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Young Teak Application for Making Products Case Study: Young Teak from the Teak Plantation in West Java Area, Indonesia

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Abstract

The demand of wood is increasing, but the supply is limited, on the contrary, there are amount of potential young teaks (*Tectona grandis* L.f.) from the thinning of teak plantations that could contribute to meet this demand. This research intends to develop the suitable application of potential young teak from the thinning of the teak plantation in West Java area, Indonesia, for making products by taking the advantage of its prominent mechanical properties and characteristics. This research has assessed the mechanical properties, including bonding practice, and the characteristics of young teak from each of age classes in the rotation age of 40 years. Mechanical properties of young teak are the determination of its MOR and MOE, The result shows that there is no significant difference of strength between teak and young teak among the age classes, and young teak is having better bonding performance than mature teak. Characteristics of young teak vary in the grain of border and its color. Various contrast border-patterns between sapwood and its heartwood parts have been identified, and by using the certain configuration and joint systems create the unique appearances for application into various products. Approaches and methods in this research are also practicable to be applied for another wood species in which comprise sapwood and heartwood part in their wood trunk.

Keywords

Young teak; border-patterns; configuration; unique appearances; application

1. Teak and Young Teak

Teak (*Tectona grandis* L.f.) has been recognized as one of the famous and important species of tree from the tropical areas. Wood from teaks is well known for its pleasant color, fine grain, and durability. The heartwood of teak varies from yellow brown to rich brown and frequently shows streaks of dark color. The wood has coarse texture, straight-grained, distinct oily feel, and unpleasant odor of leather when freshly cut (Pandey, 2010). Teak can be seasoned well but it is rather slowly and therefore requires more than ordinary care in determining both the initial and final moisture contents (Glass, 2010). Teak can be finished and glued satisfactorily, although some pre-

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finishing and special surface treatments may have to be considered to ensure good bonding of finishes and glues (Wiemann, 2010), and therefore teak is categorized as the wood with difficulty in bonding, as the effect of its high density, moisture, and extractive content inside the wood cells (Frihart, 2010).

Currently, teak is used in the construction of boats, furniture, decorative objects, veneer, and many other products. Teak has become the most tropical hardwood in demand for a specific market of special and luxury applications because of its *strength, durability*, and *distinctive aesthetic* qualities (Wiemann, 2010). Now in the market and production of wooden teak products, there are not only mature teaks that usually could be bought and to be used, but also available young teaks for this occasion, as an effect of wood increased in demand but on the other hand it become limited in supply.

Application of teak (mature teak) as one of the prominent material for making the special and luxury products are have been being used from hundreds years ago until now, but on the other hand, the use of young teak for making products is just to be considered about several years ago, due to the market demand of wood material is increasing, while the mature teak is becoming higher in market price and the supply of teak from the natural forest has decreased during the time. The other aspect also has occurred that the area of teak plantation is increased and therefore the supply of teak is dominated from the teak plantation in which the young teak is included due to the thinning process of its teak plantations (FAO-UN, 2012).

The period from planting until harvesting is called the *rotation age*. Teak plantations in Java Island, Indonesia, which is managed by Perum Perhutani, use the rotation age of 40 years and the rotation age of 80 years. During the rotation age, a number of young teak trees, which mostly comprise sapwoods, will be felled due to the *thinning* to stimulate the best growth of remaining teak trees in the teak plantations. As a particular case, in one of the teak plantations, for 1 hectare of teak plantation with the site quality index of *bonita III/IV* (average quality class) and rotation age of 40 years, from 1,769 5-year-old teak trees will be felled regularly during the rotation age until 277 39-year-old teak trees remain at harvesting. There are six site classes (bonita I - bonita VI) for recognizing areas of teak plantation in Java, and each site class has different thinning for felling a number of its teak trees (PT. Perhutani, 2001).

At the present, only in Java Island, there are at least 1.21 million hectares of teak plantations. This is the second largest area of teak plantation in a country in the world (Kollert, 2012). The average production of logs and timbers from these teak plantations area are 0.4 million m^3 annually (Perum Perhutani, 2014). Consider to the significant amount of young teaks from the thinning is available, it is necessary to utilize these potential material become suitable products by taking the advantage of its mechanical properties and prominent characteristics to enhance its utilization and value. This is important for Indonesia especially, who has the wide teak plantation area that is possible to be increased for getting the advantages from this potential material optimally, both at present and in the future.

Although the young teaks and teaks from the thinning are have been utilizing for making products, but the assessment to its mechanical properties and characteristics is relatively limited. The data and information about teak usually refers to its mature teak. Description about properties and its characteristic of teak especially refer to the heartwood part of the mature teak. It will be different to the young teak.

2. Material and Methods

Teak materials for making of specimens of tests in this research are obtained from the West Java area, Indonesia, which is categorized as:

- The young teak logs from the thinning of teak plantation, which is still comprise mostly sapwood part; and
- Small beams or planks of sawing and re-sawing of teak logs, timbers, or lumbers, which is still contain proportions of both sapwood and its heartwood part. These are recognized as removed waste material, not standard size and narrow relatively.

The mechanical properties of young teak from the thinning of West Java area's teak plantation has been recognized in the previous research that is determined uses *static bending test* (three points). In this research, another six additional tests have been conducted to complete the mechanical properties of young teak in particular, those are :

- Compression Strength Parallel to grain;
- Tension Strength Parallel to grain;
- Compression Strength Perpendicular to grain;
- Tension Strength Perpendicular to grain;
- Cleavage Strength Parallel to grain; and
- Shearing Strength Parallel to grain.

For the tests occasion, teak material has been categorized in range as Age Class I-II (10-20 year-old) and Age Class III-IV (30-40 year-old). Standard methods for testing are adapted and modified from the ASTM, Designation: D 143 (*Small Clear Specimens of Timber*) (ASTM, 2010), and then it is combined to SNI 03-3960-1995, *Test Method for Modulus of Bending Elasticity of Wood in Laboratory* (SNI, 2013). The laboratory for testing is conducted at Structure Engineering Laboratory - Bandung Institute of Technology, Indonesia. The device/machine for testing is Universal Testing Machine (UTM) Ibertest, series Eurotest - 200, Made in Spain; Year of production is 2012. The *speed of testing* (*displacement control*) of UTM is set to the type of control by position, and the speed is set according to the standard for each test categories respectively, but the *load control* for all of the test are set at 98.0665 N/s (*load increasing*). Time of tests has been arranged in March and September 2013.

For getting the appropriate result, before the test is started, all of the specimens must be confirmed of its moisture, it is not exceed more than 20% (standard of maximum), and also the humidity and temperature of the place where the test is conducted. The tests have been conducted in relative humidity 60% (±5%) and temperature 25^0C-27^0C, and the moisture content of the specimen is 15%-19% at radial and 16%-19% at tangential. Number of specimen is 2-3 pieces for each age classes and each type of specimen respectively that is conducted for six additional various tests.

The basic data has been added also by the *Measuring of Weight Density*, as one of determination factor for confirmation of strength class, and in this case, the weight density as a sample to compare among the specimen from the various age class and wood species. This research also has been conducted of tests for getting the bonding properties of young teak in particular. Falcata (*Paraserianthes falcataria)* and Kapur (*Dryobalanops beccari)*, are used for comparison in bonding test. These wood are represented as bond easily and bond with difficulty, according to ease of bonding categories (Frihart, 2010). Type of adhesive that is used in these tests is *poly vinyl acetate* (PVAc), as an ordinary glue for bonding of wood in general occasion.

This research also has conducted to determine the characteristic of color lightness of teak surface from the previous research. The data is determined uses lux meter at daylight shade in the midday condition (± 20,000 lux), and the distance between lux-meter to the specimens is 100 cm. The main purpose of this determination is conducted for getting the ratio comparison among various teak surfaces after coloring by colorant (*food grade type*) and water based polishing respectively.

3. Research Finding

3.1 Strength Class of Young Teak

According to the *strength classification of the wood* in Indonesia, as it is described in Table 1, the *strength class* of wood is divided into five classes and refers according to the weight density and MOR of its wood, and teak from Java Island has been recognized as the wood with the standard *strength class II* (Martawijaya, 1981). Based on the previous research that is compared to the *standard strength class of wood,* and therefore the young teaks from various age classes can be classified for having the strength in the same range with mature teak, according to its density and the result of Modulus of Rupture (MOR), as it is described in Table 2. The exception is just for sapwood of *age class I*, which the MOR is lower than the minimum of standard (Djati, 2015).

Table 1. The standard of strength class of wood in Indonesia (Martawijaya, 1981)

Strength Class	Weight Density	MOR (MPa)
I	> 0.90	> 107.87
II	0.60 - 0.90	71.098 - 107.87
III	0.40 - 0.60	49.03 - 71.098
IV	0.30 - 0.40	35.30 - 49.03
V	< 0.30	< 35.30

Table 2. Test data sheet of static bending (Djati, 2015)

Speed of Testing		0.1 inch/min (2.54 mm/min)			
Size of Specimen		20 x 20 x 300 mm^3 (*width x depth x length*)			
Age Class (year-old)	Part in Trunk	Weight Density (gr/cm3)	Max. Load (kN)	MOR (MPa)	MOE (GPa)
I	SW	0.613	1.004	52.709	6.989
(1-10)	HW	0.635	1.529	80.263	7.051
II	SW	0652	1.741	91.413	10.029
(11-20)	HW	0.617	1.650	86.657	8.893
III	SW	0.622	1.744	91.570	9.332
(21-30)	HW	0.720	1.745	91.615	9.438
IV	SW	*Size of sapwood part is smaller than the minimum standard size of specimen for testing*			
(31-40)	HW	0.781	1.555	81.623	8.840
Teak *(standard)*		0.67-0.75	-	101.106	12.523

3.2 Mechanical and Bonding Properties

The assessment also has been conducted to the number of tests for getting the mechanical and bonding properties of young teak. Bonding practice has been conducted and it has been compared the strength of bonding among teak, young teak and another wood material for comparison occasion. According to some research, teak has been recognized as the wood with *bonding difficulty* (Frihart, 2010). This recognition may refer to the bonding property for mature teak, and therefore it is possible that the young teak is having the different property. The determination to examine of bonding

characteristic is necessary to be conducted for comparing the ease bonding categories, and therefore the tests are conducted for each type of specimen, with and without adhesive applying. The test results for each type of testing that is especially applied to the young teak specimens and another wood material are described in several *Test Data Sheets* respectively. The tests results as are described in Table 3 - Table 8, whereas bonding tests are adapted to the four basic tests as are described in Table 4, 6, 7, and 8.

Table 3. Test data sheet of compression strength parallel to grain

Speed of Testing		0.024 inch/min (0.6 mm/min)		
Size of Specimen		20 x 20 x 80 mm³ (*width x depth x length*)		
Age Class (year-old)	Part in Trunk	Weight Density (gr/cm³)	Max. Load (kN)	Max. Load to Area (MPa)
I-II (10-20)	SW	0.63	33.539	33.539
	HW	0.63	17.726	17.726
III-IV (30-40)	SW	-	-	-
	HW	0.69	45.284	45.284
Teak (*standard*)		0.67	-	53.937

Table 4. Test data sheet of tension strength parallel to grain

Speed of Testing		0.05 inch/min (1 mm/min)		
Size of Specimen		20 x 20 x 300 mm³ (*width x depth x length*)		
Age Class (year-old)	Part in Trunk	Weight Density (gr/cm³)	Max. Load (kN)	Max. Load to Area (MPa)
I-II (10-20)	SW	0.63	9.696	96.963
	HW	0.64	8.213	82.135
III-IV (30-40)	SW	-	-	-
	HW	0.69	9.631	96.311
Adhesive applied				
I-II (10-20)	SW	0.62	1.583	3.957
	HW	0.69	1.654	4.135
III-IV (30-40)	SW	-	-	-
	HW	0.69	0.966	2.390
Falcata		0.33	1.268	3.173

Table 5. Test data sheet of compression strength perpendicular to grain

Speed of Testing		0.012 inch/min (0.305 mm/min)		
Size of Specimen		20 x 20 x 60 mm³ *(width x depth x length)*		
Age Class (year-old)	Part in Trunk	Weight Density (gr/cm³)	Max. Load (kN)	Max. Load to Area (MPa)
I-II (10-20)	SW	0.63	5.516	13.788
	HW	0.64	7.9525	19.878
III-IV (30-40)	SW	-	-	-
	HW	0.69	9.668	24.173

Table 6. Test data sheet of tension strength perpendicular to grain

Speed of Testing		0.10 inch/min (2.5 mm/min)		
Size of Specimen		35 x 20 x 40 mm³ (*width x depth x length*)		
Age Class (year-old)	Part in Trunk	Weight Density (gr/cm³)	Max. Load (kN)	Max. Load to Area (MPa)
I-II (10-20)	SW	0.63	2.328	5.820
	HW	0.63	2.812	7.031
III-IV (30-40)	SW	-	-	-
	HW	0.69	1.872	4.680
Falcata		0.33	0.901	2.254
Kapur		0.59	2.297	5.744
Adhesive applied				
I-II (10-20)	SW	0.63	1.732	4.331
	HW	0.64	1.773	4.433
III-IV (30-40)	SW	-	-	-
	HW	0.69	1.781	4.453
Falcata		0.33	0.640	1.601
Kapur		0.59	0.994	2.486

Table 7. Test data sheet of cleavage strength parallel to grain

Speed of Testing		0.10 inch/min (2.5 mm/min)		
Size of Specimen		35 x 20 x 30 mm³ (*width x depth x length*)		
Age Class (year-old)	Part in Trunk	Weight Density (gr/cm³)	Max. Load (kN)	Max. Load to Area (MPa)
I-II	SW	0.62	0.730	1.824
(10-20)	HW	0.69	0.874	2.184
III-IV	SW	-	-	-
(30-40)	HW	0.69	0.902	2.256
Adhesive applied				
I-II	SW	0.62	0.600	1.500
(10-20)	HW	0.69	0.400	1.000
IIII-V	SW	-	-	-
(30-40)	HW	0.69	0.354	0.885

Table 8. Test data sheet of shearing strength parallel to grain

Speed of Testing		0.24 inch/min (0.6 mm/min)		
Size of Specimen		20 x 20 x 30 mm³ (*width x depth x length*)		
Age Class (year-old)	Part in Trunk	Weight Density (gr/cm³)	Max. Load (kN)	Max. Load to Area (MPa)
I-II	SW	0.62	5.611	14.028
(10-20)	HW	0.69	6.820	17.049
III-IV	SW	-	-	-
(30-40)	HW	0.69	5.418	13.545
Adhesive applied				
I-II	SW	0.62	3.828	9.568
(10-20)	HW	0.69	5.265	13.162
III-IV	SW	-	-	-
(30-40)	HW	0.69	1.319	3.297

3.3 Border Patterns and Color Characteristic

Based on the previous research, the *border patterns* and the contrast of color between sapwood and its heartwood parts in mature teaks are usually obvious, and this is contrary to the young teaks in which the borders vary due to the incomplete process from sapwoods become heartwood parts. The young teaks have been recognized for having various *border patterns* on its transverse, tangential, and radial surfaces. Various types of border patterns, as shown in Fig. 1, are categorized in the *transverse surface* as (a) *serrated edge*, in contrast to the (b) *curved edge*; and (c) *obvious edge*, in contrast to the (d) *obscure edge.* At both the *radial surface* and the *tangential surface*, the various borders are categorized as (e) *linear edge*, in contrast to the (f) *meandering edge*; and (g) *obvious edge*, in contrast to the (h) *obscure edge* (Djati, 2015).

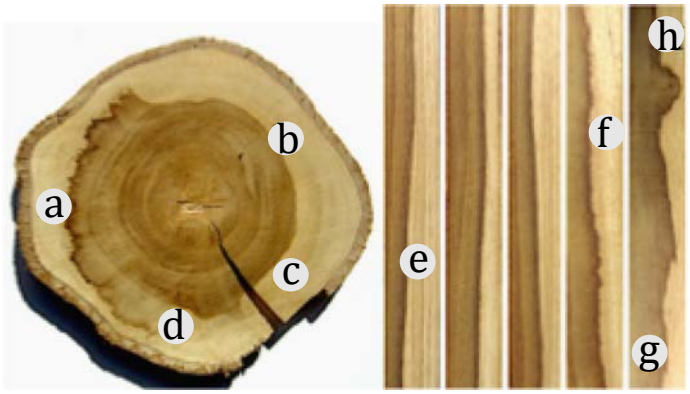

Figure 1. Various types of border patterns on transverse, tangential, and radial surfaces of young teak.

The difference of color intensity near to the borders edges on the heartwood parts also vary; darker and brighter color alternate between *early-woods* and *late-woods* at the growth rings, as an uneven process of formation and conversion of sapwood becomes heartwood. The chemical and extractive content in the borders of teak are also having the different content (Lukmandaru, 2009).

Color and lightness characteristic of young teaks those are compared to sapwood and its heartwood parts that the lighter color of sapwood surfaces have specific effect, i.e. to the finishing system as a consequence of the difference in color intensity of sapwood and its heartwood parts. Difference intensity of basic color has shown from the various part of teak after polishing that use colorant and water base polish. In the same color using, the result has shown that the darker color surface appears from the pieces of heartwood parts and the lighter color surface appears from the pieces of sapwood parts. Caused by the lighter color of sapwood surface, the coloring on sapwood surface will appear more *attractive* and *vivid* than on its heartwood as shown in Fig. 2. The sapwood surfaces are having higher lightness than its heartwood surfaces. This can be determined that after the use of colorant, the sapwood part surfaces indicate the higher ratio in which is compared to the mature teak in the same each color of colorant respectively as is described in Table 9 and Table 10.

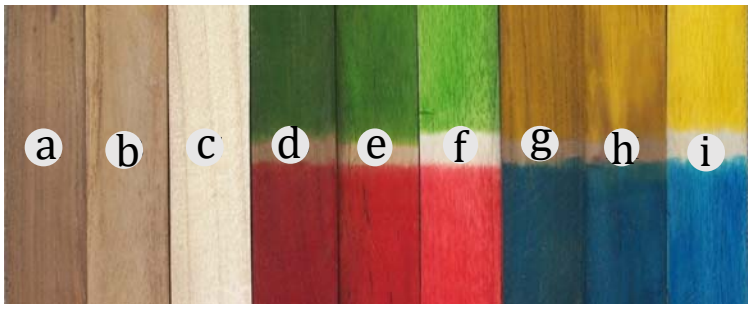

Figure 2. Difference color intensity on the surface of mature heartwood (a, d, and g), young heartwood (b, e. and h), and young softwood (c, f, and 1) of teak after coloring.

Table 9. Lightness of Teak Surfaces

Teak Surface	without colorant (klx)	use colorant			
		Red (klx)	Green (klx)	Blue (klx)	Yellow (klx)
HW (mature)	5.7	4.1	4.2	5.4	5.3
HW (young)	8.1	4.6	5.4	6.2	6.4
SW (young)	10.4	5.3	7.2	7.0	8.9

Table 10. Ratio of lightness of young teak surfaces to mature teak surface

Teak Surface	withoutcolorant (klx)	use colorant			
		Red (klx)	Green (klx)	Blue (klx)	Yellow (klx)
HW (mature)	1	1	1	1	1
HW (young)	1.42	1.12	1.28	1.14	1.20
SW (young)	1.82	1.29	1.71	1.29	1.67

4. Conclusion

The result of determination has shown that there is no significant difference in the *strength* between heartwood and its sapwood of young teak, and the young teak has the same strength class with the mature teak and therefore basically it is possible to utilize this young teak for the ordinary application as well as the mature teak. Nevertheless, due to the trunk size of young teak that is narrower than the mature teak, therefore the application of young teak should consider the suitable products according to its limited

size. In addition, it is possible to enlarge the size of young teak, i.e. its thickness or its width, by using of certain wood joint system. The result has shown also that bonding is possible relatively to be applied for young teak especially, and this bonding characteristic is usable for wood jointing in particular for making products in which bonding is applied.

Mechanical properties and characteristics of young teaks and its various border patterns of sapwood and its heartwood part are prominent aspects that can be useful in practical application for making various products. Data about the strength and durability of young teak must be recognized for its application. Although young teak, which comprised mostly sapwood is considered to have the low durability, but some extra treatments are possible to be applied to enhance this low durability.

The attractive color of sapwood parts that usually recognized as a weakness is possible to be the advantage, i.e. if these parts will be use for making suitable product, e.g. products for kids, such as toys, educational equipment, et cetera. The utilization of young teak without any necessary modifications to its characteristics and properties is also possible as long as the utilization take into consideration to the suitability of young teak for the particular products.

Utilization of young teak for substitution material and for fulfil the demand of wood in wooden products industry is possible to enhance the value of this young teak and also for getting the advantage for social empowerment and economical point of view. This research approach and methods which has been applied to the young teak is possible practicable also to apply for another wood species in which comprise sapwood and heartwood part in their wood trunk.

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