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Investigation of Strength Parameters and Physical Properties of non-class Timber Species in Sri Lanka

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ABSTRACT: Timber is a commonly used construction material in Sri Lanka. But the strength parameters of locally available non-class timber are not available. In this study main objectives are to determine strength parameters and physical properties of selected local timber materials and to develop a strength class classification with their possible applications in the construction field. Different strength parameter tests are conducted in bending, compression (grain parallel and perpendicular), tension (parallel to grains), and shear perpendicular to grain. In addition, durability, fire resistance tests and physical properties such as dry density, bulk density, and water absorption were carried out. For those tests BS 373 (1957) and EURO CODE 5 were used as references. Average moisture contents of non-class timber specimens were around 12%, modulus of elasticity varies 3200 MPa - 13,000 MPa, modulus of rupture varies 37 MPa – 85 MPa, dry density varies 600 kg/m^3 - 900 kg/m^3. Strength parameters at serviceability limit, mainly compressive strength at parallel to grains varies 13 MPa - 45 MPa, and compressive strength perpendicular to grains varies 3 MPa – 22 MPa in most of the non-class timber species. Shear capacity of perpendicular to graons of non-class timber materials varies 0.9 MPa - 5 MPa at serviceability limit. Tension capacities of timber materials vary 35 MPa - 100 MPa and charring rate of timber species varies 0.25 mm/min - 0.8 mm/min. Similarly other test parameters were investigated and presented in the paper. Finally identified non-class timber species were classified according to available strength classes and proposed suitable applications for each type.

Keywords: non-class timber, strength classes, compression, tension, durability, fire resistance

1. Introduction

Timber is one of the oldest building materials in Sri Lanka. According to Sri Lankan history, "Lovamahapaya ", which was built by King Dutugemunu in the second century BC, had a full wooden structure originally consisting of nine floors with a height of over 20 meters. Timber used as a construction material of several hundreds of different types of wood species, some of which are less well known but each species has various wood properties.

According to State Timber Cooperation (STC) Sri Lanka, there are about 400 timber species are available in Sri Lanka. STC studied about 227 type timber specimens. But that studies were limited only to visual grading and past experience of timber. So that engineering techniques unable to use due to lack of data. This research was conducted to obtain structural and resistivity parameters of local timber species which necessary for the timber classification. Kempus (*Koompassia malaccensis)* is used to validate the test results. This research tests were based on BS373:1957 and EURO CODE 5. Timber species were used in the research are shown in Table 1.

Table 1: Tested Timber Species

No	Local Name	Scientific Name
1	Pare Mara	Samanea saman
2	Lunumidella	Melia dubia
3	Ketakala	Bridelia retusa
4	Mango	Mangifera indica
5	Nikadaula	Neolitsea cassia
6	Kon	Schleichera oleosa

7	Jak	Artocarpus heterophyllus
8	Damaniya	Grewia tilliafolia
9	Madan	Syzgium cumini
10	Liyan	Homalium zeylanicum
11	Havarinuga	Alastonia macrophyla
12	Bata Domba	Syzygium operculatum
13	Mahogani	Swietenia macrophylla
14	Dawata	Carallia branchiate
15	Donga	Sandoricum indicum
16	Gini Sapu	Michelia champaca
17	Saukku	Grevillea robusta
18	Karpantine	Eucaliptus microcorys
19	Karpantine	Eucaliptus grandis

2. Methodology

Compression, Tension, Flexural and Shear tests were done to determine structural properties of Timber materials. Durability and Thermal resistivity of timber materials were also tested. Testing methodology was done according to the international standards. This experiment procedures have been referred international codes BS 373:1957 and EURO CODE 5 for the testing of above parameters. Test results were verified by using known timber parameters in species like Kempus.

All the samples for Compression, Tension and Flexural experiments were taken with the moisture content around 12%.

2.1 Dry Density

Dry weigh of the samples were taken by placing in 105C° oven for 48 hours. (BS373, 1957 [1])

$$S_0 = W_0 / (l \times b \times h) \quad (1)$$

W_0 = Weight of sample, oven-dry
l = Length
b = Breadth
h = Height

2.2 Compression Test

Compression test was conducted for specimen with 12% moisture content by parallel to grain and perpendicular to grain. Axial compression was given at the rate of 2 mm per minute up to ultimate failure by using Universal Testing Machine. (BS373, 1957 [1])

$$\text{Compressive strength} = \frac{\text{Servieability Load}}{\text{Average area}} \quad (2)$$

2.2.1 Compression parallel to Grains

Standard size of compression capacity parallel to grain test specimen is 50mm×50mm×400mm timber section as shown in Figure 1.

Figure 1: Compression parallel to Grains

2.2.2 Compression perpendicular to Grains

Compression test perpendicular to the grains was conduct by using 50mm×50mm×50mm timber sections. Same procedure was conducted for the compression in grains parallel.

2.3 Flexural Test

Specimens were subjected to centre point loading at the mid span. During the test applied load and mid span deflection was measured.

Timber specimens 50mm×50mm×750mm were used for the above test. Load was given at the rate of 2mm per minute up to ultimate failure by using Universal Testing Machine (UTM) with simply supported condition at the ends as shown in Figure 2. This test was carried out according to the BS373, 1957 [1]. Test results were used to calculate Modulus of Elasticity (MOE) and Modulus of Rufture (MOR).

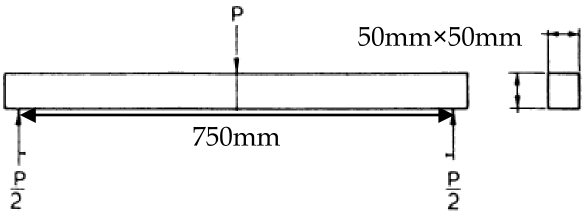

Figure 2: Flexural test

Figure 3: Flexural test apparatus

$$\mathrm{MOR} = \frac{\mathrm{M} \times \mathrm{y}}{\mathrm{I}} \qquad (3)$$

M – Maximum Bending moment
y – Maximum distance from neutral axis to edge of the section
I – Second moment of area

$$\mathrm{MOE} = \frac{\mathrm{WL}^3}{48\delta \mathrm{I}} \qquad (4)$$

L – Length of timber specimen

W – Maximum Load act in centre of specimen

δ – Maximum deflection of timber beam

I – Modulus of elasticity

2.4 Tension Test

50mm×50mm×300mm timber specimens with 12% moisture content used for the test. Test was conducted to grains parallel of the samples. This test was carried out by using Universal Testing Machines with 2mm per minute loading rate as shown in the Figure 3. (BS373, 1957 [1]).Tension capacity of the specimens were calculated using maximum load and average area of the the specimens using Eq. (5).

$$\text{Tension strength} = \frac{\text{Servieability Load}}{\text{Average area}} (5)$$

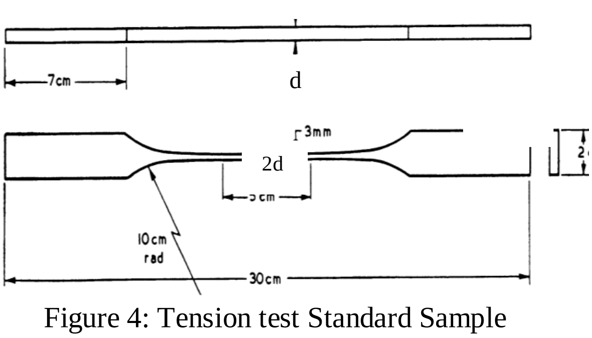

Figure 4: Tension test Standard Sample

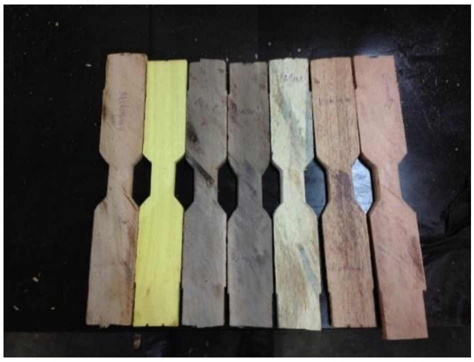

Figure 5: Sample preparation of Tension test

Figure 6: Tension test apparatus

2.6 Durability Test

This study has been done according to previous study by Breyer and Banks (1957). 50mm×50mm×400mm timber samples were oven dried and placed in 3% sulfuric acid solvent. Three specimens were soaked for a period of four weeks and dried in oven for 24 hours. Then weight loss was considered by using initial and final weight of specimens. Main parameters were considered in this test are; Compression capacity change and Weight loss.

Figure 7: Specimens Soaked in Acid bath

2.7 Thermal Resistivity

Burning length was measured of 50mm×50mm×250mm inch timber samples after 30min of burning with $250C^0$ flame and charring rate was calculated. (EUROCODE5, 1995 [3])

$$\beta = \frac{D}{t} \qquad (6)$$

D – Burning length
t – Time (30min)
β – charring rate

Figure 8: Fire Resistivity test

2.8 Water Absorption

50mm×50mm×50mm timber cubes were used for the test. First samples were oven dried at the $105C^0$ temperature for 48hrs and weighted. Then samples were placed in a water bath and measure the weight in every week.
After that weight gain vs. time relationship were plotted.

Figure 9: Water absorption Test

3. Results and Discussion

All results were compared and validated by using properties of known timber specie of Kempus. Test result of compression, tension, flexural, durability, thermal resistivity and water absorption are shown in the Tables from 2 to 5.

3.1 Dry Density

Table 2: Dry density of Timber Species

Timber Type	Avg. Dry density
Grandiz	680.32
Jak	645.82
Kempus	829.99
Kon	883.00
Micro	791.21
Havarinuga	680.03

Dry density of timber specimens shows relationship with compression capacity. Kon, Grandiz and Micro has highest compression capacity while they are having high dry density values.

3.2 Durability

Jak and Subukku timber specimens are more resistive for acids while Ketakala has low resistivity for acids.

Table 3: Weight loss after 28 days

Timber Type	Weight Loss % after 28 days
Grandiz	6.52
Havarinuga	0.70
Jak	0.50
Kempus	4.62
Ketakala	13.93
Micro	9.19
Subukku	0.34

These results are very essential to select timber materials for different structural applications. It was revealed that members with high moisture content caused high insect & fungi attacks. Therefore selection timber species with less moisture content and high dry density is most desirable selection.

3.3 Structural Properties

Structure properties of Timber species are very important to design timber element and structures. Table 4 summarized parameters of tension, MOR, MOE and compressive strength obtain from above test mentioned.

Tension capacity of specimens of same species has high deviation due to their grain pattern. Kon, Grandiz and Micro have high tension capacity while they are having highest compression capacity. Kon, Grandiz and Micro also have high MOR.

Table 4: Structural properties of Timber Species

Timber Type	Compression strength (MPa)		Tension capacity (Mpa)	Shear capacity (MPa)	MOR (MPa)	MOE (MPa)
	Parallel to grains	Perpendicular to grains				
Grandiz	28.96	3.17	70.39	0.95	80.14	12912.89
Paremara	22.90	9.79	59.30	2.42	57.85	6624.91
Kempus	47.31	26.54	64.40	1.40	63.31	17404.76
Kon	44.75	21.31	88.59	4.12	71.56	6026.51
Micro	23.97	8.38	117.55	2.18	66.07	5340.50
Havarinuga	27.98	6.46	86.33	1.56	84.51	5574.57

MOR value is indicate ultimate flexural strength of timber species. This parameters is very important to designing beams elements. Grandiz, Kon and Havarinuga have high MOR value regarding the other non-class timber materials. Stiffness of timber materials indicate by MOE value. It's very essential parameter to determine deflection of timber beams. Grandiz has highest MOE value compare to other timber species. Kon has highest shear capacity perpendicular to grain while Grandiz has lowest.

3.4 Water Absorption

Table 5: Water Absorption after 5th week

Timber Type	Water absorption % after 5th week	Ult. Compressive strength N/mm2
Kempus	24.09	55.36
Kon	49.60	55.04
Grandiz	73.10	40.48
Sabukku	104.00	36.17
Lunumidella	134.01	25.61

High strength timber materials have less water absorption. Subukku and Lunumidella has high water absorption. These timber specimens have low strength capacity.

Figures 10 and 11 show variation of water absorption of Kon and Lunumidella timber species. Absorb water content was tend to constant after 3rd weeks.

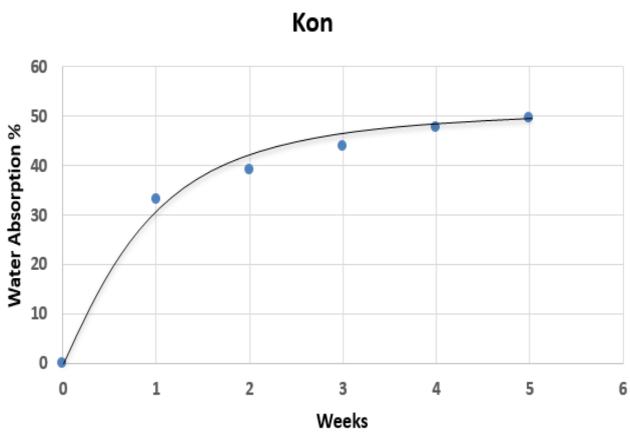

Figure 10: Water absorption results of Kon

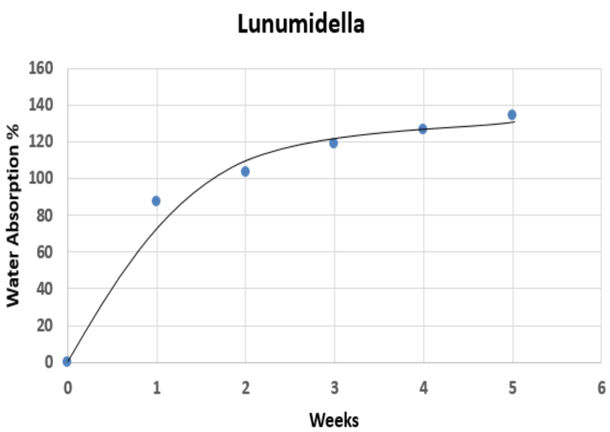

Figure 11: Water absorption results of Lunumidella

Lunumidella has much higher water absorption capacity compare to Kon but shows less compressive strength relative to Kon.
Therefore water absorption indicate porosity of timber material which effect to timber strength characteristics.

3.5 Thermal Resistivity

Table 6: Charring rate values

Timber Type	Charring rate (β value) mm/min
Lunumidella	0.27
Sabukku	0.37
Kempus	0.43
Grandiz	0.43
Havarinuga	0.47
Paremara	0.57
Jak	0.77

Subbukku and Lunumidella have low charring rate while timber species which have high density have high charring value. Voids are effect to charring value.

4. Conclusions

According to the test results, strength parameters of Kempus lies between standard values. Therefore test results values of other timber species were validated.
From this study following conclusion were derived; Average dry density of selected timber materials lies between 600-900 kg/m^3. Strength parameters at serviceability limit, mainly compressive strength at parallel to grains varies from 13 MPa to 45 MPa and compressive strength perpendicular to grains varies from 3 MPa to 22 MPa in most of the non-class timber species. "Kon" has highest strength values in compression (parallel to grains and perpendicular to grains) compare to others. Modulus of Rupture and Modulus of Elasticity values varies 3200 MPa - 13,000 MPa, and 37 MPa – 85 MPa which have highest values in "Grandiz". "Micro" has the highest tension capacity compare to other non-class timber materials where tension capacity varies 35 Mpa - 110 Mpa. Compressive strength of timber materials are decreased with increment of water absorption. Shear strength perpendicular to grain varies 0.9 MPa - 5 MPa. Highest acidic resistivity timber materials are "Jak" and "Subukku". Charring rate of timber species varies 0.25 mm/min - 0.8 mm/min. Lunnumidella and Subukku have low charring value thus they are more fire resistive while they are having high porosity.

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References

[1]. BS373, 1957. *Methods of testing small clear specimens of timber*

[2]. Civilengineering, 2012. *Civil Engineering.* [Online] Available at: http://www.civilengineeringx.com/traditional-materials/classification-of-timber [Accessed 1 6 2015].

[3]. EUROCODE5, 1995. *Structural Timber Design.*

[4]. G.Breyer, M. & :C.H.Banks, 1957. Comparison of resistance of six timbers to sulpuric acid. *South african furestry association*, 30(1), pp. 7-29.

[5]. Ruwanpathirana, N., 2008. [Online] Available at: http://timber.lk/timberindustry/publish/Timber%20Utilization%20in%20Sri%20Lank%20-presentation.pdf

[6]. Ruwanpathirana, N., 2011. 2011 World Forest Day. *Vidusara.*

[7]. Ruwanpathirana,N., 2005. *State Timber Corporation.* [Online] Available at: http://www.timco.lk/statetimco/ [Accessed 03 06 2015].