The Effect of Site Class, Tree-age and Axial Direction on Adhesion Properties of Teakwood

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Abstract

Teak wood is a well-known prime wood species in Indonesia. The teak forest had been managed well by PERHUTANI, a state forest company for a long time. In the teak forest the site quality has been classified according to land's capability to grow the teak plant. This site classification had been set up from the beginning of forest management and it has not been reviewed yet. This research's objectives are to know the effect of teak forest site quality class and axial direction on the adhesion properties of the teak wood. The research conducted using Completely Randomized Design arranged in factorial experiment. The first experiment used site quality and axial direction factors, while the second experiment used tree's age and axial direction. The site quality factor consisted of three levels of site index III, III/IV and IV. The three levels of axial direction of the teak stem were butt, center and top. The tree's age consisted of three age class of 25, 35 and 45 years. Three teak trees employed as replication. The adhesion properties parameter were wood specific gravity, adhesion compression shear test and wood failure in both dry and wet condition using block test. The first research result showed that no interaction factor affected in adhesion properties. The teak growing site-class influenced significantly to the wood specific gravity and adhesion shear strength. The more fertile of teak growing site class, the lower wood specific gravity and adhesion strength. The site class of III, III/IV and IV revealed the average wood's specific gravity of 0.54; 0.50 and 0.47 consecutively. The adhesion strength produced from the three site classes were 41.71; 32.56 and 23.52 kg/cm^2 consecutively. The axial direction (from the butt to the top) showed a decreasing trend of wood specific gravity and adhesion strength. The second research showed that tree age affected significantly the wood specific gravity. The wood specific gravity increased from 0.57 to 0.67 and 0.69 produced from tree age of 25, 35 and 45 year old consecutively.

Keywords: teak wood, site class, age, axial direction, adhesion strength.

Introduction

Teak wood is considered as a prime wood globally. It is also a prime wood in Indonesia and is used by high rank social status of Indonesian people. When someone has a house made of teak wood, this means the man is considered as a rich and famous people. This condition is caused by very high price of teak wood. For that reason all Indonesian people are trying to build a house using teak wood.

Teak wood in Indonesia had been produced for quite long time from natural teak forest found in Java since the Dutch occupation. The Dutch Company has employed a relatively good teak forest management. They had set up a normal teak wood standing volume per unit area of teak plantation. This table that is called WvW table has been used up to now and it has not been experiencing a significant change. During the Political Reformation in 1998, the teak plantation had been suffering significant damages in such a way that a normal condition of teak forest has altered (Anonymous 1998). In this condition the teak forest has been receiving significant change in terms of the total number of teak trees per unit area and basal area of teak trees as well. This condition has been detected to affect the site quality whereon the teak trees had been planted.

In terms of teak silviculture, teak follows many stages of forest plantation namely, seedling in nursery, field planting in a close spacing, thinning, pruning and harvesting. After field planting, the teak forest is classified into tree age class of ten years. Teak seedlings are planted in a small compartment based on homogenous site quality index (SQI). Marsono and Soeseno (1992) states the principles of silviculture in forest plantation in order to come to the big volume of wood at the end of rotation.

Based on the above discussion, a research has been planned. The research used the site quality whereon the teak trees had been planted, that is called site quality index (SQI). The second factor used in the research was chosen from the tree ages.

Materials and Methods

Materials

The teak trees were obtained from Kalibodri, Kendal Teak Management Unit of PERHUTANI. The teak trees were classified into three trees ages class namely 25 year old, 35 year old and 45 year old. Each tree age class was procured from three site quality index namely SQI III, SQI III/IV and SQI IV. Total of 9 trees were collected from the Kendal Teak Management Unit. The teak trees were sawn into radial sawn in Semarang and make samples for adhesion block test.

Research Design and Procedure

The research was conducted in two separate sub research or sub-experiment. The first sub-research used two factors namely site quality index (SQI) and axial position along the teak stem. The second sub-research used two factors namely tree age class and axial position along the teak stem. Those two sub-researches were designed using Completely Randomized Design with factorial experiment. Three replications were employed in each sub-research. Analysis of Variance used to know the effect of interaction factors and individual factor on the adhesion properties. The separation of means used HSD-Tukey procedure based on the probability of factors involved in the research.

In the first sub-experiment, the teak stem from each site quality index (SQI III, SQI III/IV and SQI IV) was divided into three axial positions namely butt, middle and top portion. From the axial position logs were then sawn into radial sawn type samples. Six wood radial type samples with dimension 2cm x 2cm x 30" were obtained from each axial position. They were glued by epoxy adhesive with 40#/MDGL in composing to three adhesion block test measuring 2 cm x 2 cm x 30 cm (Prayitno 1994). The block tests were conditioned for a week before subjected to adhesion test sample cutting measuring 2cmx2cmx2cm. The adhesion test were the tested by compression stress according to British Standard 373 (Anonymous 1957). Adhesion testing was conducted in dry condition and wet condition. Two adhesion parameters were adhesion strength and percentage of wood failure. Wood specific gravity of each adhesion samples were measured as well.

In the second sub-experiment, three teak trees age-classes was chosen, namely class of 25, 35 and 45 year-old. Teak logs obtained were then cut into three axial positions namely butt, middle and top portion. Each log was then sawn to obtain radial lumber. From these lumber, samples were prepared following the British Standard as stated in first sub-experiment procedure.

Results and Discussion

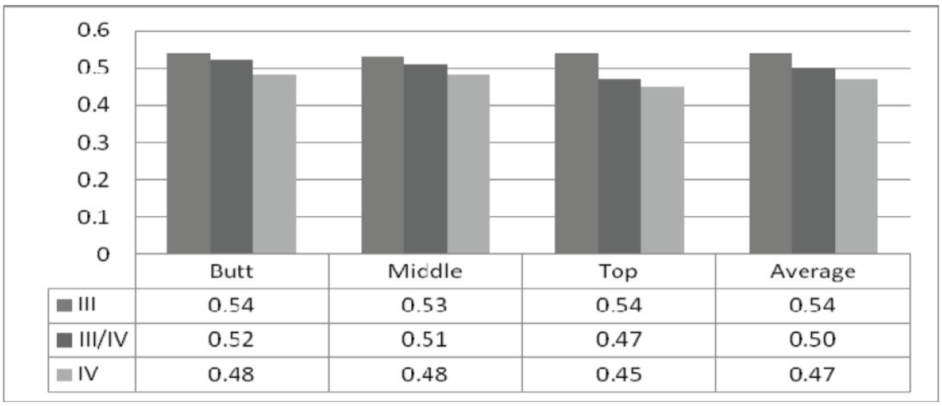
The ANOVA of data obtained from first experiment showed that interaction factors of SQI and axial position did not affect the adhesion strength of teak wood. The single factor of axial position did not exert a significant effect on the adhesion strength as well. Site Quality Index (SQI), however, revealed the significant effect on the wet adhesion strength and high significant effect on wood specific gravity (Table 1). This means that SQI whereon teak tree grow has really affected its wood specific gravity (Figure 1) and dry and wet adhesion strength (Figure 2). The dry adhesion strength was affected by SQI at 90%, therefore it is not significant at 95% level. Site quality index (SQI) is a measure of fertility of the soil whereon the teak trees grow. More fertile the soil means more soil nutrient for teak to grow fast and healthy (Bermejo *et al*. 2004). In this case teak trees has been supplied by enough chemical elements and water for making buds, growing hormones and faster cells division and enlargement. This condition has promoted the higher number of cells produced but having thinner cell wall. This condition consequently producing large diameter of teak trees but smaller wood specific gravity (Brown *et al.* 1952; Kollmann *et al*., 1975).

Site quality whereon plant grows really affects the wood properties (Dreschel *et al*. 1990). Soil fertility reveals enough nutrients available for plant to grow such as Mg, K, Ca and other ion uptake by the plants. Abod and Siddiqui (2002) measured the teak growth upon application of Nitrogen, phosphorous and potassium fertilizers. For that reason the soil fertility represented by SQI in PERHUTANI has been proven to be the important factors that affect the growth of teak plantation (Kollert and Cherubini 2010). Figure 1 showed that from SQI III, SQI III/IV to SQI IV (meaning from low fertile soil to more fertile soil), the wood specific gravity has decreased from 0.54, 0.50 to 0.47. In addition Site quality reveals the faster growth of teak in Kerala for developing intrinsic growth to set a correction of growth model (Rugmini and Jayaraman 2009). This constant decreasing trend of wood specific gravity has been observed in three axial positions namely butt, middle and top portion of teak samples. Haygreen and Bowyer (1996) states that wood properties from butt to top portion of the stem have been observed following the same pattern.

In terms of adhesion strength, the result of the first sub-experiment showed that wet adhesion strength was significantly affected by SQI. This could be true, since the adhesion strength has been observed to have a very close relationship with wood specific gravity. Prayitno (1997) states that wood specific gravity has parallel relationship with adhesion strength. Based on Freeman data of adhesion strength of American wood (1959), higher specific gravity up to 0.8 higher adhesion strength. Wood specific gravity above 0.8 did not significantly affect the adhesion strength (Prayitno 1983). Dry adhesion strength is also affected by SQI at 90% level. Numerically, SQI has a decreasing effect on adhesion strength both at dry and wet condition (Figure 2). On the other hand factor axial position did not exert a significant effect on adhesion strength (Table 1). Numerically, there is an actual decrease trend of adhesion strength of samples obtained from butt, middle and top portion. Average of dry adhesion strength from butt, middle and top portion of teak stem are 48.86; 47.06 and 43.66 kg/cm^2 respectively. Wet adhesion strength from butt, middle and top portion of teak stem are 35.52; 32.99 and 29.29 kg/cm^2 respectively. Those adhesion strength data shows a decreasing trend effect of axial position. This trend is parallel to the effect of axial position on wood specific gravity (Farida 2005).

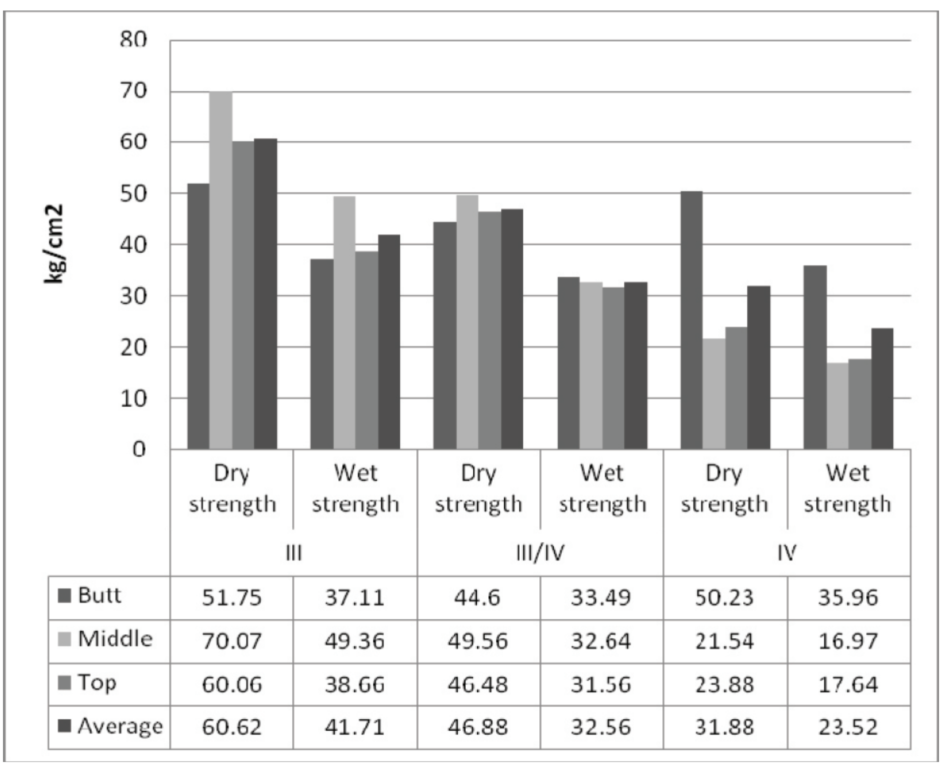
Table 1. ANOVA of effect of site quality (SQI) and axial position on adhesion strength, wood failure and wood specific gravity.

Research Variables	SQI	Axial Position	Interaction
Wood Specific Gravity	14,857**	1,852^{ns}	1,291^{ns}
Dry Shear Strength	2,630^{ns}	0,088^{ns}	0,676^{ns}
Wet Shear Strength	3,678*	0,437^{ns}	0,980^{ns}
Dry Percentage Wood Failure	3,192^{ns}	0,051^{ns}	0,802^{ns}
Wet Percentage Wood Failure	0,211^{ns}	0,836^{ns}	0,442^{ns}



	Butt	Middle	Top	Average
III	0.54	0.53	0.54	0.54
III/IV	0.52	0.51	0.47	0.50
IV	0.48	0.48	0.45	0.47

Figure 1. Wood specific gravity of teakwood affected by SQI.



	III		III/IV		IV	
	Dry strength	Wet strength	Dry strength	Wet strength	Dry strength	Wet strength
Butt	51.75	37.11	44.6	33.49	50.23	35.96
Middle	70.07	49.36	49.56	32.64	21.54	16.97
Top	60.06	38.66	46.48	31.56	23.88	17.64
Average	60.62	41.71	46.88	32.56	31.88	23.52

Figure 2. Variation of dry and wet adhesion strength of teak wood affected by SQI and axial position.

The second sub-experiment used two factors namely tree age class and axial position of the teak stem. The result of the research showed that interaction factors did not affect the adhesion strength. The single factor of the research, namely axial position has revealed a significant effect on wet adhesion strength and wet wood failure percentage at 95% level (Table 2). The axial position factor and tree age class exerted high significant effect on wood specific gravity (99%). The single factor tree age class only affected dry adhesion strength at 93%, but wet adhesion strength. Wood specific gravity of teak samples shows an increasing trend according to tree age class and axial position. Tree age class from 25 year-old, 35 year-old and 45 year-old produce wood specific gravity of 0.57; 0.67 and 0.69. Analogy, the tree axial position has parallel relationship with wood specific gravity as well. Average wood specific gravity of 0.69; 0.64 and 0.62 are shown by butt, middle and top position of the stem respectively (Figure 3). Tsoumis (1991) states that butt portion has a relatively bigger portion of heartwood, bigger percentage of mature wood thus produces high wood specific gravity consequently. Older tree reveals bigger diameter at breast height at the same site condition and upon observing its cross section resulting lower percentage of sapwood (Panshin and de Zeeuw 1980). Farida (2005) has shown the same trend on wood specific gravity in *Acacia auriculiformis* affected by tree ages and axial position.

In terms of wood adhesion properties, factor tree age class did not show a significant effect on dry and wet adhesion strength and wood failure in dry and wet condition as well (Figure 4 and 5). These results are very confusing. Numerically, dry adhesion strength, wet adhesion strength, wood failure at dry and wet condition show no specific pattern of data variation. Steel and Torrie (1981) stated that a significant effect can be produced by high precision data. On the other hand a relatively scattered, random data will result low level of significant probability. Normally, variation of wood specific gravity will be followed by the adhesion properties. This means that high wood specific gravity will produce high adhesion strength. Low wood specific gravity will result low adhesion strength respectively, as long as the range of wood specific gravity is still under 0.8 (Prayitno 1996; 1997). The wood variation according to tree age class factor shows a significant increase from 25 year-old to 35 year-old, but little increase shown by 35 year old to 45 year old. This might be responsible for the higher variation of adhesion strength.

Table 2. ANOVA of effect of Tree age class and axial position on adhesion strength, wood failure and wood specific gravity.

Variables Research	Tree Age	Axial Position	Interaction
Wood Specific Gravity	0,000**	0,004**	0,766 ^{ns}
Dry Adhesion Strength	0,087 ^{ns}	0,788 ^{ns}	0,995 ^{ns}
Wet Adhesion Strength	0,883^{ns}	0,042*	0,292^{ns}
Dry Percentage Wood Failure	0,143^{ns}	0,704^{ns}	0,758^{ns}
Wet Percentage Wood Failure	0,479^{ns}	0,040*	0,193^{ns}

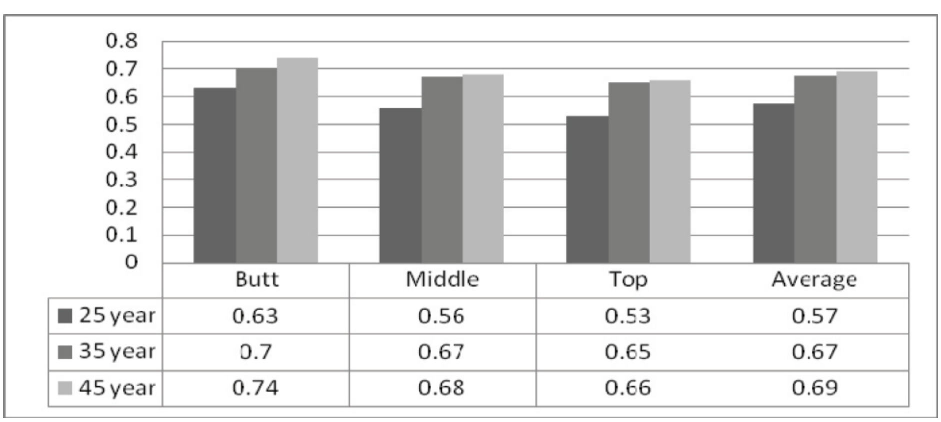


Figure 3. Wood specific gravity of teakwood affected by tree age class and axial position factors.

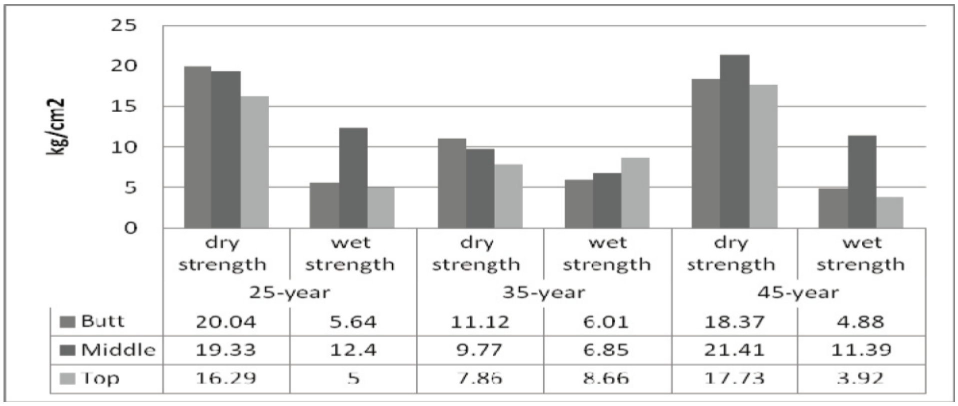


Figure 4. Adhesion strength of teakwood affected by tree age class and axial position factors.

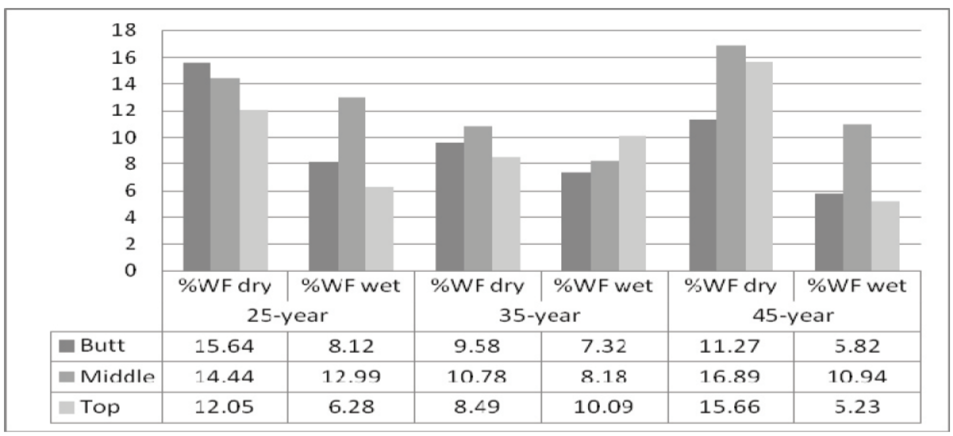


Figure 5. Percentage wood failure of teakwood affected by tree age class and axial position factors.

The axial position factor shows a fixed decrease trend of adhesion strength. The butt portion produces high adhesion strength than middle and top portion. Vick (1999) states that butt portion of the stem produces high value wood specific gravity. This will produce high adhesion strength consequently. Upper portion of the stem usually shows a decrease of wood specific gravity, thus produces lower value of adhesion strength (Tsoumis 1991).

The percentage of wood failure appears to follow the unidentified pattern of adhesion strength due to tree age classes. On the other hand axial position factor has revealed specific decrease pattern of wood failure percentage. From butt to top portion of the teak stem, it shows a decrease value of percentage of wood failure. Upon observation on the adhesion line, it shows difficulties to separate the epoxy glue from the wood fibers. This might increase the variation of wood failure (Putra *et al.* 2007).

Conclusions

The research on the effect of site quality index, tree age class and axial position has come to several conclusions as follows. The research result showed that no interaction factor affected in adhesion properties and wood specific gravity. In the first experiment no interaction factors effect observed in SQI and axial position and tree age class and axial position as well (second sub-experiment).

The teak growing site index (SQI) influenced significantly to the wood specific gravity and adhesion shear strength. The more fertile of teak growing site class (SQI), the lower wood specific gravity and adhesion strength. The site class of III, III/IV and IV revealed the average wood specific gravity of 0.54; 0.50 and 0.47 consecutively. The adhesion strength produced from the three site classes were 41.71; 32.56 and 23.52 kg/cm^2 consecutively. The tree age class and axial position factors affected significantly the wood specific gravity. The wood specific gravity increased from 0.57 to 0.67 and 0.69 produced from tree age of 25, 35 and 45 year old consecutively. The axial direction (from the butt to the top) showed a decreasing trend of wood specific gravity in both sub experiments. This factor did not show a homogenous effect on adhesion strength in both sub-experiments.

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