water absorbed between 2 hours and 168 hours of water soaking of particleboard from Tembo Chipboard Ltd and those imported from S. Africa were almost 40% and 26% respectively.

But from the comparison it has been shown that particleboard from Tembo Chipboard Ltd at every water soaking time absorbed less water compared to amount of water absorbed by boards from S. Africa. Also the low values of coefficient of variations in South Africa particleboard compared to Tembo particleboard indicate the big difference in mean values reported due to similar reasons discussed earlier.

Irreversible thickness swelling

Irreversible thickness swelling is defined as the amount of non-recoverable thickness swelling when water soaked samples are re-dried to initial board thickness. In other words it demonstrates the amount of damage caused in the board by water. While irreversible thickness swelling for Tembo particleboard were about 12 % and 3%, those for S. Africa particleboard were 18% and 8% for conditioned and oven dry basis respectively (Figure 3). Conditioned

Irreversible TS was obtained after conditioning the water soaked samples at 70% relative humidity and 22 °C. The oven dry Irreversible TS was obtained after drying the conditioned water soaked samples in the oven at 105 ± 2°C for 24 hours, to constant weight. The oven dry irreversible TS was lower than conditioned irreversible TS by about 75% for particleboard from Tembo Chipboard Ltd and by 56% for particleboard from south Africa.

It is clear from the figure that particleboard form Tembo Chipboard Ltd experienced less damage as shown by low amount of unrecoverable thickness swelling in both condition and oven dry values compared to board form South Africa.

The irreversible thickness swelling of the boards from Tembo Chipboard Ltd were lower than boards from South Africa by about 33% and 62% for condition and oven dry irreversible thickness swelling respectively.

Irreversible TS is an additional dimensional stability information to thickness swelling and water absorption properties. The lower values of conditioned and oven dry irreversible thickness swelling on top of lower TS and WAB values of boards from Tembo Chipboard Ltd compared to particleboards imported from S. Africa, shows that Tembo Chipboard Ltd boards are more dimensionally stable than boards from S. Africa.

CONCLUSION AND RECOMMENDATION

Conclusion

The particleboards examined in this study had similar basic densities i.e. 687 kg/m^3 for particleboards from Tembo Chipboard Ltd and 671 kg/m^3 for particleboards imported from South Africa. They were classified as

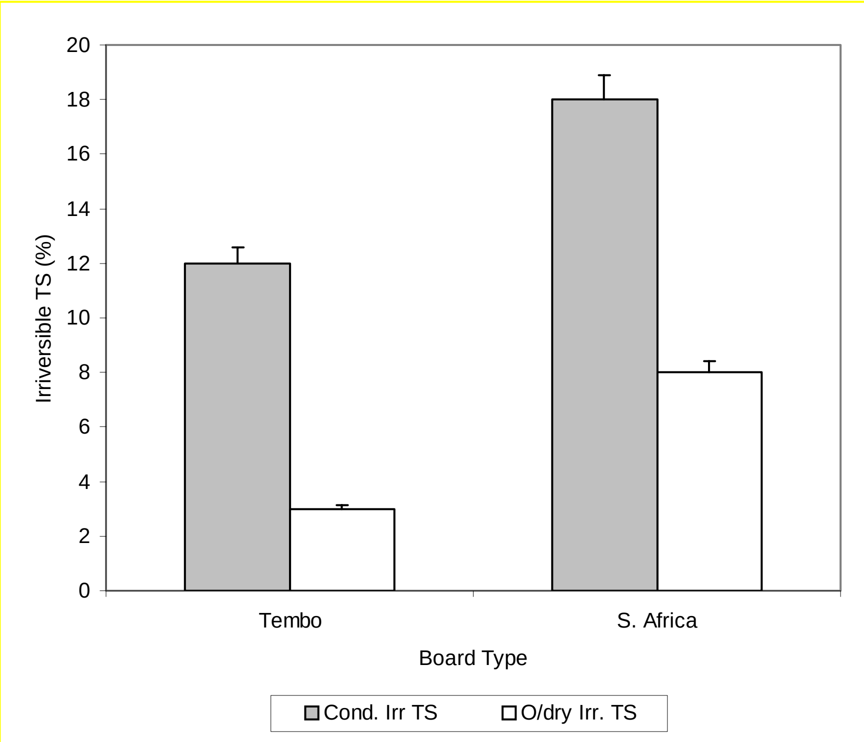

Figure 3. Irreversible thickness swelling of particleboard from Tembo factory and S. Africa.

(i) medium in density. Similarities in board densities made it possible to compare their properties.

(ii) Both thickness swelling and water absorption values of both boards showed an increasing trend with water soaking/immersion time. Values are lower after 2 hours soaking and highest after 168 hours of soaking.

(iii) Comparatively, boards from Tembo Chipboard Ltd had lower TS and WAB values than boards from S. Africa at each water soaking time.

(iv) Particleboard from Tembo Chipboard Ltd had lower conditioned and oven dry irreversible thickness swelling values than boards from S. Africa. This shows that, less damage was caused by water in boards from Tembo Chipboard Ltd than boards from S. Africa.

(v) Due to lower TS, WAB and irreversible TS values of particleboard from Tembo Chipboard Ltd than the board from S. Africa at the same board moisture content and density, the boards from Tembo Chipboard Ltd are therefore more dimensionally stable than boards from S. Africa.

Recommendations

It is clear from this study that boards from Tembo chipboard Ltd are more dimensionally stable than boards from S. Africa. The problem could be due to the inconsistency in resin application during particleboard production. It is therefore recommended that the factory look more closely into its resin application system and improve spraying in order to have a more even resin spraying system and thus improve consistency.

Customers normally prefer the S. Africa particleboards than Tembo Chipboard Ltd particleboards. This could be due to the fact that it looks better than board from Tembo factory. However, Tembo factory boards proved to be more dimensionally stable. It is therefore suggested for factories to provide board properties data to customers, so that they can compare both their appearance and expected performance levels.

This study measured dimensional stability of the particleboards. Dimensional stability of boards when exposed to environment of changing relative humidity as well as mechanical properties of the boards should also be determined. A combination of dimensional stability results from this study and the mechanical properties will give a better comparison of board performance between the two types of particleboards.

REFERENCES

Anon, 1967. America Society for testing and materials. Standard definitions in terms of relation to wood-based fibre and particleboard. Panel materials. ASTM Design. D 1554 - 67. Philadelphia, Perinysylvania, USA.

EN: 317.1993. Standard method for determination of swelling in thickness swelling after immersion in water. European committee for standardization, Brussels.

EN: 322.1993. Wood based panels. Determination of moisture content. European committee for standardization, Brussels.

EN: 323. 1993. Wood based panel. Determination of density. European committee for standardization, Brussels.

EN: 326 - 1. 1994. Wood based panels-sampling cutting and inspection. Part 1. sampling and cutting of test pieces and expression of test results. European committee for standardization, Brussels.

FAO, 1976. The processing of the world consultant on wood based panels. New Delhi, India.

FAO, 1993. Forest products. FAO Year Book, Rome.

FAO, 1999. Forest products. FAO Year Book, Rome

Gatchell, C.J, Heebink, B.G. & Hefty, F.V. 1966. Influence of component variables on properties of particleboard of exterior use. For Prod. J.16(4) 46-59.

Haygreen, J. G. 1982. Forest products and wood science. Iowa state University Press, Iowa. Mention total pages (p..).

Kelly,W. or Myron, K.W. 1977 Critical Literature Review of Relationships between processing parameters and physical properties of particleboard. US Department of Agriculture Forest Services, Forest Product Laboratory , Madson.

Malimbwi, R. E. 2001. Interim report on forest management in Tanzania. Forestry and Beekeeping Division on Dar es Salaam.

Moslemi, A.A 1974. Particleboard material Vol. 1 Southern III. Univ. Press, London and Amstedam.

Ngaga Y. M. 1998. Analysis of production and trade in forest products of Tanzania. Doctor of science thesis, the Agricultural University of Norway.

Tsoumis, G. T. 1991. Science and technology of wood. Chapman and Hall, New York.