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Sustainable Material : Used Wood As Building Material

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Abstract–Wood consumption as building material and component in Indonesia is still considerably high. This affects forest destruction, in a way that most of the wood production still roots from wood forests. Hence, the demand of these woods better be supplied from other source, one of them is through using used woods. Used wood utilization in building construction is an application of reuse and recycle strategy in sustainable material concept. Due to the assumption among the people that used woods have low performance its utilization is nowadays limited. This paper addresses the result of research and laboratory test on a range of used wood samples collected from Jakarta great area (Jabodetabek), consist of 5 technical parameters: water content, density, compressive strength, flexure strength, and tension strength. The research proves that based on certain parameters, used woods perfom technical capacity as good as – or even better than – newly produced woods.

Keyword – *sustainable, material, used wood*

I. Introduction

Wood is commonly used as building materials since long ago. Due to its natural characteristic, ease to get, simple fabrication methode, human safety and health consideration, and its multi-functionability the role of the woods as building material is irreplaceable. Nowadays almost 25% of the construction material consumption is still globally rooted from forest woods [1]. The high demand rate for woods leads to the forest over-exploitation in order to fulfill the demand of woods. Within a day, it is predicted by United Nation that 256 km square of tropical forest is destructed because of deforestation [2]. Based on the tendencies Ryn and Cowan (2007) predicted that all of the forests in Indonesia would be extinct in 2022 [3]. This situation does not meet one of the basic principles in ‘sustainable development’ that “consuming resources should be no faster than the rate at which they can be replenished” [1]. Therefore it is crucial to look for another source for woods replacement, and one of them is used woods.

Utilization of used woods in Jabodetabek has apparently been happening in society, where used woods would be transformed into a range of uses such as scaffolding construction, door or window frames, roof structure, etc. In a variety of places in this region it is very easy to find used wood station. Based on the survey done in this research, 9 wood stations spread in Jabodetabek have been operating since five years, even some of them have taken more than thirty years. Used woods are usually collected from demolition of old buildings especially old houses that are then kept in these stations. After being collected, the used woods would be selected usually through visual check in order to scan the defect or damage resulted from the old construction or termites. The used woods would then be processed through some steps such as cleaning, plastering, refinement (with caulking especially for woods with small damage) and or being processed into a renewed product. Yet the utilization of these used woods are still considered insignificant.

Society considers the utilization of used woods is a right decision because of its considerably cheap price. Used woods are sold in a form of bars, commonly in 5x7 cm^2 and 6x12 m^2 along with the various length. The consumers would revolve around middle to low class society with the purpose of building simple houses, or housing developer or agents that want to minimize the construction cost. Sometimes in order to increase their value, the woods are sold as a newly formed product such as door frame, window frame, or even furnitures. Meanwhile woods with considerably bad condition would be sold as firewood to food sellers or red brick craftmen from out of the city. From this survey, it is Fig. d out that the continuity of this utilization of used woods in this region is anchored by networks that are made up of three elements, which are house demolition service, wood station, and used wood craftmen.

One of three principles of sustainable in architecture – economy of resources – is concerned with the reduction, reuse, and recycling of the natural resources that are input to a building [4]. The reuse of used woods is apparently parallel to two reuse and recycle strategies mentioned above, yet as how it was mentioned before, this activity still does not reach a high added value because of the existing assumption that used wood quality is low. This thing is not completely right, Frick (2004) states that there are certain types of woods whose *‘life-time’* is long, or even predicted to reach hundreds of years for example teak woods/*Tectona grandis L.f* [5]. Therefore a further research is required to see how the quality of woods really work.

II. Basic Theory

First of all, quality of wood could be measured from its natural traits. Based on plant taxonomy. Woods are classified into two types, which is *Hardwood* and *Softwood*. *Hardwood* is a wood that is resulted from angiosperms plants, which are plants that reproduce using flowers pollination, have relatively wide leaves and moult during its season. *Hardwood* is commonly called porous woods because of its thick vessel that transfers sap throughout its stems, other than its thick vessel that anchors the plant itself [6]. Some types of *hardwood* woods are teak, camphour, *meranti*, and ironwood.

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While the structure of *softwood* is relatively simpler because everything happens in *longitudinal tracheid*, whether it is water transfer or plant anchor. Some of the examples of *softwood* are pines, *agathis*, *jumuju*, etc.. Trees classified as hardwood take a longer growth time and harder quality than trees classified in *Softwood*. Quality of woods is also determined from the fiber structures and the location of the knots. Woods with straight fiber structure and less knots would be stronger with it is in the opposite condition [7].

Wood quality really depends on its physical traits that include water capacity and density. The wood density is a ratio between the closeness of the matter and the closeness of the water. Density could also be called relative density [7]. Woods have variety of densities, and these differences do not only revolve around the type of the woods but also other aspects such as the content of the matter, extractive content, and the water capacity. There are some factors that affect the density of the wood, which are: tree age, growth place, position of wood in the stem, and growth rate. The strength and the hardness of the woods tend to be parallel to the density of the woods themselves. The denser or bigger it is, the stronger it gets. Based on its pure volume, the density of wood has a classification like: wood with light weight (<0.3), wood with medium weight (0.36 – 0.56) and wood with heavy weight (> 0.56). The level of water in wood in the other side is the amount of water found in the wood that is measured within the percentage to the dry weight of the wood itself. There are two types of water in woods, first is free water that could be found within the cells pores and the second is water that is found in cell walls. Condition where water within the wood is only found in cell wall is called fiber vicosity condition. The difference in the water content within certain woods is caused by difference in structures and chemical components that are different in each wood.

The rate of water in woods need to be decreased or woods need to be dried before being used. The drying process would lead to shrinkage so that the wood cells would become rigid. The more rigid it gets, the thicker the cell walls get. This would make the density and the rigidness of the wood increase [5]. A decrease in water level would increase the strength of the wood itself. The drying process would be done through natural way such as drying under the sun or through mechanical way such as using oven. An increase in quality of the wood could also be done through chemical way by soaking the woods in certain solutions.

Wood quality could be measured from its mechanical trait, which is a trait or character that shows the strength or the ability of wood to respond or resist force or external loads that act on it. Force or external load could lead to deformation or a change in fom of the wood along with its change in dimension, or even to a destruction. This quality would then be the main considerations before utilizing, twisting, connecting or bending the woods [5]. In the construction world, the mechanical trait of the wood is stated in six parameters, such as: the elastic modulus of bending, (b) flexural strength, (c) tensile strength parallel to the fiber, (d) of compressive strength parallel to the fiber, (e) the shear strength and (f) The compressive strength perpendicular to the fiber [8] .

In wood construction practice in Indonesia, there are several classifications of wood which are set by the BSN (Badan Standarisasi Nasional) as a reference of wood quality in Indonesia [8].

1. The wood classification based on the strength wood is published by PKKI - NI - 1961 which divides the timber into five classes: I, II , III and IV and V. the strength Class-I is the highest strength class, it’s the wood with a specific gravity above 0.9, compressive strength parallel to the fiber above 650 kg/cm2 and a flexural strength above 1,100 kg/cm2, for example Resak wood, Belian wood and Kempas wood. Class-V is the lowest strength class, covering the wood with a specific gravity below 0.3, compressive strength parallel to the fiber under 215 kg/cm2 and a flexural strength above 360 kg/cm2 [9].

2. The wood classification based on the Strength Reference Values Based on the Mechanical Separation Water Content 15%, published by SNI, a revision of the classification of the previous timber. This classification is grouping Indonesian timber into 26 different classes. Wood with a code E1 is wood with the lowest quality with the code E26 is wood with the highest quality. This classification using the Mpa unit [8].

3. The product classification is based on the durability of wood which are divided by the level of resistance in environmental factors such as temperature, humidity, the presence of organisms such as fungi, insects etc. The wood is devided into five durability classes, namely I, II, III , IV and V Class. I is the highest one, it’s the wood with an unlimited lifetime if its use in conditions not exposed to water and doesn’t contact with moist soil directly and get plenty air, the wood in this classification such as teak. Wood with durable class V is a group of wood that has a very short lifetime [9].

Based on three types of classification mentioned above, classification type that works formally and commonly is it is that is based on the strength of the wood, because this classification system is still developing and the measuring point would adjust the international standard. Meanwhile the classification of wood’s durability is not based on the result of research, but only on information listed on herbarium/specimens as an observational result in field or interview with local society living around the growth location of the trees that is suited to data from a range of sources [10]. That’s why the third classification will not be used as a tools of analysis.

III. Research Method

This study aims to determine the used wood quality has two main character, that is physical character and mechanical character. There are 5 parameters which can be measured and can be tested: (1) wood density (2) the water level of wood (3) compressive strength perpendicular to the fiber (4) compressive strength parallel to the fiber, and (5) flexural strength. Actually, there are other parameter to find used wood quality but this five factor are comsidered as a main parameter. This object that is being measured or tested is a used wood sample which is collected randomly from 9 used wood station in Great Jakarta. In total, there are 9 used wood samples that comes from 3 types of wood: Champor, Meranti and Duren. Although it can't be determined accurately, bute the sample is predicted already more than 10 years old. As a comparrison, other type of wood can be tested and measured, such as Champor and Meranti. The measuring and testing wood sample is done by BSN (Badan Standarisasi Nasional Indonesia) method [8]. The detail method for each measuring and testing are as follows

1. Density Measurement Method:
   a. Tools: (a) minimum capacity of 500 digital scales with an accuracy of 0.01 gr, (b) bar/caliper, (c) stationery, blank field observations, and calculators.
   b. Objects measurement: 3 pieces of 5x5x5 cm^3 sample wood.
   c. Set the density object with the following formula.

$$Bj = \frac{K \cdot BKO}{V}$$

   Description: Bj (Gravity); K (constant); BKO (measuring body weight in grams); V (volume of objects measured in mm^3).

2. Compressive Strength Perpendicular to The Fiber Testing Method
   a. Tools: Engineering Materials Laboratory pressure tests at the Department of Metallurgy and Materials Engineering, University of Indonesia.
   b. Objects measurement: 3 pieces of free sized wood sample
   c. Specify and count the compressive strength with the following formula:

$$fc = \frac{P}{(b.h)}$$

   Description: fc (compressive strength), P (maximum test load), b (width of the test specimen), H (High test specimens).

3. Tensile Strength Parallel to The Fiber Testing Method
   a. Tools: tensile testing machine at the Materials Laboratory of the Department of Metallurgy and Materials Engineering, University of Indonesia.
   b. Objects measurement: 3 pieces of free sized wood sample
   c. Set and count the compressive strength with the following formula:

$$ft = \frac{P}{(b.h)}$$

   Description: fc (Tensile strength), P (maximum test load), b (width of the test specimen), H (High test specimens).

4. Flexural Strength Testing Method:
   a. Tools: Bending Test Machine in the Material Laboratory Engineering Department of Metallurgy and Materials, University of Indonesia.
   b. The test specimen: 3 pieces of 5x5x5 cm^3 sample wood.
   c. Set and count the compressive strength with the following formula:

$$fb = \frac{3PL}{2bh_2}$$

Description: fb (bending strength fibers parallel and perpendicular to the fiber), P (maximum test load), b (width of specimen), h (height of the test specimen). L (distance pedestal)

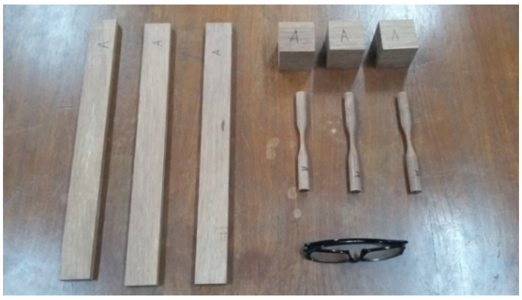

Fig. 1: research object – used wood sample
(source : taken by researcher)

IV. Result and Discussion

From the results of measuring and testing can be seen that in the aspect of density, used wood is not decreased on strength wood class, all used wood sample is still in each for their strength wood classification. If referring to the classification PKKI-NI-1961 [9], Camphor wood is grouped in wood strength class II, it's the wood with 0,6-0,9 density. All kinds of Camphor wood (Samarinda, Banjar and Singkil) has the density between 0,598 to 0,793. Meanwhile Meranti wood is in wood strength class III with 0,4-0,6 for the density, in this test for meranti used wood sample showed the 5,53 for density. It shows that the density aspect of camphor wood performance doesnt show the decreasing of wood strength class.

Table 1: The Result of Water Level and Density Used Wood Sample and New Wood Sample

No.	Name / wood code	The level or water	Density
Used Wood			
1	Samarinda Champor Wood A	10.00%	0.583
2	Samarinda Champor Wood B	12.33%	0.564
3	Samarinda Champor Wood C	10.83%	0.771
4	Banjar Champor Wood A	10.50%	0.903
5	Banjar Champor Wood B	10.67%	0.605
6	Banjar Champor Wood C	11.33%	0.871
7	Singkil Champor Wood	12.33%	0.598
8	Meranti Wood A	11.67%	0.553
9	Duren Wood A	13.17%	0.375
New Production Wood			
1	Samarinda Camphor	11.00%	0.829
2	Meranti	11.67%	0.548

Table 2: The Result of Press and Bend Test, Used Wood Sample & New Wood Sample

No	Name and wood code	Compressive strength perpendicular to the fiber (Mpa)	Compressive strength parallel to the fiber (Mpa)	Flexural strength (Mpa)
Used Wood				
1	Camphor Samarinda A	17.72	98.00	22.20
2	Camphor Samarinda B	12.03	152.00	29.42
3	Camphor Samarinda C	24.67	235.00	43.29
4	Camphor Banjar A	16.49	108.00	31.53
5	Camphor Banjar B	12.33	132.50	35.87
6	Camphor Banjar C	24.67	132.50	52.69
7	Camphor Singkil A	16.67	147.00	26.31
8	Meranti A	10.80	39.00	20.57
9	Duren A	5.03	39.00	16.46
New Production Wood				
1	Samarinda Camphor	13.07	137.00	37.67
2	Meranti	7.69	108.00	24.47

The performance of used wood in the compressive strength perpendicular to the fiber is very good. The Samarinda camphor used wood sample has an average compressive strength perpendicular to the fiber in 18.14 Mpa, Banjar Camphor 17,83 Mpa and Singkil Camphor 16,67 Mpa, it's far surpass the new Samarinda Camphor wood in 13,07 Mpa.

Comparisons are pretty much also can be seen in aspects of tensile strength parallel to the fiber in the sample scrap wood and new wood types Camphor Samarinda. The average tensile strength parallel to the fiber at the samarinda camphor used wood of 161.67 MPa, it's a far surpass the new samarinda camphor wood for 137 MPa. However, this was not seen in the case of meranti wood. In the used meranti wood tensile strength parallel to the fiber only reached 39.00 MPa, almost four times smaller than the new wood for the same type that is equal to 108 MPa .

In the flextural aspect data, it shows that the used wood performance is lower than the new wood. The Samarinda Champor used wood sample group has a flextural strength is about 31,64 in E14 category, it's smaller than Samarinda Champor new wood has a stronger flexural strength is 37,67 in E16. It's also can be found in Meranti Wood case. The Used Meranti wood shows the flexural strength is about 20,57 and in E11 quality category, it's smaller than the flexural strength of New meranti wood is about 24,47 and in E12 quality category. In average, the Banjar Camphor used wood sample has a bigger flexural strength, that is 40,03 and in E18 quality category.

Tabel 3: Comparison Results of Measure and Test on Used Wood and New Wood

Type of wood	Average water level	Wood density	Compressive strength perpendicular to the fiber	Compressive strength parallel to the fiber	Flexural Strength
Used wood					
Samarinda Camphor	11.05%	0.639	18.14	161.67	31.64
Banjar Camphor	10.83%	0.793	17.83	124.3	40.03
Singkil Camphor	12.33%	0.598	16.67	147.0	26.31
New Production Wood					
Samarinda Camphor	11.00%	0.829	13.07	137.0	37.67

Table 4: The Comparison of Measurement and Test Result of Used Meranti Wood & New Meranti Wood

wood type	Average of water level	Wood density	Compressive strength perpendicular to the fiber	Tensile strength parallel to the fiber	Flexural strength
Used Wood					
Meranti wood	11.67%	0.553	10.80	39.00	20.57
New Production Wood					
Meranti Camphor	11.67%	0.548	7.69	108.00	24.47

V. CONCLUSSION

There's some conclusion that can be gotten from the testing of the wood. First, although the used wood is older on the age and it was exposed by the weather during its use, yet the physical and mechanical performance is relatively not going to be bad. Second, the used wood, especially from the compressive strength minimum II and III doesn't get degradation on wood class due to the previous use. Third, the used wood is relatively will be able to compete with the new wood production, because of some of variant of the used wood has an excellence performance in some technical parameter such as compressive strength and tensile strength against the new wood production. Forth, based on the good quality of physical and mechanical character on the used wood, so in technically the used wood from some wood variant, mainly the wood from minimum II and III strength class, is considered feasible for reuse as a building material. This conclusion is still required to be anchored by advanced research, because it is inevitable to admit that the eleven samples of bars (nine used woods and two newly produced woods) are still not enough to represent the quality of used woods in comprehensive way especially in Jakarta and widely in Indonesia. However, the result of this research could be an initial base or at least a perspective opener for society or even architects that even used woods along with its defects still have physical quality that is not as bad as it is in newly produced woods.

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