Feature Article

Development of a Timber Property Classification Based on the End-Use with Reference to Twenty Sri Lankan Timber Species

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Abstract

An investigation was carried out on selected 20 timber species of Sri Lanka to study different wood properties, i.e., wood density, modulus of rapture, modulus of elasticity, compression parallel to grain, shrinkage/movement, workability (sawing, nailing, sanding and finishing), treatability of preservative, timber durability, timber texture by vessel diameter and some gross properties, timber colour and present timber uses. Based on the results, an attempt was made to classify the studied timber species into property levels. The final objective of this study was to develop relationships between the end-uses of timber and their property requirements and levels with reference to 20 Sri Lankan timber species.

Timber selection for the use in Sri Lanka is species-oriented and sometimes it is based on the traditional use. Based on wood properties of 20 Sri Lankan timber species selected, an attempt was made to recognise the most important wood properties and their levels to develop a four end-use property classification. In general, the proposed end-use property classification in this study could be differentiated as (i.) for building construction, (ii.) for furniture and joinery (iii.) for light construction, and (iv.) for miscellaneous uses. Among the selected timber species, *Dipterocarpus zeylanicus* is eminently suitable for under-water work. *Eucalyptus microcorys* is regarded as one of the best timbers for dancing floors. These specialty and causative factors of timber, however, must be explored and documented in order to prepare end-use property classification for miscellaneous use.

1. Introduction

Sri Lanka a small island of 6,561,000 ha, posses a significant biodiversity along with various tree species. Total natural forest cover in Sri Lanka is 1,951,472 ha which consists 1,521,987 ha of closed canopy forests and 429,485 ha of open canopy forests. There are over 350 timber tree species present in these forests and other crown lands. Present annual timber consumption in Sri Lanka is 1.6 million m^3 from which around 10% is supplied by imports. Forest plantations and homegardens that have the potential of producing good quality timber contribute about 10% and 40% of national timber requirements respectively.

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ISSN 2235-9370 Print/ISSN 2235-9362 Online

Wood properties vary with timber species and each and every property may bring a unique value and important feature to timber and its end-use. This variability of timber serves a variety of uses and if a particular timber is good for one purpose it may not be useful for another purpose. In general, selection of timber species for particular end-use depends on technical performance of timber such as durability, movement, strength, stiffness and toughness, permeability and ease of processing. Lack of knowledge on mechanical properties of structural timber leads to structural application of unnecessarily high safety margins in timber design. As far as wood properties of Sri Lankan timber species are concerned, comprehensive studies were not conducted on physical properties, mechanical properties, and anatomical properties, gross features, working properties, durability, timber seasoning and preservation. Timber selection for the use is species oriented, sometimes on the basis of traditional use, however, more frequently on considerations of availability, cost, size and performance. Therefore information is much useful for the selection of timber species for the end-use because an appropriate combination such technical information is often among the last to be considered at present.

An end-use property classification can be defined in the first place for building construction, furniture and joinery, light construction work and miscellaneous uses, flooring and furniture. For instance, property requirements and preferable property level for property classification for major user groups can be judged based on experience of the factors which affecting performance, and guided by standards and specifications. This paper provides most of important wood properties with its property levels such as density, some mechanical properties, natural durability and treatability, dimensional movement and seasoning properties, working properties, gross features (colour and texture). Hence using this information on property requirements for a product, it is possible to select the suitable timber species in which required technical information is available.

The objectives of the present study were to determine wood properties of 20 selected Sri Lankan timber species (Table 1), to classify the studied wood properties into property levels and to develop relationships between the end-uses of timber and their property requirement and levels with reference to twenty Sri Lankan timber species.

Table 1: List of commonly used timber species.

No	Name	Scientific name	Family
1	Acacia	*Acacia malanoxylon*	Fabaceae
2	Ginisapu	*Michelia champaca*	Magnoliaceae
3	Grandis	*Eucalyptus grandis*	Myrtaceae
4	Havarinuga	*Alstonia macrophylla*	Apocynaceae
5	Hora	*Dipterocarpus zeylanicus*	Dipterocarpaceae
6	Ketakala	*Bridelia retusa*	Phyllanthaceae
7	Khaya	*Khaya senegalensis*	Meliaceae
8	Kohomba	*Azadirachta indica*	Meliaceae
9	Kolon	*Adina cordifolia*	Rubiaceae
10	Kos	*Artocarpus heterophyllus*	Moraceae
11	Kumbuk	*Terminalia arjuna*	Combretaceae

12	Liyan	*Homalium zeylanicum*	Salicaceae
13	Lunumidella	*Melia dubia*	Meliaceae
14	Mahogany	*Swietenia macrophylla*	Fabaceae
15	Mee	*Madhuca longifolia*	Sapotaceae
16	Microcorys	*Eucalyptus microcorys*	Myrtaceae
17	Para Mara	*Albizia saman*	Fabaceae
18	Rubber	*Hevea brasiliensis*	Euphorbiaceae
19	Teak	*Tectona grandis*	Verbenaceae
20	Toona	*Toona ciliata*	Fabaceae

2. Materials and Methods

Authentic timber samples of 20 Sri Lankan timber species were collected from the Research Division of State Timber Corporation (STC) along with fresh wood samples from the mature trees in the field. Wood samples and disks were cut from each species at breast height of the tree. The collected specimens from the two sources mentioned above were compared anatomically with each other for the confirmation of species identity. A radial strip was cut from each disk for the investigation of anatomical characteristics. Required number of timber samples with necessary dimensions were cut and removed for the measurement of specific gravity, mechanical properties, shrinkage and movement, durability testing at grave yard, boron preservation, working properties, wood texture and heartwood colour.

2.1 Timber density

A radial strip cut from each disk was used for the measurement of timber density. Timber density was determined on the basis of oven-dry weight and green volume. Timber density of 20 species studied were grouped into four categories as light wood (<= 500 kgm^{-3} at 12% moisture content), medium density wood (500-640 kgm^{-3}), high density wood (640-840 kgm^{-3}) and very high density wood (>840 kgm^{-3}).

2.2 Shrinkage and movement

Wood specimens (2×2 cm in cross section and 5 cm long) in green state were weighed up to the accuracy of 0.001 g and conditioned to achieve constant weights at about 10-12% moisture and then oven-dried at 103^0 C until a constant weight was obtained. Lengths of the specimens along radial and tangential plane at green, air dry and oven dry conditions were measured and radial and tangential shrinkages were calculated. These samples, prior to use for oven dry measurement were subjected to determine the timber movement under atmospheric condition from relative humidity of 80% to relative humidity of 60%. Shrinkage and movement properties levels were categorised into three groups as high (>12%), medium (7%-12%) and low (<7%).

2.3 Mechanical properties

Static bending test of air-dried 2×2 cm (cross section) and 30 cm long specimen was carried out using a universal test machine. Deflections and the corresponding loads were recorded and load deflection curves were prepared. Modulus of rapture and modulus of elasticity were calculated.

Compression perpendicular to grain was also carried out by same machine using timber sample of 2×2 cm (cross section) and 6.2 cm long specimen.

2.4 Wood durability.

Heartwood timber samples (5×5×60 cm) were buried in ground following the principle of grave yard experiment and deterioration of timber with time table were observed. Timber durability was classified as non-durable (<5 years), moderately durable (5-10 years) and durable (>10 years). In addition, ground survey was conducted to collect information of timber durability.

2.5 Timber treatability with boron preservation

Depth of penetration and retention of boron preservative were calculated after timber samples were immersed in the boron solution complying for standard procedure. Boron retention levels were classified as easy (>10 kgm^{-3}), medium (6-10 kgm^{-3}) and difficult (<6 kgm^{-3}).

2.6 Wood colour

Wood samples containing both heartwood and sapwood were used to determine wood colour according to IAWA (1989) category No. 197 to 202 by naked eye. Heartwood colour was categorised mainly into four groups, namely, (i.) basically brown or shade of brown, (ii.) red or shade of red, (iii.) yellow or shade of yellow and (iv.) white to grey. Visible differentiation of heartwood color from sapwood was also studied.

2.7 Anatomical characteristics

A radial strip taken from the pith to bark was used for the investigation of anatomical characteristics. These wood samples were boiled in water for about two hours to soften them. Each wood sample was shaped and sized into wood block of 2×2×3 cm. Transverse, radial and tangential sections at the range of 10-15 µm thickness were obtained by using a sledge microtome (Model Leica SM2000 R). The permanent slides of wood were prepared after dehydrated and stained in safranin. Sections were mounted using Canada balsam using standard procedure.

Microscopic observations of each slide were made for qualitative and quantitative analysis of parameters under the light microscope at 4×10 magnifications. Measurements on wood anatomical features were taken after photomicrographs of each slide were made by Olympus microscope and Micromertics SE Premium 4 software available in the Research Division of STC. Measurements of tangential vessel diameter were used to determine the wood texture.

2.8 Wood texture

Mean vessel tangential diameter, ray width and ray height were measured in this study from which average tangential diameter of the vessel (µm) was used to determine wood texture. Vessel size is primarily responsible for texture, however, in a wood with large rays and vessels of moderate size or small size, coarse texture may ensure from large rays alone. The classification given in Table 2 and ray information studied serve to indicate roughly the basis of classification.

Table 2: Classification of wood texture.

Type of wood texture	Average tangential vessel diameter (μm)
Fine textured	< 100
Medium textured	100 - 200
Coarse textured	>200

2.9 Wood working properties

Wood working properties such as sawing, nailing, sanding and polishing were determined with the assistance of an experienced carpenter. Accuracy of the results was maintained by doing repeated tests. In order to obtain an idea of sawing ability, air seasoned, uniform thickened mature heartwood potions were also tested by the experienced carpenters. In order to depict data clearly, results were grouped into three categories as easy, moderate and difficult. For nailing, the air seasoned mature heartwood samples in dimensions of 132×7.5×12 mm were used. The nailing was done on cross section surface 13 mm interior to the border. Results were categorised into three groups as easy, moderate and difficult. Sanding data were obtained through number 320 sanding paper and results were categorized as very good, good and moderate. Final finishing property also classified as very good, good and moderate.

2.10 Islandwide survey

An Islandwide questionnaire survey was conducted to gather information from timber users who have experience on timber durability particularly using timber in outdoor uses.

3. Results

Table 3, 4, 5, and 6 present in the following sections illustrate all wood properties studied in this research work.

Table 3: Wood density and density property classes, modulus of elasticity, modulus of rupture and compression parallel to grain of the selected timber species.

No	Species	Density class	Density At 12% m.c.	Modulus of elasticity (Nmm^{-2})	Modulus of rupture (Nmm^{-2})	Compression parallel to grain (Nmm^{-2})
1	*Acacia malanoxylon*	HD	738	11,811	90	45
2	*Michelia champaca*	LD	500	8,503	64	32
3	*Eucalyptus grandis*	MD	595	9,827	74	37
4	*Alstonia macrophylla*	HD	690	11,150	84	43
5	*Dipterocarpus zeylanicus*	HD	762	12,142	92	47
6	*Bridelia retusa*	VHD	850	13,500	103	50
7	*Khaya senegalensis*	MD	603	9,932	75	37
8	*Azadirachta indica*	HD	714	11,481	87	44
9	*Adina cordifolia*	HD	666	10,819	82	41
10	*Artocarpus heterophyllus*	MD	625	10,250	78	39

11	*Terminalia arjuna*	HD	714	11,481	87	44
12	*Homalium zeylanicum*	HD	738	11,811	90	45
13	*Melia dubia*	LD	400	6,050	40	20
14	*Swietenia macrophylla*	MD	609	10,025	76	38
15	*Madhuca longifolia*	VHD	900	14,250	115	58
16	*Eucalyptus microcorys*	VHD	875	13,719	105	53
17	*Albizia saman*	MD	585	9,694	73	36
18	*Hevea brasiliensis*	MD	540	9,059	68	34
19	*Tectona grandis*	HD	720	11,550	88	43
20	*Toona ciliata*	LD	500	850	60	30

* LD = Low density, MD = Medium density, HD = High density, VHD = Very high density.

Table 4: Wood working properties, seasoning and wood shrinkage in twenty timber trees.

No	Scientific name	Seasoning and shrinkage	Working properties
1	*Acacia malanoxylon*	Must be thoroughly seasoned. Seasons well. Shrinkage green to oven dry is 6%.	Easy to work with hand and machine tools. Excellent polishing properties. Glues and stains well. Poor nailing. Splits easily and pre-boring is recommended.
2	*Michelia champaca*	Seasoning is not easy as the timber is liable to split especially if left in the log form. Shrinkage green to oven dry is 8.4%.	Easy to saw and works to a smooth surface. Good polishing.
3	*Eucalyptus grandis*	Difficult to season, Cupping may occur in back-sawn boards, but can be removed by reconditioning treatment. Shrinkage green to 10% moisture content is 6.03%.	Young trees work easily. Old material may produce certain surface wooliness and tendency to split. Free from defects. Good polishing..
4	*Alstonia macrophylla*	Green conversion and immediate seasoning give best results. Shrinkage green to 10% moisture content 8.92%.	Sawing and nailing are somewhat difficult. Easy to sanding and takes a good polish.
5	*Dipterocarpus zeylanicus*	Seasoning is somewhat difficult. Air drying is needed before kiln drying. Shrinkage green to 10% moisture content is 6.63%.	Easy to sawing. Somewhat easy to nailing. Easy to sanding and finishing is somewhat good.
6	*Bridelia retusa*	Seasons defects sometimes appear and hence green conversion and prompt stacking for slow drying is recommended. Shrinkage green to 10% moisture content is 5.45%.	Saws and machines well and works to a smooth surface. Easily worked with hand tools.
7	*Khaya senegalensis*	Seasons well. Shrinkage green to 10% moisture content 4.78%.	Easy to sawing, nailing and sand papering. Good finish when polished. Filling materials should be used.

8	*Azadirachta indica*	Seasons well. Shrinkage green to 10% moisture content is 2.48%.	Somewhat difficult to sawing. Easy to nailing and sand papering. Poor finish when polishing (good for staining).
9	*Adina cordifolia*	Seasons well. Shrinkage green to oven dry is 10.2%. Shrinkage green to 10% moisture content is 5.88%.	Easy to sawing and sand papering, slightly difficult to nailing, good finish after polishing.
10	*Artocarpus heterophyllus*	Seasons easily. Shrinkage green to 10% moisture content is 1.62%.	Easy to saw and work. Finish well particularly if fillers and sealers are used. Polish with a high lustre.
11	*Terminalia arjuna*	Seasons well. Should dry slowly. Large timber prone to crack split and bend. Shrinkage green to 10% moisture content is 5.79%.	Difficult to sawing and nailing. Sand papering is easy. Good finish when polishing.
12	*Homalium zeylanicum*	Somewhat difficult to seasons. Shrinkage green to 10% moisture content 14.4%.	Saws and works easily. Takes a good polish.
13	*Melia dubia*	Seasons easily. Shrinkage green to 10% moisture content is 6.06%.	Easy to saw and work, but difficult to obtain a smooth finish on the account of its softness.
14	*Swietenia macrophylla*	Seasons well and easily without much checking or distortion. Kiln drying satisfactorily when moderate scheduling. Shrinkage green to 10% moisture content is 2.93%.	Saws, planes and moulds easily, finish to a smooth surface. Wood takes an excellent polish. Gluing and nailing are good. Discolorations in contact with iron, copper and brass.
15	*Madhuca longifolia*	Seasons well. If converted green, log tend to split at the ends if left unconverted. Shrinkage green to 10% moisture content is 8.65%.	Sawing is somewhat easy. Difficult to nailing and easy for sand papering. Good finish when polished.
16	*Eucalyptus microcorys*	Somewhat difficult especially with fast grown timber. Shrinkage green to 10% moisture content is 9.77%.	Easy to saw. Difficult to nail, sanding and polishing. Difficult to obtain a good polish.
17	*Albizia saman*	Seasons well. Shrinkage green to 10% moisture content is 9.18%.	Easy to sawing, nailing and sand papering.
18	*Hevea brasiliensis*	Seasons well. Shrinkage green to 10% moisture content 7.69%.	Easy to sawing, nailing and sand papering. Good finish when polishing.
19	*Tectona grandis*	Once seasoned "movements" are very little. Shrinkage green to oven dry is 9.9%.	Not difficult to saw or work, but care is need in working as the timber is somewhat brittle.
20	*Toona ciliata*	Seasons easily but radial checks and heart-shakes develop in the log. Careful stacking is required to prevent warping. Shrinkage green to 10% moisture content is 9.85%.	Saws and works easily with good finishing qualities.

Table 5: Durability of wood , wood texture and heartwood colour.

No	Scientific name	Durability	Heart wood colour and wood texture
1	*Acacia malanoxylon*	Durable. Resistant to effective preservative treatments.	Brown or shaded of brown (IAWA). Rich reddish brown to nearly black banded with golden brown or red. Even, medium to even textured.
2	*Michelia champaca*	Durable. Easy to medium ability to apply preservative treatments.	Yellow or shaded of yellow (IAWA). Light yellowish brown to olive brown. Lustrous. Even and medium textured.
3	*Eucalyptus grandis*	Moderately durable. Somewhat difficult to apply preservative treatments.	Red or shaded of red (IAWA). White to pink or light to dark red brown with a pink tinge, depending on age and area of origin. Medium or coarse textured.
4	*Alstonia macrophylla*	Moderately durable. Easy to apply preservative treatments.	Yellow or shaded of yellow (IAWA). No distinct heartwood. Cream colour. Medium, even textured.
5	*Dipterocarpus zeylanicus*	Moderately durable. Somewhat difficult to apply preservatives.	Red or shaded of red (IAWA). Light pinkish brown on first exposure ageing to reddish brown. Even and coarse textured.
6	*Bridelia retusa*	Durable. Difficult to apply preservative treatments.	Brown to shaded of brown (IAWA). Dark to olive brown sometimes with darker streaks. Medium and fairly even textured.
7	*Khaya senegalensis*	Moderately durable. Easy to apply preservative treatments.	Red or shaded of red (IAWA). Even pink colour to reddish brown (mahogany brown). Medium and coarse textured.
8	*Azadirachta indica*	Durable. Difficult to apply preservative treatments to heartwood.	Red or shaded of red (IAWA). Red when first exposed darkening to reddish brown and then resembling mahogany. Medium to somewhat coarse textured.
9	*Adina cordifolia*	Moderately durable. Easy to apply preservative treatments.	Yellow or shaded of yellow (IAWA). Citron yellow when first exposed, turning pale yellowish or reddish brown with age. Fine and even textured.
10	*Artocarpus heterophyllus*	Durable. Resistant to effective preservative treatments.	Yellow or shaded of yellow (IAWA). Yellow or lemon yellow gradually turning to a rich mahogany brown, very old wood to a warm Vandyke brown. Coarse textured.
11	*Terminalia arjuna*	Durable. Easy to apply preservative treatments.	Brown to shaded of brown (IAWA). Olive brown streaked with dark blackish lines. Coarse and even textured.
12	*Homalium zeylanicum*	Durable. Difficult to apply preservative treatments.	Brown to shaded of brown (IAWA). Yellowish brown to yellowish red on first exposure. Even and fine textured.

13	*Melia dubia*	Non-Durable. Easy to apply preservative treatments.	Red or shaded of red (IAWA). Light pink to light red, when first exposed ageing to reddish brown. Coarse and somewhat uneven textured. Subject to a grey stain.
14	*Swietenia macrophylla*	Durable. Resistant to effective preservative treatments.	Red or shaded of red (IAWA). Reddish, pinkish, salmon coloured or yellowish when fresh, darkening to deep red or brown with age. Moderately fine to rather coarse.
15	*Madhuca longifolia*	Durable. Difficult to apply preservative treatments.	Red or shaded of red (IAWA). Dull, dark red, ageing to dull reddish brown streaked with light brown lines. Coarse and even textured.
16	*Eucalyptus microcorys*	Durable. Resistant to effective preservative treatments.	Yellow or shaded of yellow (IAWA). Pale or yellowish brown or straw colour. Moderately coarse and even textured.
17	*Albizia saman*	Moderately durable. Resistant to effective preservative treatments.	Brown to shaded of brown (IAWA). Golden brown to dark brown. Coarse textured.
18	*Hevea brasiliensis*	Non-Durable. Easy to apply preservative treatments.	Brown to shaded of brown (IAWA). Difficult to distinct from the softwood. White colour when first exposed, turn into pale brown when ageing. Pink tinge present. Coarse and even textured.
19	*Tectona grandis*	Durable. Difficult to apply preservative treatments.	Brown to shaded of brown (IAWA). Golden brown which darkens with age. Coarse and uneven textured.
20	*Toona ciliata*	Moderately durable. Difficult to apply preservative treatments.	Red or shaded of red (IAWA). Light brick red when first exposed, ageing to a rich reddish brown. Moderately fine and somewhat uneven textured.

Table 6: Uses twenty timber species.

No	Scientific Name	Uses
1	*Acacia malanoxylon*	Furniture, boats, cabinets, plywood, doors and window frames, fittings in banks, railway carriages, gun stocks, decorative works.
2	*Michelia champaca*	Reapers, ceiling spacers, door and window sashes, partition frames, floor boards, buildings, cheap furniture, valance boards.
3	*Eucalyptus Grandis*	General construction, bridges, poles, posts, furniture, paneling, sleepers.
4	*Alstonia macrophylla*	General construction, toys, match-boxes, posts, cheap furniture, coffins, carving, blackboards, transmission poles.

5	*Dipterocarpus zeylanicus*	Reapers, ceiling spacers, fascia boards, door frames, partition frames, cheap furniture, treated sleepers, transmission poles, construction, under-water work, piles, boards, scaffoldings, rafters, beams.
6	*Bridelia retusa*	Rafters, purlins, ridge hips, ceiling joists, wall plates, beams, reapers, buildings, furniture, agriculture implements, drums, carts, cart shaft.
7	*Khaya senegalensis*	Boxes, posts, light construction, ceiling boards, door and window sashes.
8	*Azadirachta indica*	Furniture, paneling and decorative work, rafters purlins, ridges hips, ceiling joists, wall plates, reapers, buildings, panels, carvings, bottom of drawers.
9	*Adina cordifolia*	General utility timber, purlins, ridge hips, reapers, railing spacers, door andwindow sashes, furniture, carvings, fine turnery wood, ornamental caskets, picture frames, brush-backs.
10	*Artocarpus heterophyllus*	House building, furniture, carriages, cabinet making, musical instruments, boats, building, casks.
11	*Terminalia arjuna*	Beams, rafters, purlins, ridge hips, ceiling joists, wall plates, furniture, construction, bridges.
12	*Homalium zeylanicum*	Beams, rafters purlins, ridges hips, ceiling joists, wall plates, flooring, buildings, boats, oars, stair cases, brush backs, posts.
13	*Melia dubia*	Ceiling boards, paneling and packing cases, cigar boxes.
14	*Swietenia macrophylla*	Door andwindow frames, partition frames, furniture, cabinets, paneling and decorative work, railway carriages, piano cases, veneers.
15	*Madhuca longifolia*	Heavy construction, agricultural implement, reapers, ceiling spacers, door andwindow frames, partition frames, heavy construction, posts, beams, boats, bridges.
16	*Eucalyptus microcorys*	Piles, poles, posts, flooring, sleepers, transmission poles, heavy construction work, excellent for dance floors.
17	*Albizia saman*	Beams, rafters, purlins, ridges hips, ceiling joists, wall plates, furniture, paneling, flooring.
18	*Hevea brasiliensis*	Partition frames, ceiling boards, furniture, light construction, brush handles.
19	*Tectona grandis*	Ship building, high class joinery, flooring, interior fittings, door and windows frame and sashes, stair cases, fancy goods, veneers, railway carriers, beams, rafters purlins, ridges hips, ceiling joists, wall plates, reapers, ceiling spacers, furniture, railway carriages.
20	*Toona ciliata*	Furniture, paneling, cigar boxes, racing boats, musical instruments.

4. Discussion

It can be understood that when popular or well known timber is not available or not affordable due to high cost, another timber species is sought often on the basis of comparability with that formerly used. In this timber selection process, the cost involved is often considerable and users may be reluctant to face risk accepting the unknown timber species. This situation can be altered by providing guidance on property needs for the appropriate to end-use. The end-use property classification given in this paper provides the means to make an objective assessment of

the suitability for a particular purpose of timber use. However, this suitability of timber depends on the combined cost of the selected timber and additional cost involved for processing (e.g. preservation). This cost is compared with the cost of a timber which is not required for additional processing.

Thelandersson and Hansson (1999) stated that wood has significant variations in its properties both between and within timber elements. Variations in strength properties may be species-specific, age-dependent and environmentally responsive. Therefore it is suggested to conduct more research work in this field based on more timber samples representing of the entire population.

Understanding physical properties, mechanical properties, durability and gross features of various timber species are very much important in selecting timbers for various purposes. Correct use of timber always increases the life time of the final product, whether it is high class furniture or a simple craft work. This paper provides most important wood properties facilitating to select timber species according to end-use or end use requirement of twenty Sri Lankan timber species.

In general, the proposed property classification in this paper can be categorised as (i.) end-use property classification for building construction, (ii.) end-use property classification for furniture and joinery (iii.) end-use property classification for light construction and (iv.) end-use property classification for miscellaneous uses. It is an imperative exercise to find out the most influential wood properties for each category of end use property classification given here with.

Very high density timber such as *Madhuca longifolia* and *Eucalyptus microcorys*, studied in this research work are often chosen for heavy construction work due to not only its high strength property but also good performance experience in use for centuries. It was found that timber density of *M. longifolia* and *E. microcorys* are 900 kgm^{-3} and 875 kgm^{-3} at 12% m.c respectively. In addition, both species showed high values of mechanical properties such as modulus elasticity, modulus of rapture and compression parallel to grain (Table 3). Both timber species demonstrated effective resistant to boron treatment when application of preservatives was done. Furthermore, results of grave yard test showed that both timber species can be classified as durable timber. As far as wood working properties are concerned, sawing is easy and nailing is difficult for both species. Working properties like sanding and polishing did not demonstrate such similarity in *M. longifolia* and *E. microcorys*. These finding might be used to define the standard for quality requirement and quality level for end-use property classification for construction timber. In this classification, some important quality requirements like seasoning defects, dimensional movement etc. can also be included for further improvement. Further it is recommended that preferable property level of timber for major end-uses should be studied in future research.

End-use property classification for furniture and joinery category which involves end-use products like window joinery, door and window frames, flooring and cabinet work etc. can be derived for the construction timber category mentioned in the earlier section. *Acacia malanoxylon, Adina cordifolia, Artocarpus heterophyllus, Terminalia arjuna, Swietenia macrophylla. Tectona grandis* and *Eucalyptus grandis* have proven timber quality complying with technical requirements, needed for end-use category of furniture and joinery. When variations of timber density of furniture and joinery category were analysed it was found that all the species can be categorised as medium to high density. This group of timber has somewhat lower density than to construction timber category. Results in Table 4 show that the timber in this category seasons well and demonstrated comparatively better working properties than those in the construction category. According to

IAWA (1989) classification, the heartwood colour of furniture category timber consists of different wood colour. *A. malanoxylon, T. arjuna* and *T. grandis* have brown or shaded brown colour and *S. macrophylla* and *E. grandis* have red or shaded red colour followed by *A. cordifolia* and *A. heterophyllus* with yellow and shaded yellow. According to this finding, property requirements and level for the end-use classification for furniture and joinery might be derived from these research findings and further development can be made with increased number of timber species. In this direction, we have initiated a research program to collect wood properties of 235 Sri Lankan timbers. The publication of "Sri Lankan timber: Timber properties and its uses" covering 100 timber species is now in the press and it will be helpful to those who are willing to continue research in this regard.

Among many timber varieties used for light construction work in Sri Lanka, *M. champaca, M. dubia, T. ciliate* and *H. brasiliensis* are the most popular timber species. It can be assumed that wood properties in this study might influence mainly for the end-use application. Therefore by recognising these influential wood properties, it was possible to list out major property requirements and level for end-use property classification. According to Table 3, all the above timber species belong to light to medium density categories and having low mechanical properties. Both *H. brasiliensis* and *M. dubia* are non-durable and both timber can be preserved easily. According to the results of the boron treatment (Table 5), *M. champaca* and *T. ciliate* were classified as easy/medium category and difficult category respectively. All three species which were tested for working properties showed almost similar results indicating that working properties such as sawing and nailing are easy. Major property requirements for end-use property classification for light construction can be identified by these results.

End-use property classification for miscellaneous uses might be developed for the specific end-use application. For instance, *M. longifolia* timber is perfect for storing boxes of paddy seeds or container because this timber is capable to repulse pests or insects that use to come and destroy the paddy yield.

Some timber species such as *B. cordifolia* is highly demanded for manufacturing of vats. It is believed that *B. cordifolia* timber can enhance the quality of liquor by absorbing unfavorable matters and improve the taste and smell. Timber like *B. retusa* and *V. pinnata* possess special wood quality which helps to persist the timber in ground contact environment without getting deterioration. *D. zeylanicus* is eminently suitable for under-water work. *E. microcorys* is regarded as one of the best timber for dance floors. This specialty and causative factors of timber must be explored and documented in order to prepare end-use property classification for miscellaneous use.

Finally, if there is a timber property classification, i.e., requirement and property level for major end-uses as discussed in this paper and comprehensive information on wood properties of Sri Lankan timbers is available, then the timber industry will be able to define the technical information of timber which they need for their end-use applications. Subsequently the timber supplier can easily quote and supply the most suitable timber variety which is complying its technical performance with the requirement of end-use.

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