Available online at www.banglajol.info

Bangladesh J. Sci. Ind. Res. **52(1),** 49-52, 2017

BCSIR

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

E-mail: bjsir07@gmail.com

Effect of waterlogging on physical and mechanical properties of *Samanea saman* (Jacq.) Merr. tree

Elias[1], A. K. Das[1,2]*, M. M. Rahman[1], M. A. Islam[1]

[1]*Forestry and Wood Technology Discipline, Khulna University, Khulna-9208, Bangladesh*
[2]*Pulp and Paper Technology, Asian Institute of Technology, Klong Luang, Pathumthani-12120, Thailand*

Abstract

This research intends to explore the mechanical and physical properties of waterlogged rain tree (*Samanea saman*). The variation of mechanical and physical wood properties grown in waterlogged and non-waterlogged area were studied. Four trees of the species were selected from two areas. Important mechanical and physical properties were examined for the wood of two types of trees. Oven dry density for the wood of waterlogged tree was 420 kg/m^3 whether it was 550 kg/m^3 for the wood of non-waterlogged tree. The MOR of wood of waterlogged tree was 58.2 N/mm^2 and wood of non-waterlogged tree produced 78.1 N/mm^2. The MOE of the wood of waterlogged tree and non-waterlogged tree were 1478 and 4876 N/mm^2. The physical and mechanical properties were lower for the wood of waterlogged tree. Such findings may in proper uses of the species.

Key words: *Samanea saman;* Waterlogging; Non-waterlogging; Physical properties; Mechanical properties

Introduction

Waterlogging is a process or condition in which the water table reaches or rises above the ground surface, or its capillary fringe is near to the surface; or any condition of the soil where, due to its moisture content, aeration does not suffice to maintain the health of a given period. Waterlogging is the major problem affecting the agricultural productivity and sometimes becomes too severe to take it out from economic crop production (Jackson and Ram, 2003).

Samanea saman (rain tree) is a tree of liguminosae (Mimosoideae) and is a middle sized to large evergreen tree with a short bole and enormous wide spread umbrella shaped crown extending up to 30 m in diameter. In natural forest, it reaches a height of 20-30 meters and diameter at breast height (dbh) is 80-100 cm. When it is planted in parks or roadsides, it develops an umbrella- like crown attaining a height of about 15- 20 m and dbh of 150 cm and above (Luna, 1996). The rain tree survives impeded drainage and waterlogging (Staples and Elevitch, 2006).

Biological process is the way to produce wood. Wide ranges of genetic and environmental influences are important factors to grow wood. It has a wide range of properties and characteristics (Punches, 2004). Difference between site fertility and geographic location (temperature, sunlight) are the major sources of the variation between different stands (Barntt and Jeronimidis, 2003). Environmental factors affect the structure of the wood of a tree in a number of ways (Desch and Dinwoodie, 1996). Environment includes a large diversity of factors that act both below the ground (e.g., moisture, nutrients in the soil) and above the ground (e.g., light, temperature) (Green *et al*., 1999).

Utilization of wood for various purposes is dependent on the properties of wood. Properties of wood for construction engineering are different from musical instrument. Physical and mechanical properties are important factors to consider the suitable end uses (Mullins and McKnight, 1981).

S. saman wood is mainly used as a second-class fuel in the urban areas and also for petty constructional work. The wood is durable under water (Luna, 1996). As *S. saman* is grown in waterlogged and non-waterlogged region and properties are dependent on environment where it is grown as well. It is thus important to identify the properties of both the types. In this study, it was tried to compare the physical and mechanical properties of wood of waterlogged *S. saman* and non-waterlogged *S. saman*.

Materials and methods

The trees used in this study were grown in Nowapara, Tala

*Corresponding author: e-mail: atanu03ku@yahoo.com

(22°76/ N and 89°21/ E) in Satkhira District in Bangladesh. The trees were 15-year-old, fairly straight and free from natural defects. Among four trees, two trees were taken from the water logged and another two trees were from non-waterlogged area.

Each bole was cut into 1.5 m logs after felling trees. The base of the tree was considered up to 1.5 m from the stump height, up to 1.5 m above the base was considered as middle and above the middle was considered as top. All these positions were crosscut through marking and sawn into specimens. Samples were collected from the base, middle, and top of the tree. Ensuring heartwood in each position, the specimens were collected from near the center of the log avoiding the pith.

Physical properties were determined by the standard ASTM D 1037-100 (ASTM 2006). DIN 52362 (DIN 1984) was used to accomplish mechanical properties. Physical and mechanical properties were done in three portions of each type of tree. The results were made average for each variety to conclude the findings.

The data obtained during the laboratory test were analyzed for the interpretation of physical and mechanical properties. Microsoft Office Excel 2013 and SPSS (Statistical Package of Social Survey) 11.5 software were used for the analysis of both type of properties.

Results and discussion

Physical properties

The average moisture content of the wood of waterlogged tree was 22.6% and 16.5% for non-waterlogged tree. Statistical analysis showed that the moisture content (%) of wood of waterlogged tree was significantly different from wood of non-waterlogged tree (Table I). Wood of waterlogged contained more moisture in comparison to wood of non-waterlogged tree. (Arnold and Mauseth, 1999) stated that wood contains more moisture due to getting availability of water where it is grown and its lower cell density enhances containing higher moisture. Similar tendency was observed by Alam *et al*. (2015).

It was observed that air dry density of wood of waterlogged tree was 410 kg/m^3 while it was 520 kg/m^3 for the wood of non-waterlogged tree (Fig. 1). Oven dry density was 420 kg/m^3 for the wood of waterlogged tree but wood of non-waterlogged tree showed density of 550 kg/m^3 (Fig. 1). Wood of waterlogged tree showed slightly lower density than that of non-waterlogged tree. From the independent sample test, significant difference was found between wood of waterlogged and non-waterlogged tree for both types of density (Table I). Alam *et al*. (2015) also found that waterlogged tree had lower density wood than that of non-waterlogged tree. Waterlogged tree has lower cell wall density due to availability of moisture in all around the year and this reason produces lower density wood (Arnold and Mauseth, 1999). Low density wood is the result of low cell wall density (Haygreen and Bowyer, 1989; Desch and Dinwoodie, 1996).

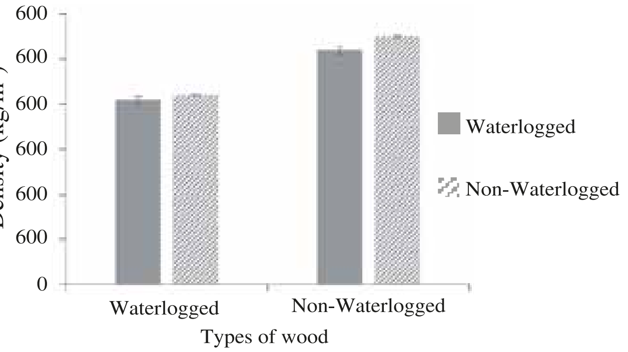

Fig. 1. Density of wood of waterlogged and non-waterlogged tree

Tangential (TS), radial (RS), longitudinal (LS) and volumetric (VS) shrinkage were 1.78, 1.26, 1.02 and 4.17% respectively for wood of non-water logged tree and 1.60, 1.24, 0.84 and 3.71% respectively for wood of waterlogged tree (Fig. 2). Three types of shrinkage (%) were higher for wood of non-waterlogged tree in contrast with wood of waterlogged tree. Shrinkage (%) of wood of waterlogged tree was significantly different from wood of non-waterlogged tree (Table I). Wood of non-waterlogged tree showed higher shrinkage (%) because of higher density. Higher density wood shows higher shrinkage (%) (Koubaa and Smith, 1959; Karki, 2001; Pliura *et al*., 2005; Kord *et al*., 2010; Alam *et al*., 2015).

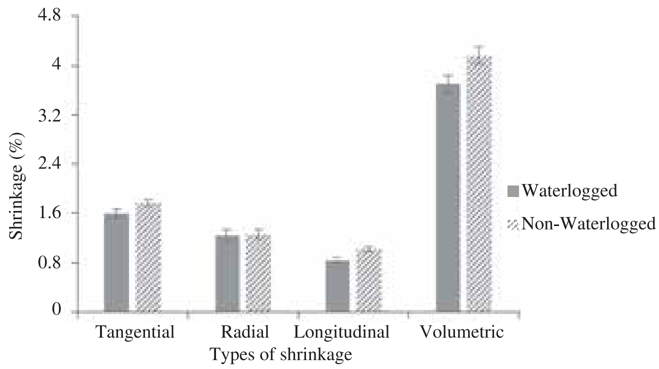

Fig. 2. Shrinkage of wood of waterlogged and non-waterlogged tree

Wood of non-waterlogged tree showed swelling of tangential (TSW), radial (RSW), longitudinal (LSW) and volumetric (VSW) 3.04, 1.94, 0.99 and 6.01% respectively (Fig. 3). Waterlogged tree showed tangential, radial, longitudinal and volumetric swelling of 2.07, 1.31, 0.72 and

4.09% respectively for wood (Fig. 3). Swelling (%) was significantly higher for wood of non-waterlogged tree (Table I). Swelling (%) increases with increasing density (Koubaa and Smith, 1959; Karki, 2001; Pliura *et al*., 2005; Alam *et al*., 2015). Density of wood of non-waterlogged tree was higher than that of wood of waterlogged tree.

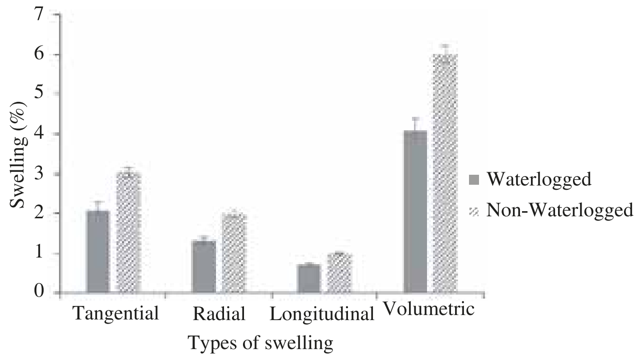

Fig. 3. Swelling of wood of waterlogged and non-waterlogged tree

difference between two types of wood (Table III). MOR of wood is influenced by density and moisture content (%). (Haygreen and Bowyer, 1989; and Desch and Dinwoodie, 1996) investigated that the MOR increased with increasing density of wood. (Gerhards, 1982; Matan and Kyokong, 2003; and Alam *et al*., 2015) stated that MOR of wood is increased with decreasing of moisture content (%). In this study, high density and low moisture content (%) containing wood of non-waterlogged tree showed higher value of MOR.

The Modulus of Elasticity (MOE) was 1478 N/mm^2 for the wood of waterlogged tree and MOE of wood of non-waterlogged tree was 4876 N/mm^2 (Table II). The MOE was higher for the wood of non-waterlogged tree. The independent sample test showed significant difference between two types of wood for MOE (Table III). In previous studies, higher MOE with increasing density was observed (Haygreen and Bowyer, 1989; Desch and Dinwoodie, 1996). Low moisture content (%) enhances MOE (Gerhards, 1982; Matan and Kyokong, 2003; Alam *et al*., 2015). In the case of wood of non-waterlogged tree showed higher MOE as it had high density and low moisture content (%).

Table I. Summaries of independent sample t-test of physical properties

Moisture Content* (%)	Density kg/m^3		Shrinkage (%)				Swelling (%)			
	Air Dry*	Oven Dry*	TS*	RS*	LS*	VS*	TSW*	RSW*	LSW*	VSW*
df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05	df=34, t=7.08 and P<0.05

*Significant difference at 95% level of confidence

Mechanical properties

The tensile strength of the wood of waterlogged tree was 32.3 N/mm^2 and it was 44.8 N/mm^2 for the wood of non-waterlogged tree (Table II). The lower tensile strength was found for wood of waterlogged tree. The independent sample t-test proved that there was significant difference between two types of wood (Table III). According to (Tsoumis, 1991), the mechanical performance of wood with low density being inferior to that of wood with high density. Wood density of non-waterlogged tree was higher and it showed higher tensile strength. Previous investigator found that tensile strength increased with increasing density of wood (Haygreen and Bowyer, 1989; Desch and Dinwoodie, 1996). Tensile strength decreased with increasing of moisture content (%). Wood of waterlogged tree had higher moisture content (%). (Gerhards, 1982; Matan and Kyokong, 2003; and Alam *et al*., 2015) observed the similar result.

The Modulus of Rupture (MOR) of wood of waterlogged tree and non-waterlogged tree were 58.2 and 78.1 N/mm^2 (Table II). Statistical analysis showed the significant

Table II. Mechanical properties of wood of waterlogged and non-waterlogged tree

Types of wood	Mechanical properties		
	Tensile Strength (N/mm^2)	MOR (N/mm^2)	MOE (N/mm^2)
Waterlogged	32.3 (2.5)	58.2 (3.5)	1478 (107.2)
Non-waterlogged	44.8 (2.3)	78.1 (2.7)	4876 (103.0)

*Values in parenthesis indicate standard error

Table III. Summaries of independent sample t-test of mechanical properties

Tensile Strength (N/mm^2)*	MOR (N/mm^2)*	MOE (N/mm^2)*
df =34, t = 3.68 and P<0.05	df =34, t = -2.55 and P<0.05	df =34, t = -15.69 and P<0.05

*Significant difference at 95% level of confidence

Conclusion

The density, moisture content and mechanical properties were better for the wood of non-waterlogged tree. The swelling and shrinkage were better for the wood of waterlogged tree. The utilization of wood depends on the properties of wood. This type of study will help to utilize the wood of waterlogged tree based on its properties. Further study is necessary for the determination of the effect of water logging condition on minute structure of wood of waterlogged tree.

References

Alam J, Das AK, Rahman MM and Islam MA (2015), Effect of waterlogged condition on wood properties of *Acacia nilotica* (L) Debile tree, *Bangladesh J. Sci. Ind. Res.* **50**(2): 71-76, DOI: http://dx.doi.org/10.3329/bjsir.v50i2.24347.

Arnold DH and Mauseth JD (1999), Effects of Environmental Factors on Development of Wood, *American Journal of Botany* **86**(3): 367–371.

ASTM (AMERICAN SOCIETY FOR TESTIG MATERIALS) (2006), ASTM D 1037-100. Standard Test Methods for Evaluating Properties in of wood-based fiber and particle panel materials, ASTM International, West Conshohocken.

Barnett JR and Jeronimidis G (2003), Wood Quality and Its Biological Basis, CRC Press LLC, 2000 Corporate Blvd., N.W., Boca Raton FL 33431, USA ISBN 0-8493-2819-5. pp 1-226.

Desch HE and Dinwoodie JM (1996), Timber Structure, Properties, Conversion and Use.7th Ed. (Macmillan press Limited. London), p 306.

DIN (DEUTSCHES INSTITUT FUR NORMUNG) (1984), DIN 52362. Testing of Wood Chipboards Bending Test, Determination of Bending Strength. Normen Fur Holz Faserplaten Spanplatten Sperrholz, Berlin.

Gerhards CC (1982), Effect of Moisture Content and Temperature on The Mechanical Properties of Wood: An Analysis Of Immediate Effects, *Wood and Fiber* **14**(1): 4-36.

Green WD, Winandy JE. and Kretschmann DE (1999), Mechanical Properties of Wood. Wood handbook-Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory p 463.

Haygreen JG and Bowyer JL (1989), Forest Products and Wood Science, Iowa State University Press, USA.

Jackson MB and Ram PC (2003), Physiological and Molecular Basis of Susceptibility and Tolerance of Rice Plants to Complete Submergence. *Annals of Botany* **91**: 227-241.

Karki T (2001), Variation of wood density and shrinkage in European aspen (Populus tremula), *Holz J* **59**: 79-84.

Kord B, Kialashaki A and Kord B (2010), The within-tree variation in wood density and shrinkage, and their relationship in Populus euramericana, *Turk J Agric For* **34**:121-126.

Koubaa RW and Smith JHG (1959), The effect of some genetic and environmental factors on wood quality in poplar, *Pulp & Paper J* **59**: 37-38.

Luna RK (1996). Plantation Trees. International Book Distributors, India pp 662-664

Matan N and Kyokong B (2003), Effect of moisture content on some physical and mechanical properties of juvenile rubberwood (*Hevea brasiliensis* Muell. Arg.). Songklanakarin *J. Sci. Technol.* **25**(3): 327-340.

Mullins EJ and McKnight TS (1981), Canadian Woods, Their Properties and Uses, 3rd Edition, Supply and Services Canada, Ottawa.

Pliura A, Yu Q, Zhang SY, Mackay J, Pierre P and Bousquet J (2005), Variation in wood density and shrinkage and their relationship to growth young poplar hybrids crosses, *Forest Sci J* **51**: 472-482.

Punches J (2004), Tree Growth, Forest Management, and Their Implications for Wood Quality, PNW 576, 8 pages, illustrated.

Staples GW and Elevitch CR (2006), Samanea saman (rain tree), ver. 2.1. ***In:*** Ed. Elevitch C.R. Species Profiles for Pacific Island Agroforestry, Permanent Agriculture Resources (PAR), Holualoa, Hawai, Available at: http://www.traditionaltree.org Date accessed on 21st March, 2008).

Tsoumis G (1991), Science and Technology of Wood Structure, Properties, Utilisation, Van Nostrand Reinhold, New York, USA, ISBN 0-442-23985-8, pp 69-72, 112, 114-120, 128-130, 163-165, 172-176.

Received: 12 July 2016; Revised: 26 July 2016; Accepted: 28 July 2016.