International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 05 | Aug-2015 www.irjet.net p-ISSN: 2395-0072

Variations of the Physical and Mechanical Wood Properties of *Swietenia macrophylla* in Mixed and Monoculture Plantations

Sharmin A.[1], Ashaduzzaman M.[1*], Shamsuzzaman M.[1]

[1]*Forestry and Wood Technology Discipline, Khulna University, Khulna -9208, Bangladesh*

** Corresponding Author: a_zaman24@yahoo.com*

Abstract - *The variation of physical and mechanical properties of Mahogany (Swietenia macrophylla King.) wood grown in mixed and monoculture plantation were studied. S. macrophylla grown in mixed culture plantation showed slightly higher wood values in case of density, radial shrinkage, compressive strength (both in parallel and perpendicular to grain), tensile strength parallel to grain and static bending properties (MOR, MOE). While, S. macrophylla grown in monoculture plantation showed slightly higher wood values in case of moisture content, tangential and volumetric shrinkage. Statistically significantly differences were not found in different physical and mechanical wood properties of S. macrophylla wood between mixed and monoculture plantation.*

Key Words: *Swietenia macrophylla, Density, Moisture content, Shrinkage Tensile strength, Compression Strength, MOR, MOE.*

1. INTRODUCTION

The forests of Bangladesh have nearly 500 hardwood species [1]. Mahogony (*Swietenia macrophylla* King.*)* is one of them. It belongs to the family Meliaceae, which is found in the tropical region. It is a large tropical tree with an umbrella shaped crown frequently over 30 meters in height, commonly 120 to 150 cm in diameter but sometimes may be more [2]. In 1989, the species was first planted in Kaptai forest of Bangladesh [2]. It is extensively cultivated in home gardens, roadsides and in the plantation forests of Bangladesh. Since nineteenth century the farmers of northern and western part of Bangladesh have been planting this species along roadside, around farmland and homestead [3, 4]. It is a medium weight timber, which is rather soft. The heartwood is reddish or pinkish or yellowish when fresh. The colour is darkening with increasing age to a deep red or brown sapwood usually yellowish and up to 400 mm wide [5]. The wood is excellent material for furniture, interior decoration such as doors, paneling, decorative borders, boat construction, models and patterns, wood carvings, novelties, toys, musical instruments etc [2].

Physical properties are very important consideration in selecting wood for numerous uses, such as furniture manufacturing, cabinet manufacturing, construction of frame, bridge, building structures, sporting goods, measuring instruments, musical instruments, particle boards, decorative surfaces, insulating media etc. Mechanical properties of wood indicate the ability of wood to resist various types of external forces, static or dynamic, which may act on it. Mechanical properties are very much important in case of constructional and structural purposes timber. The properties not only vary with species, with reference to the nature of their fiber structure but also with the moisture content, temperature and defects of wood.

The management practice of *S. macrophylla* in mixed and monoculture plantations are quite different. Thus, there may be possibility of differentiation in their wood quality in different plantation area. Several initiatives have been made to find out the difference of wood properties of *S. macrophylla* between natural and monoculture plantation. But no attempt has been made to determine the variation of wood properties between mixed and monoculture plantation. In Bangladesh *S. macrophylla* is planted both in mixed and monoculture plantation in different social forestry and agroforestry programs. *S. macrophylla* is planted as monoculture plantation in the form of woodlot. Beside this it is planted gregariously in roadside, sometimes in association with *Dalbergia sissoo, Leucaena leucocephala, Albizia spp.* and *Samanea saman*. *S. macrophylla* also planted largely in cropland agroforestry and homestead agroforestry programs. Where as in homestead *S. macrophylla* planted along with a variety of species of which, Koroi (*Albizia procera)*, Coconut (*Cocos nucifera*), Tentul (*Tamarindus indica*), Sissoo(*Dalbergia sissoo*), Shimul *(Bombux cieba*), Raintree (*Samanea saman*) etc. are important [6, 7, 8].

Variability or variation in properties is common to all materials. Because wood is a natural material and the tree is subject to numerous constantly changing influences (such as moisture, soil conditions, and growing space), wood properties vary considerably even in clear (no knots) material. The timber of *S. macrophylla* is generally regarded as superior species of the Meliaceae family.

Comparison between natural and plantation grown *S. macrophylla* timber indicate that plantation grown timber is slightly less dense and lighter in colour; the grain may be coarser. The ration of sapwood to heartwood is greater [9]. In this study, the variation of physical and mechanical wood properties of *S. macrophylla* grown between mixed and monoculture plantation has been evaluated.

2.1 Collection of trees for samples

Three representative trees of average growth and health of *S. macrophylla* from mixed and monoculture plantation were collected from Bashundia Union at Jessore District of Bangladesh. The age of the trees was ranging from 14-17 years. The average height and girth of these trees were approximately 6 meters and 18-20 cm respectively. Trees of monoculture plantation were collected from village woodlots while the trees of mixed plantation came from mixed woodlots and home gardens. Trees uncommonly straight or crocked boles were excluded.

2.2 Preparation of wood specimens

Samples were collected from three different heights i.e. top, middle and bottom of the trees. The bottom of the tree was considered as the base after the stump height, 1.5 meter above the base was considered as middle and 1.5 meter above the middle was considered as top and all these positions were marked and sawn into specimen. The specimens for testing the physical properties were prepared to 7.5 x 5 x 2.5 cm (longitudinal x tangential x radial) in size. The specimens were collected from heartwood zone.

The specimens for compression test were in the form of 7 x 2.5 x 2.5 cm (longitudinal x tangential x radial). For tensile test cylindrical specimens of 1.5 cm in diameter with 5.5 cm gauge length and 1 cm diameter were used. The length of grips was 7.5 cm at each end. Samples were selected from both the parallel to grain and perpendicular to grain for compression test and only parallel to grain for tensile test. The specimens for static bending test e.g. modulus of rupture (MOR) and modulus of elasticity (MOE) were cut in the form of 35 x 5.5 x 2 cm (longitudinal x tangential x radial). A total of 9 samples, 3 from each of the height position of tree (i.e. top, middle and bottom) were examined to evaluate each of the physical and mechanical properties.

2.3 Evaluation of physical properties

Moisture content was assessed by weighing (to 0.001 g accuracy) before and after oven drying at 103^0c ± 2^0c for 24 h. Shrinkage in three linear directions was evaluated as percentage dimensional change from green condition to oven dry condition. Dimensional measurements were taken with digital caliper (0.002 cm constant). Density was determined from specimens based on green volume and oven dry volume to dry weight. The weight measurements were taken in an electric balance to an accuracy of 0.02 g and the volume was measured by measuring three dimensions.

2.4 Evaluation of mechanical properties

The mechanical properties e.g. Compression strength, tensile strength, MOR and MOE were carried out by Universal Testing Machine (UTM). The load was applied at a constant speed of 0.01 mm/s as suggested by Desch and Dinwoodie [10].

2.5 Statistical analysis

The data obtained were analyzed by the Independent Sample t-test using IBM@SPSS 12 to determine the statistical differences. The results with $P<0.05$ were considered to be significantly different.

3. RESULTS AND DISCUSSION

The results of the physical and mechanical properties of *Swietenia macrophylla* grown in mixed and monoculture plantation are presented in the Table 1. In Bangladesh, *Tectona grandis* has been considered as the standard for comparing the wood properties as it is very good timber for all purposes. The physical and mechanical properties of Chittagong *T. grandis* of 40 years age group was found to attain the optimum values and this was recommended as the standard for Bangladesh to which all other timber species may be compared in determining the suitability for various purposes [11]. Hence, the physical and mechanical properties of 40 year's old *T. grandis* are presented in Table 1. The relative values to those of *T. grandis* expressed as percentage are also given in Table 2 and Table 3 respectively. Table 4 and Table 5 show the statistical analysis of physical and mechanical properties between mixed plantation and monoculture plantation respectively.

3.1 Moisture content

The moisture content of wood in the living trees, even of the same species, is highly variable. It appears to be variously affected by a number of factors, such as position in the stem (longitudinal or transverse, sapwood or heartwood), density variation, locality factors and seasons of the year [11, 12]. From the study it has been found that values of moisture content of mixed and monoculture plantation of *S. macrophylla* were 35.46% and 37.27% respectively (Table 1). The moisture content is higher in monoculture plantation but no statistically significantly difference between mixed and monoculture plantation (Table 4). The values were compared with the values of the moisture content of *Tectona grandis* and it was found that 35% and 32% lower moisture content in *S. macrophylla* when grown in mixed and monoculture plantation respectively.

Table - 1: Physical and mechanical properties of *Swietenia macrophylla* wood grown in different plantations

Properties and conditions		*Swietenia macrophylla*		*Tectona grandis*
		Mixed plantation	Monoculture plantation	
Moisture content (%)		35.46	37.27	55.0
Shrinkage (%)	Tangential	3.11	3.52	3.00
	Radial	2.20	2.15	2.00
	Volumetric	5.59	5.96	5.00
Density (gm/cm^3)	Green condition	0.50	0.49	0.58
	Oven dry condition	0.54	0.52	0.61
Compression strength (N/mm^2)	Parallel to grain	44.51	41.21	39.00
	Perpendicular to grain	17.38	14.78	-
Tensile strength (N/mm^2)	Parallel to grain	108.08	96.07	103.60
MOR	Oven dry	69.97	68.57	85.02
MOE	Oven dry	7343.10	7210.34	10767.98

Table - 2: Physical properties of mixed and monoculture plantation grown *S. macrophylla* wood relative to *T. grandis* expressed as percentage

Type of plantation	Moisture content	Shrinkage			Density	
		Tangential	Radial	Volumetric	Green	Oven dry
Mixed	65	104	110	112	86	89
Monoculture	68	117	108	119	84	85

Table - 3: Mechanical properties of mixed and monoculture plantation grown *S. macrophylla* wood relative to *T. grandis* expressed as percentage

Type of plantation	Tensile strength parallel to grain	Compression strength parallel to grain	MOR	MOE
Mixed	104	116	82	67
Monoculture	93	108	81	68

Table - 4: Summery of Independent Sample t-test for physical properties of *S. macrophylla* wood grown between mixed and monoculture plantation

Moisture content	Shrinkage			Density	
	Tangential	Radial	Volumetric	Green	Oven dry
ns	ns	ns	ns	ns	ns

Note: ns = not significant at P = 0.05.

Table - 5: Summery of Independent Sample t-test for mechanical properties of *S. macrophylla* wood grown between mixed and monoculture plantation

Compression strength		Tensile strength		MOR	MOE
Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		
ns	ns	ns	ns	ns	ns

Note: ns= not significant at P = 0.05

3.2 Tangential shrinkage

Tangential shrinkage of mixed and monoculture plantation grown *S. macrophylla* were 3.11% and 3.52% respectively (Table 1). The tangential shrinkage of monoculture plantation grown *S. macrophylla* was higher than the mixed plantation. But there was insignificant difference between the two types of plantation (Table 4). Sattar *et al.* [13] reported 2.58% tangential shrinkage of *S. macrophylla* grown in monoculture plantation in Chittagong. 3.0% tangential shrinkage was also reported by Building Research Establishment [14]. While some author found the higher tangential shrinkage compare to the present study. Dayan [5] reported tangential shrinkage of *S. macrophylla* in Indoneshia varies from 4.1% to 5.7%. In comparison to the monoculture plantation grown tangential shrinkage of *S. macrophylla*, Haslett *et al.* [15] reported 2.2% tangential shrinkage when *S. macrophylla* planted in mixed plantation in South Pacific Islands.

Thus from the above discussion it is proved that the tangential shrinkage of *S. macrophylla* is higher in monoculture plantation than mixed plantation, which is similar to the present study. The values were compared with the values of *T. grandis* and 4% and 17% higher tangential shrinkage had been found in mixed and monoculture plantation grown *S. macrophylla.*

3.3 Radial shrinkage

The radial shrinkage of mixed and monoculture plantation of *S. macrophylla* was 2.20% and 2.15% respectively (Table 1). In this case the mixed plantation grown *S. macrophylla* showed the higher values than monoculture plantation grown *S. macrophylla* but there was insignificant (Table 4) difference in radial shrinkage between these two types of plantation. Building Research Establishment [14] also reported that the radial shrinkage of S*. macrophylla* planted in monoculture plantation was 2.0%. Dayan [5] reported radial shrinkage of *S. macrophylla* in Indoneshia varies from 3.0% to 3.3%. Haslett *et al.* [15] reported that the radial shrinkage of *S. macrophylla* in mixed culture plantation was 1.4%.

From the above discussion it is clear that the radial shrinkage values can be higher or lower with in mixed and monoculture plantation *S. macrophylla*. The values were compared with the values of *T. grandis* and it had been found that the radial shrinkage of mixed and monoculture plantation was 10% and 8% higher respectively than *T. grandis.*

3.4 Volumetric shrinkage

The observed volumetric shrinkage of mixed and monoculture plantation was 5.59% and 5.96% respectively. So it was found that the volumetric shrinkage value of monoculture plantation of *S. macrophylla* was higher than the mixed plantation but it was also insignificant (Table 4) between two types of plantation. Sattar *et al*. [13] reported that the volumetric shrinkage of monoculture plantation *S. macrophylla* was 5.1%. Dayan [5] reported that the volumetric shrinkage of S*. macrophylla* was 7.4%. The tested values were compared with the teak and it was found that the volumetric shrinkage of mixed and monoculture plantation was 12% and 19% higher than T. grandis.

3.5 Density

The green density of mixed and monoculture plantation of S. macrophylla was 0.50 gm/cm^3 and 0.49 gm/cm^3 respectively. On the other hand, the oven dry density of mixed and monoculture plantation was 0.54 gm/cm^3 and 0.52 gm/cm^3 respectively. In both case the difference between two types of plantation was not significant (Table 4). From the study it had been found that *S. macrophylla* grown in mixed plantation had higher density both in green and oven dry condition. Sattar *et al*. [13] reported that green and oven dry density of *S. macrophylla* were 0.45 gm/cm^3 and 0.50 gm/cm^3 grown in Chittagong and Chittagong hill tracts. Moreover, others reported the density of *S. macrophylla* when grown as a monoculture plantation; Mayhew and Newton [9] found that the density of *S. macrophylla* was quite variable, ranging from 0.55 to 0.71 gm/cm^3. Again, Dayan [5] stated that the oven dry density of monoculture plantation grown *S. macrophylla* in Indonesia was 0.54 gm/cm^3. Irrespective of the monoculture or mixed plantation, according to Building Research Establishment [14] 0.54 gm/cm^3 density was found for *S. macrophylla*.

In comparison to density of *S. macrophylla* in monoculture plantation, Haslett *et al.* [15] reported that the green and oven dry density of *S. macrophylla* were 0.46 gm/cm^3 and 0.53 gm/cm^3 respectively in mixed plantation in South Pacific Islands. In comparison of the relative values to *T. grandis* the green density of *S. macrophylla* were 14% and 16% lower in mixed culture and monoculture plantation respectively. The oven dry densities were 11% and 15% lower than that of *T. grandis* wood.

3.6 Compression strength

The observed value of compression parallel to grain was 44.51 N/mm^2 in mixed plantation and 41.21 N/mm^2 was in monoculture plantation, it had been found that the compression parallel to grain was higher in mixed plantation *S. macrophylla* than monoculture plantation.

The difference of this property was also insignificant between two types of plantation (Table 5). Dayen [5] reported that the compressive strength parallel to grain of *S. macrophylla* ranged from 36 to 40 N/mm^2, when grown in monoculture plantation in Indonesia. While, Haslett *et al.*, [15] found that the compressive strength parallel to grain of *S. macrophylla* 43 N/mm^2 when grown in mixed

plantation in South Pacific Islands. It was also found that the value of compression parallel to grain was 116% of *T. grandis* in mixed plantation and 108% of *T. grandis* in monoculture plantation. The result of compression perpendicular to grain was 17.38 N/mm^2 in mixed plantation and 14.78 N/mm^2 in monoculture plantation of *S. macrophylla*. The difference of compression perpendicular to grain was also insignificant between the two types of plantation (Table 5).

3.7 Tensile strength

Tension parallel to grain was 108.08 N/mm^2 in mixed plantation and 96.07 N/mm^2 in monoculture plantation of *S. macrophylla*. Mixed plantation showed the higher values than the monoculture plantation but there was insignificant difference of tension parallel to grain between mixed and monoculture plantation (Table 5). The value of tensile strength parallel to grain of *S. macrophylla* grown in mixed plantation was higher than that of *T. grandis* and the relative value was 104%, while the value of tensile strength parallel to grain in monoculture plantation was lower than that of *T. grandis* and the relative value was 93%.

3.8 MOR and MOE

The MOR and MOE value of mixed plantation grown wood were slightly higher than wood from monoculture plantation but there were no significantly difference of these properties between the two type plantations grown wood. *S. macrophylla* grown in Chittagong region showed MOE 10204 N/mm^2 and MOR 61 N/mm^2 [13]. Soerjanegara and Lemmens [16] reported MOR 55 to 61 N/mm^2 and MOE 9000 to 9950 N/mm^2 of *S. macrophylla* wood in Indonesia. Anon [17] found the MOR and MOE of American mahogany as 62.10 N/mm$_2$ and 9200 N/mm^2 respectively. The MOR and MOE of *S. macrophylla* were relatively lower than *T. grandis* in both type of wood.

4. CONCLUSION

Swietenia macrophylla is regarded as the world's finest timber for high class furniture and cabinetwork. This species is planted both in mixed and monoculture plantation in Bangladesh. From the study it has been found that the physical and mechanical wood properties of *S. macrophylla* grown in mixed plantation showed slightly higher value than that of monoculture plantation grown *S. macrophylla* wood but these variations were not statistically significantly different. In general, the management practices, microclimate, genetic properties and edaphic factors are variable between mixed and monoculture plantation which may have effect on the properties of wood but in the present study the variations of wood properties between these two types of plantations were not evident.

ACKNOWLEDGEMENT

The authors wish to thank the Department of Mechanical Engineering of Khulna University of Engineering and Technology (KUET), Khulna, Bangladesh for providing the support to test the mechanical properties of wood specimens.

REFERENCES

[1] M. A. Sattar M.A. and A. F. M. Akhtaruzzaman. *End-use Classification of Lesser Used or Un-used wood species*. Forest Product Branch, Bangladesh Forest Research Institute, Chittagong, 117 pp. 1997.

[2] N. Q. Zabala. *Silviculture of Species*. Institute of Forestry, Chittagong University, Chittagong, Bangladesh. 135-139 pp. 1990.

[3] M. A. Latif. Growth and yield of Bokain, Koroi, Mahagony, Sissoo and Eucalyptus planted on croplands in Bangladesh. Village and Farm Forestry Program, Swiss Agency for Development and Co-operation. Dhaka, 29 pp. 1999.

[4] M. A. Latif. Growth and yield of Sissoo (*Dalbergia sissoo*) and Mahagony (*Swietenia macrophylla*) planted as woodlot in the western part of Bangladesh. Village and Farm Forestry Program, Swiss Agency for Development and Co-operation. Dhaka, 29 pp. 1999.

[5] M. P. Dayan. Mahagoni: A compilation of RISE issues. Ecosystem Research and Development Bureau. pp. 64-74. 1989.

[6] M. K. Chowdhury. Agroforestry in homesteads and croplands: Existing practices and potentials. In M. K. Alam, F. U. Ahmed and S. M. R. Amin Ed. *Agroforestry: Bangladesh Perspective*. Bangladesh Agriculture Research Council, 1997.

[7] M. M. Mustafa. Floristics and indigenous management techniques of home gardens in Bangladesh. In M. K. Alam, F. U. Ahmed and S. M. R. Amin Ed. *Agroforestry: Bangladesh Perspective*. Bangladesh Agriculture Research Council, 1997.

[8] M. M. Mustafa, M. A. Hossain, and M. S. Shamim. "Existing traditional agroforestry practices in Kustia district - a case study in system concept". Journal of Forestry and Environment, vol. 2, pp. 79-89. 2004.

[9] J. E. Mayhew and A. C. Newton. *The Silviculture of Mahagony*. Institute of Ecology and Resource Management, University of Edinburgh, UK, 1998.

[10] H. E. Desch and J. M. Dinwoodie.. *Timber: its Structure, Properties and Utilization*. McMillan Education Ltd., New York, 385 pp. 1980.

[11] M. Yakub, M. O. Ali and D. K. Bhattacharjee. Strength properties of Chittagong Teak (*Tectona grandis*) representing different age groups. Bulletin 4, Timber Physics Series, Bangladesh Forest Research Institute, Chittagong, 12 pp. 1978.

[12] J. L. Bowyer, R. Shmulsky and J. G. Hygreen. *Forest Products and Wood Science: An Introduction*, 5th Edn. Iowa State University Press, USA. 2007.

[13] M. A. Sattar., D. K. Bhattacharjee and M. F. Kabir. Physical and mechanical properties and uses of timbers of Bangladesh. Seasoning and Timber Physics Division, Bangladesh Forest Research Institute. Chittagong, 57 pp. 1999.

[14] BRE. *A Handbook of Hardwoods*. Building Research Establishment, UK, pp. 56-77. 1972.

[15] N. Haslett, G. D. Young and Britton, R. A. J. "Plantation grown tropical timbers-2: properties, processing and uses". Journal of Tropical Forest Science, vol. 3, no. 3, page 229-237, 1990.

[16] S. Soerjanegara and R.H.M.J Lemmens. *Timber Trees: Major Commercial Timbers.* Plant Resources of South East Asia, Philippines, pp. 442-446. 1994.

[17] Anon. *Wood Handbook: Wood as an Engineering Material*. Forest Products Laboratory, USDA Forest Service, Madison, USA, pp. 239-345, 1999.