Physical and mechanical properties and uses of timbers of Bangladesh

M. A. Sattar

D. K. Bhattacharjee
Research Officer
and
M. F. Kabir
Research Officer

Seasoning and Timber Physics Division

Government of the People's Republic of Bangladesh
Bangladesh Forest Research Institute
Chittagong

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FOREWORD

There is an acute shortage of timber in Bangladesh. This is why there exists an imbalance between the supply and demand position. Lack of proper processing and utilization is one of the major factors for such a position. An adequate knowledge of the basic physical and mechanical properties of timber is a pre-requisite for efficient utilization. It is also useful in the purchase of timber, preparation of specifications in engineering structures, and in the selection and classification of wood and wooden products.

There has been extensive studies in the Bangladesh Forest Research Institute to evaluate different physical and mechanical properties of commercial and commercially less acceptable timber species. Based on the properties, the present and potential uses of these species have been mentioned. The results have been published as bulletins, reports and research papers. These are scattered, and it is thus difficult to get access to this information at a time. All these information have been collated and published in this booklet. It is expected that it will be convenient for various government, non-government and other organizations as well as concerned individuals to use the information for deriving maximum advantage.

Dr. M. A. Sattar
Director
Bangladesh Forest Research Institute
Chittagong.

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INTRODUCTION

Bangladesh has a total land area of 14.3 million ha of which 2.2 million ha is under forests. The forest area amounts to about 15% of total land, but only 6.5% is actually under the tree cover. There are also village forests covering an area of about 0.27 million ha. These are scattered around the homesteads all over the country under the private ownership. The village forest accounts about 11% of the total forest areas, but supplies a major portion of sawn wood, fuelwood, etc. of the total consumption.

From the beginning of time man has found in wood the answer to many of the problems of his existence. Wood is considered as the prime material for the survival of mankind and also as the fundamental one for the enhancement of civilization. But wood is not being properly used due to lack of the knowledge of information on its proper utilization characteristics. So in selecting wood for a particular purpose, the researchers have found that a basic knowledge of the physical and mechanical properties of a species of timber is essential if it is to be used in an economical and efficient manner.

There are more than 500 timber species in the forests and village groves of Bangladesh. These differ widely in their appearance and in different technological properties. Of them, there are some species which are being used traditionally and are considered as commercial important timber species. Rest of the species is thus treated as commercially less acceptable ones. About 84 timber species of both commercially important and less important have been studied time to time for evaluating their physical and mechanical properties. The information on the properties and their utilization were reported in different publications. (Ali *et al.* 1974; Bhattacharjee *et al.* 1987, 88; Kabir 1992, 1994, 1995; Sattar and Ali 1978; Sattar *et al.* 1980, 1991, 1991, 1995; Sattar and Bhattacharjee 1983, 1987, 1988, 1990; Sattar 1981, 1983, 1992, 1995, 1997, 1998; Sattar and Akhtaruzzaman 1997, 1997; Yakeeb *et al.* 1970, 1972, 1978, 1980, 1983.) It is, at present, considered necessary that the physical and mechanical properties of all the species tested so far should be consolidated in one publication in order to facilitate the endusers to readily get the information. This publication is aimed at to serve the purpose.

MATERIALS AND METHODS

Eighty two different timber species were collected for finding out their physical and mechanical properties. Of them, twenty six species are considered commercial timber species. These are as follows :

1. Teak (*Tectona grandis*)
2. Champa (*Michelia champaca*)
3. Chapalish *(Artocarpus chaplasha)*
4. Civit *(Swintonia floribunda)*
5. Chickrassi *(Chickrassia tabularis)*
6. Gamar *(Gmelina arborea)*
7. Garjan, dholi *(Dipterocarpus pilosus)*
8. Garjan, baittya *(Dipterocarpus scaber)*
9. Garjan, dholya *(Dipterocarpus alatus)*
10. Garjan, tellya *(Dipterocarpus turbinatus)*
11. Jackfruit *(Artocarpus heterophyllus)*
12. Jarul *(Lagerstroemia speciosa)*
13. Bhadi *(Lannea coromandelica)*
14. Babla *(Acacia nilotica)*
15. Dhakijam *(Syzygium grande)*
16. Jam *(Syzygium* sp.*)*
17. Mango *(Mangifera indica)*
18. Pitraj *(Amoora rohituka)*
19. Raintree *(Samanea saman)*
20. Neem *(Azadirachta indica)*
21. Batna *(Quercus* sp.*)*
22. Sal *(Shorea robusta)*
23. Silkoroi *(Albizia procera)*
24. Sissoo *(Dalbergia sissoo)*
25. Tali *(Palaquium polyanthum)*
26. Telsur *(Hopea odorata)*

The rest 58 species are thus, treated as commercially less acceptable timber species. There are some exotic species which were introduced in the country. These are as follows:

1. Akshmoni (*Acacia auriculiformis*)
2. Eucalyptus camaldulensis(*Eucalyptus camaldulensis*)
3. Eucalyptus brassiana *(Eucalyptus brassiana)*
4. Eucalyptus citriodora *(Eucalyptus citriodora)*
5. Eucalyptus tereticornis *(Eucalyptus tereticornis)*
6. Mangium *(Acacia mangium)*

ndigenous commercially less acceptable species are as follows :

Ambarela *(Myristica linifolia)*
Bandarhola *(Duabanga grandiflora)*
Banspata *(Podocarpus nerrifolius)*
Baen *(Avicenia alba)*
Barta *(Artocarpus lacucha)*
Barela *(Holigarna caustica)*
Baruna *(Crataeva magna)*
Bhuikadam *(Hymenodictyon orixensis)*
Bonsimul *(Bombax insigne)*
Bohera *(Terminalia bellirica)*
Chakuakorai *(Albizia chinensis)*
Chundul *(Tetrameles nudiflora)*
Chalta *(Dillenia indica)*
Dumur *(Ficus* sp.*)*
Dakroom *(Mitragyna rotundifola)*
Dharmara *(Stereospermum personatum)*
Ghora neem *(Melia azadarach)*
Gab *(Diospyros peregrina)*
Goda *(Vitex peduncularis)*
Gutguttya *(Protium serratum)*
Jansak *(Xanthophyllum flavescens)*
Jargaza *(Dillenia pentagyna)*
Jaritaki *(Terminalia chebula)*
Komaliam *(Homalium bhamoense)*
Lchri *(Anogeissus acuminata)*
Madam *(Anthocephalus chinensis)*
Mumka bhadi *(Engelhardtia spicata)*
Namdev *(Calophyllum polyanthum)*
Nao *(Garcinia cowa)*
Nasturi *(Cinnamonum cecidodaphne)*
Nerung *(Pongamia pinnata)*
Neora *(Sonneratia apetala)*
Nanak *(Schima wallichii)*
Nankra *(Bruguiera conjugata)*
Nandar *(Erythrina orientalis)*
Nonkona *(Pajanelia longifolia)*
Noos *(Pterospermum acerifolium)*
Sinjiri *(Cassia siamea)*
Sarikeli *(Pterygota alata)*
Sageshwar *(Mesua ferrea)*

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28. Kamdev *(Calophyllum polyanthum)*
29. Kao *(Garcinia cowa)*
30. Kasturi *(Cinnamonum cecidodaphne)*
31. Kerung *(Pongamia pinnata)*
32. Keora *(Sonneratia apetala)*
33. Kanak *(Schima wallichii)*
34. Kankra *(Bruguiera conjugata)*
35. Mandar *(Erythrina orientalis)*
36. Monkona *(Pajanelia longifolia)*
37. Moos *(Pterospermum acerifolium)*
38. Minjiri *(Cassia siamea)*
39. Narikeli *(Pterygota alata)*
40. Nageshwar *(Mesua ferrea)*

41. Painya mandar *(Erythrina ovalifolia)*
42. Pitali *(Trewia nudiflora)*
43. Pairag *(Canarium resiniferum)*
44. Passur *(Xylocarpus mollocensis)*
45. Raktan *(Lophopetalum fimbriatum)*
46. Rata *(Aphanamixis polystachya)*
47. Rubber *(Hevea brasiliensis)*
48. Sundri *(Heritiera fomes)*
49. Tentul *(Tamarindus indica)*
50. Toon *(Cedrela toona)*
51. Udal *(Sterculia villosa)*
52. Uriam *(Mangifera sylvatica)*

Three representative trees of these species were collected from different forests and villages of Chittagong, Dhaka, Mymensingh, Khulna, Rajshahi and other areas of the country. The following procedures were followed to evaluate the properties.

Specific gravity

For each species 10 cm discs were cut from the butt, middle and top trunk. Six specimens having nominal size of 2.5 cm x 2.5 cm x 7.5 cm were prepared from each disc totalling 54 specimens for each species. The green specimens were soaked overnight till these were fully saturated, and the green volume of the individual specimen was determined by the water displacement method. The specimens were then equilibriated at 12% moisture content (emc). The volume at this condition was determined by measuring the actual dimension of the specimen with the help of a dial gauge. The specimens were dried in an oven at a temperature of 103 ± 2^{0}C till the specimens attained constant weights. The ovendry weights of specimens were taken by an electric balance and the ovendry volumes were measured by coating the specimens with paraffin wax. Specific gravity was determined based on ovendry weight and volumes at green, 12% moisture content (mc) and ovendry conditions.

Shrinkage

Three specimens, each in the radial and tangential direction, having size of 2.5 cm x 2.5 cm x 7.5 cm were prepared from the butt, middle and top trunk of each tree. The 7.5 cm dimension was in the direction of shrinkage measurement. The initial dimension was taken with the help of a dial gauge. The specimens were then equilibriated at 12% equilibrium moisture content (emc) and the dimensions were measured at that condition. Finally the specimens were placed in an oven maintained initially at 60^{0}C and then progressively raising the temperature to 103 ± 2^{0}C. Care was exercised while drying the specimens so that no drying defect developed. The dimension of each specimen was then recorded. The tangential and radial shrinkages were

determined based on the initial green dimension and dimensions at 12% mc and ovendry condition. Volumetric shrinkage was determined from the data for density measurements. The volume values at green, 12% mc and ovendry conditions were used for the determination of volumetric shrinkage.

Mechanical properties

From each tree 2.4 m bolt was cut from the butt, middle and top trunk. Two paired sticks of 7cm x 7cm were prepared totalling 36 sticks. One pair of sticks was kept under wet condition and the other pair was airdried to about 12% moisture content. All the sticks were dressed to 5.08cm x 5.08cm strips and clear specimens were prepared from these strips according to the sizes specified by ASTM standards (Anon. 1971). The specimens of various tests were tested in accordance with the specifications of ASTM. Except for toughness, all other mechanical tests were carried out in a Riehle screw power type universal testing machine. Toughness tests were performed in a toughness testing machine designed by the US Forest Products Laboratory, Madison.

Details of different tests and properties of wood are given in appendix 1. Factors affecting the strength of wood are discussed in appendix 2.

RESULTS AND DISCUSSION

Specific gravity values were averaged for each species and classified into four groups, *viz*; light, medium heavy, heavy and very heavy wood (Sattar 1981). The average specific gravity values are presented in Table 1. Similarly shrinkage values were averaged for each species. According to shrinkage characteristics the species was then grouped into four groups, *viz*; very stable, stable, medium stable and unstable ones. The shrinkage values are given in Table 2.

In respect of mechanical properties, individual strength value was computed from the data collected from eleven different tests. The average values of various strength properties in both green and airdry conditions are shown in Table 3. Teak of 40-year old has been considered as the standard for comparing the properties as it is well known and widely used timber in Bangladesh for all sorts of work (Yakub *et al*, 1978). In fact it is a very good timber for all purposes. Hence, the strength values of 40-year old teak are given on the top of the table for the sake of comparison. Table 4 represents the strength values of all the species relative to Chittagong teak of 40-year old.

The species tested so far have been classified into two categories. One is of commercially important timber species and the other is of commercially less acceptable ones. Hence, each table is represented as per species classification.

The results of the investigation have been discussed species-wise and are mentioned as follows.

Teak (*Tectona grandis*)

The timber is moderately heavy, moderately strong and very stable. There is probably no other timber in the world which can be put to such a great

variety of uses as teak. Because of its unique dimensional stability, graceful grain and colour, teak is an excellent timber for prized furniture. It is used for door, window, panelling, planking, cabinet making, boat building, pattern making and many other purposes. Teak is rightly termed as an all purpose versatile wood.

Champa (***Michelia champaca***)

It is a moderately heavy, strong and stable timber. Because of its attractive colour and texture, it is ideally suitable for furniture, joinery and cabinet making, door, window, panelling and house hold equipment.

Chapalish (***Artocarpus chaplasha***)

Its timber is light, weak but stable. It is used for furniture, joinery and cabinet making and light constructional works like door and window.

Civit (***Swintonia floribunda***)

It is moderately heavy, moderately strong and moderately stable. It is used as accessories of furniture, joinery and light constructional works.

Chickrassi (***Chickrassia tabularis***)

The timber is moderately heavy, moderately strong and moderately stable. Being a lustrous and often ornamental wood, it is suitable for furniture, panelling and cabinet making. It may be used for door, window and other constructional purposes.

Eucalyptus camaldulensis (***Eucalyptus camaldulensis***)

It is a medium heavy, moderately strong and unstable timber. It can be used in furniture, panelling and joinery. It is also used as transmission and electric pole.

Eucalyptus brassiana (***Eucalyptus brassiana***)

Its timber is heavy, moderately strong and unstable. It is used as furniture and constructional works.

Eucalyptus citriodora (***Eucalyptus citriodora***)

The timber is heavy, strong but unstable. It is suitable for constructional work such as beam and rafter, planking and other purposes.

Eucalyptus tereticornis (***Eucalyptus tereticornis***)

The timber is very heavy, strong but unstable. It can be used for constructional works, poles, posts, and other purposes requiring hard and strong timber.

Gamar (***Gmelina arborea***)

It is a timber of light weight, weak strength but of very stable one. It is one of the most reliable timbers due to its dimensional stability and durability. It is suitable for furniture, door, window, panelling, planking, cabinet making, boat building and pattern making. It is also suitable for musical instrument, toy and novelty item.

Garjan, dholi (*Dipterocarpus pilosus*)

The timber is of moderately heavy, strong but of moderately stable one. It is suitable for constructional purposes like beam, column and bridge. It is used for making railway sleeper and transmission pole.

Garjan, baittya (*Dipterocarpus scaber*)

Its timber is of heavy weight and moderate strength. The timber is moderately stable. It is suitable for constructional purposes and railway sleepers.

Garjan, dholya (*Dipterocarpus alatus*)

It is a moderately heavy, moderately strong but unstable timber. It is used for constructional purposes like beam, column, etc.

Garjan, tellya (*Dipterocarpus turbinatus*)

The timber is of heavy weight, strong, hard but unstable. It is thus ideally suitable for heavy constructional purposes like beam, column and bridge. If treated, it makes excellent railway sleeper. In round form, it is used for transmission pole and post. It may be used for boat and ship building.

Jackfruit, kanthal (*Artocarpus heterophyllus*)

It is a timber of light weight and moderate strength. It is very stable. It is a popular homestead timber used extensively for furniture and cabinet making. It is also used for door, window and other constructional purposes.

Jarul (*Lagerstroemia speciosa*)

It is a moderately heavy, moderately strong and moderately stable timber. It is an excellent constructional timber and in great demand for door, window, beam, rafter and bridge works. It may be used for boat building, railway wagon work, shoe heels, boot lasts and a variety of other purposes.

Bhadi (*Lannea coromandelica*)

Its timber is of medium heavy weight, moderate strength and of moderate stability. It is suitable for planking, packing cages, light constructions, sleepers, plywood and rough furniture.

Dhakijam (*Syzygium grande*)

It is a timber of heavy weight, moderate strength and moderate stability. So it is a good constructional timber. It may be used for door, window and furniture. It is also suitable for boat building, carts and railway sleepers.

Jam (*Syzygium* **sp.**)

The timber is heavy, moderately strong and moderately stable. It is suitable for constructional works, beams, columns, doors and windows, planking, boat building, sleepers, etc.

Mango (*Mangifera indica*)

It is moderately heavy, moderately strong and stable. Because of its moderate weight and hardness, it can be used for furniture, planking and packing cages. If treated, it can be used for door, window and constructional purposes. It makes good veneer for the production of plywood.

Mangium (*Acacia mangium*)

The timber is moderately heavy, weak but stable. It is suitable for furniture, door, window and cabinet making. It can also be used for different purposes requiring medium dense timber.

Pitraj (*Amoora rohituka*)

It is moderately heavy, moderately strong and moderately stable. It is suitable for packing cages and plywood. It can also be used for furniture and cabinet making.

Rain tree (*Samanea saman*)

The timber is moderately heavy, weak but very stable. It is used for furniture, cabinet making and constructional purposes because of its dark colours and good texture. It can produce suitable veneer for plywood.

Neem (*Azadirachta indica*)

Its timber is heavy, very strong and moderately stable. It is a pinkish and lustrous wood with fine texture. It is suitable for furniture, panelling and cabinet making. It can also be used for constructional purposes.

Batna (*Quercus* **sp.**)

The timber is very heavy, very strong but unstable. It is used for constructional works, tool handles, cross arms, sports goods, jute and textile mill accessories, drawing equipment, tent accessories, etc.

Sal (*Shorea robusta*)

It is a heavy, strong and moderately stable timber. It is suitable for all types of construction, beams, columns, bridges, piles, minework, agricultural implements, tool handles, wheel work, wagons, sleepers and poles. It is a general utility timber.

Sil koroi (*Albizia procera*)

The timber is heavy, moderately strong and very stable. Because of its rich chocolate colour and often stripped with darker streak, it offers an excellent figure in wood. It is used for furniture, door, window, panelling and flooring. The decorative veneer can be made from it.

Sissoo (*Dalbergia sissoo*)

The timber is heavy, moderately strong and very stable with graceful colour. It can be used for making furniture of better quality. It is suitable for door, window, beam, flooring and such other purposes. It is also used for cart and wheel and general utility works.

Tali (*Palaquium polyanthum*)

It is a moderately heavy, strong and moderately stable timber. It is suitable for construction works, tool handles, poles and cross arms, etc.

Telsur (*Hopea odorata*)

The timber is moderately heavy, moderately strong and very stable, It is suitable for constructional purposes. It is used for boat building, bridge work, piling, beam, rafter, masts, cart and many other uses considering its quality of strength.

Keora (*Sonneratia apetala*)

It is moderately heavy, weak but moderately stable. It can be used for cheap furniture, light construction, planking and packing cases. It is also suitable for making hardboard and can thus be a substitute for sundri (*Heritiera fomes*) which is a common species for making hardboard.

Akashmoni (*Acacia auriculiformis*)

The timber is moderately heavy, moderately strong and moderately stable. It is suitable for furniture, door, window and other constructional purposes. Transmission pole and post can also be made from round timber.

Banderhola (*Duabanga sonneratioides*)

Its timber is light, weak and stable. It is suitable for light constructional works, packing cases, plywood, door, window, ventilator, etc.

Ambarela (*Myristica linifolia*)

It is a light, weak but stable timber. It can be used in making packing boxes, crates, matches and other uses.

Banspata (*Podocarpus nerrifolius*)

The timber is light, weak and moderately stable, It may be used in making light furniture, joinery, panelling and other uses.

Baen (*Avicenia alba*)

Its timber is of moderately heavy weight, moderate strength and unstable. It is used for constructional works, furniture accessories, tool handles, etc.

Barta (*Artocarpus lacucha*)

It is moderately heavy, weak and moderately stable, It is used in construction in wells and for building as posts, beams, rafters and scantlings. It is also commonly used for piles, boats, oars, dugouts and sometimes for furniture.

Barela (*Holigarna caustica*)

The timber is light, weak but stable. It may be used in making packing boxes, crates, matches and other uses.

Baruna (*Crateva magna*)

It is light, weak but stable. It is suitable for making crates, matches, packing boxes and other uses.

Bhuikadam (*Hymenodictyon orixensis*)

It is a timber of light weight, weak strength but stable. Its uses are for packing boxes, crates, matches, etc.

Bonsimul (*Bombax insigne*)

Its timber is light, weak but stable. It is unique for packing boxes, plywood, crates, matches, etc.

Babla (*Acacia nilotica*)

The timber is heavy, strong but unstable. It is used for house posts and beams. agricultural implements, railway keys, tent pegs, keels and knees of boats, etc. It is used as general utility timber for the agriculturist.

Bohera (*Terminalia bellirica*)

It is a heavy, very strong and moderately stable timber. It is used for house building, chiefly as rafters and boards, packing cases, plough shafts, carts, etc.

Chakua koroi (*Albizia chinensis*)

The timber is light, weak and stable. It is suitable for making packing cases, plywood, cross arms, crates, etc.

Chundul (*Tetrameles nudiflora*)

It is light, weak but stable. It is used in making packing cases, plywood, block boards, etc.

Chalta (*Dillenia indica*)

The timber is moderately heavy, weak and moderately stable. It can be used for furniture joinery, panelling, plywood, flush door, etc.

Dumur (*Ficus* sp.)

It is a light, weak but stable timber. It is occasionally used for tea boxes, more commonly for curbs of wells. The branches are used for palanquin poles, cart yokes, tent poles.

Dakroom (*Mitragyna rotundifolia*)

The timber is moderately heavy, moderately strong and moderately stable. It is suitable for planking, furniture, bobins, turnery work, combs, brush backs, pattern making, plywood and shovel handles, etc.

Dharmara (*Stereospermum personatum*)

It is a moderately heavy, very strong and moderately stable timber. It may be used for house construction, beams, doors and windows, planking, furniture, panelling, tool handles, etc.

Ghora neem (*Melia azadarach*)

It is a light, weak and moderately stable timber. It is used in making packing cases, pencil slat and artificial limbs, etc.

Gab (*Diospyros peregrina*)

The timber is moderately heavy, weak and moderately stable. It is suitable for construction works, plywood, furniture, joinery, panelling and other uses.

Goda (*Vitex peduncularis*)

It is a timber of very heavy weight, very strong but unstable one. It can be used for construction works, railway sleepers, tool handles and ladder etc.

Gutguttya (*Protium serratum*)

The timber is very heavy, moderately strong but unstable. It is suitable for heavy construction works and also for heavy furniture and cabinet making.

Hansak (*Xanthophyllum flavescens*)

It is a moderately heavy, moderately strong and moderately stable timber. It can be used for making furniture, joinery, panelling and other uses.

Hargaza (*Dillenia pentagyna*)

The timber is moderately heavy, strong and moderately stable. It is suitable for making furniture, joinery, panelling, etc.

Haritaki (*Terminalia chebula*)

It is very heavy, strong but unstable. It may be used for construction purposes, railway sleepers, poles, bridges, tool handles.

Homalium (*Homalium bhamoense*)

The timber of the species is very heavy, moderately strong and unstable. It is suitable for construction, sleepers, poles, bridge works, tool handles, etc.

Itchri (*Anogeissus acuminata*)

It is a very heavy, moderately strong but unstable timber. It is a timber for making tool handles and shelves of all sorts. It is also useful for wheel spokes, cart axles, stratchers.

Kadam (*Anthocephalus chinensis*)

It is light, weak but stable. It is suitable for light construction, packing cases, plywood, pencil slats and matches.

Jhumka bhadi (*Engelhardtia spicata*)

The timber is moderately heavy, weak and moderately stable. It is used for making furniture, joinery panelling, etc.

Kamdev (*Calophyllum polyanthum*)

It is a moderately heavy, moderately strong and moderately stable timber. It can be used for making furniture joinery, panelling and other uses.

Kao (*Garcinia cowa*)

The timber is moderately heavy, weak and moderately stable. Furniture, joinery, panelling can be made of it.

Kasturi (*Cinnamomum cecidodaphne*)

It is moderately heavy, strong and moderately stable. It is used for light furniture, packing cases, door, window, flush door, etc.

Kerung (*Pongamia pinnata*)

The timber is moderately heavy, moderately strong and moderately stable. It is used for construction works and tool handles, etc.

Kanak (*Schima wallichii)*

Its timber is heavy, weak and moderately stable. It may be used for construction works, packing cases, plywood, flush door, etc.

Kankra (*Burguiera conjugata*)

The timber is heavy, very strong and moderately stable. It can be used as poles, cross-arms, ballies, etc.

Mandar (*Erythrina orientalis*)

It is a light, weak and unstable timber. If may be used for making packing boxes, matches, etc.

Monkona (*Pajanelia longifolia*)

The timber is light, weak and stable. It can be used in making packing boxes, crates, matches and other uses.

Moos (*Pterospermum acerifolium*)

Its timber is moderately heavy, moderately strong and moderately stable. It can be used in making furniture, joinery, panelling, plywood and other uses.

Minjiri (*Cassia siamea*)

The timber is heavy, weak and unstable. It is suitable to be used as construction purposes, tool handles, furniture accessories.

Narikeli (*Pterigota alata*)

It is a moderately heavy, strong and moderately stable timber. It is used in making packing cases, plywood, furniture, joinery, panelling, etc.

Nageswar (*Mesua ferrea*)

The timber is very heavy, very strong but unstable. It can be used for construction, sleeper, tool handles, poles, cross-arms and anvil block.

Painya mandar (*Erythrina ovalifolia*)

It is a light, weak and moderately stable timber. It may be used for packing box, crates, etc.

Pitali (*Trewia nudiflora*)

The timber is light, weak and stable. It is suitable for packing cases, plywood. sports and athletic goods and matches.

Pairag (*Canarium resiniferum*)

Its timber is moderately heavy, weak and moderately stable. It can be used as furniture, joinery, panelling, etc.

Passur (*Xylocarpus mollocensis*)

The timber is heavy, strong and moderately stable. The timber of the species can be used as construction works, tool handles, poles, cross-arms, plywood, flush doors, etc.

Raktan (*Lophopetalum fimbriatum*)

The timber is light, weak and moderately stable. Its timber may be used for packing cases, plywood, pencil slats, sports goods, matches, light furniture, brush wares, etc.

Rata (*Aphanamixis polystachya*)

Its timber is moderately heavy,weak and moderately stable. It can be used for furniture, joinery, panelling and other uses.

Rubber (*Hevea brasiliensis*)

It is a timber of moderately heavy weight, weak strength, but it is a stable timber. It makes good furniture, plywood, packing cases, crates, but needs treatment.

Sundri *(Heritiera fomes)*

The timber is very heavy, very strong but moderate stable. It is extensively used in boat building as planks, boat oars, spars, masts. Its timber is used for construction as posts and beams. It can be used in making agricultural implements, raw materials for making hard board.

Tentul (*Tamarindus indica*)

The timber is heavy, very strong but unstable. It can be used for tent accessories, jute and textile accessories.

Toon (*Cedrela toona*)

It is a timber of light weight, weak strength and unstable one. It can be used for light furniture, doors, panels, windows, teaboxes, implements for boats, toys, carving materials, musical instruments etc.

Udal (*Sterculia villosa*)

Its timber is light, weak and stable. Its timber can be used for making packing boxes, crates, matches and other uses.

Uriam (*Mangifera sylvatica*)

The timber is moderately heavy, weak but stable. It can be used for light furniture, planking and packing cases. If treated with a preservative, it can be used for door and window. It makes good veneer for plywood.

CONCLUSION

Teak and some other popular species like champa, chapalish, jarul, jam, sal, gamar, garjan, etc. are used in the country for almost all purposes. Owing to continued development activities and execution of various wood based industries in the recent years, acute shortage of popular timbers is now very prominent. On the other hand, several secondary timber species have been found technically suitable for various end-uses. They are not being fully exploited due to absence of technical properties, non-availability near consuming centres, high cost of processing , orthodox trade practices, etc. The need of rational utilization of timber resources and coordinated efforts for balancing the supply and demand and healthy growth of wood based industries in the country, can be met up by using all sorts of timbers.

The results of the works are presented to the public including test data on 84 species from different parts of the country. With these data and information, it is now possible to compare the properties of these woods with teak, and with each other, and thereby to arrive at sound conclusion as to the best timber to use for any specific purpose.

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Table 1. Specific gravity of timber species of Bangladesh

Species	Density based on ovendry weight and volume at			Grouping
	Green	Airdry	Ovendry	
Ambarela (*Myristica linifolia*)	0.36	0.38	0.39	Light
Bandarhola (*Duabanga grandiflora*)	0.41	0.42	0.46	
Banspata (*Podocarpus nerrifolius*)	0.43	0.44	0.52	
Barela (*Holigarna caustica*)	0.37	0.38	0.40	
Baruna (*Crataeva magna*)	0.36	0.40	0.43	
Bhui kadam (*Hymenodictyon orixensis*)	0.40	0.41	0.42	
Bonsimul (*Bombax insigne*)	0.33	0.34	0.36	
Chakua koroi (*Albizia chinensis*)	0.39	0.41	0.45	
Chapalish (*Artocarpus chaplasha*)	0.44	0.47	0.49	
Chundal (*Tetrameles nudiflora*)	0.31	0.33	0.36	
Dumur (*Ficus* sp.)	0.29	0.33	0.34	
Gamar (*Gmelina arborea*)	0.41	0.42	0.44	
Ghora neem (*Melia azadarach*)	0.40	0.43	0.46	
Jackfruit (*Artocarpus heterophylus*)	0.46	0.48	0.49	

Table 1. Specific gravity of timber species of Bangladesh - Contd.

Species	Density based on ovendry weight and volume at			Grouping
	Green	Airdry	Ovendry	
Kadam *(Anthocephalus chinensis)*	0.43	0.44	0.47	Light
Mandar *(Erythrina orientalis)*	0.22	0.23	0.24	
Monkona *(Pajanelia longifolia)*	0.39	0.40	0.42	
Painya mandar *(Erythrina ovalifolia)*	0.25	0.30	0.31	
Pitali *(Trewia nudiflora)*	0.40	0.42	0.44	
Raktan *(Lophopetalum fimbriatum)*	0.38	0.39	0.42	
Toon *(Cedrela toona)*	0.40	0.43	0.48	
Udal *(Sterculia villosa)*	0.29	0.33	0.33	
Akashmoni *(Acacia auriculiformis)*	0.61	0.65	0.70	Moderate heavy
Baen *(Avicenia alba)*	0.53	0.55	0.58	
Barta *(Artocarpus lacucha)*	0.45	0.51	0.53	
Bhadi *(Lanea coromandelica)*	0.58	0.62	0.65	
Civit *(Swintonia floribunda)*	0.53	0.58	0.61	
Chalta *(Dellenia indica)*	0.51	0.56	0.58	

Table 1. Specific gravity of timber species of Bangladesh - Contd.

Species	Density based on ovendry weight and volume at			Grouping
	Green	Airdry	Ovendry	
Champa *(Michelia champaca)*	0.53	0.56	0.59	Moderate heavy
Chickrassi *(Chickrasiia tabularis)*	0.55	0.57	0.58	
Dakroom *(Mitragyna rotundifolia)*	0.58	0.65	0.68	
Dharmara *(Stereospermum personatum)*	0.62	0.65	0.72	
Eucalyptus *(Eucalyptus camaldulensis)*	0.54	0.59	0.68	
Gab *(Diospyros peregrina)*	0.56	0.59	0.63	
Garjan, dholi *(Dipterocarpus pilosus)*	0.58	0.63	0.71	
Garjan, dholya *(Dipterocarpus alatus)*	0.55	0.57	0.64	
Hansak *(Xanthophylum flavescens)*	0.50	0.52	0.56	
Hargaza *(Dillenia petagyna)*	0.52	0.60	0.64	
Jarul *(Lagerstroemia speciosa)*	0.51	0.57	0.61	
Jhumka bhadi *(Engelhardtia spicata)*	0.48	0.51	0.55	
Kamdev *(Calophylum polyanthum)*	0.56	0.59	0.64	
Kao *(Garcinia cowa)*	0.50	0.52	0.56	

Table 1. Specific gravity of timber species of Bangladesh - Contd.

Species	Density based on ovendry weight and volume at			Grouping
	Green	Airdry	Ovendry	
Kasturi *(Cinnamomum cecidodaphne)*	0.52	0.55	0.59	Moderate heavy
Kerung *(Pongamia pinnata)*	0.54	0.59	0.62	
Keora *(Sonneratia apetala)*	0.51	0.54	0.56	
Mangium *(Acacia mangium)*	0.52	0.53	0.56	
Mango *(Mangifera indica)*	0.52	0.53	0.54	
Moos *(Pterospermum acerifolium)*	0.56	0.58	0.62	
Narikeli *(Pterygota alata)*	0.57	0.63	0.66	
Pairag *(Canarium resiniferum)*	0.51	0.54	0.58	
Pitraj *(Amoora rohitoka)*	0.48	0.51	0.54	
Rain tree *(Samanea saman)*	0.54	0.57	0.59	
Rubber *(Hevea brasiliensis)*	0.51	0.54	0.56	
Rata *(Aphanamixis polystachya)*	0.55	0.60	0.62	
Tali *(Palaquium polyanthum)*	0.56	0.57	0.60	
Teak *(Tectona grandis)*	0.58	0.59	0.61	

Table 1. Specific gravity of timber species of Bangladesh - Contd.

Species	Density based on ovendry weight and volume at			Grouping
	Green	Airdry	Ovendry	
Telsur *(Hopea odorata)*	0.59	0.62	0.64	Moderate heavy
Uriam *(Mangifera sylvatica)*	0.49	0.50	0.54	
Babla *(Acacia nilotica)*	0.63	0.69	0.73	Heavy
Bohera *(Terminalia bellirica)*	0.67	0.71	0.78	
Dhakijam *(Syzygium grande)*	0.68	0.72	0.79	
Eucalyptus *(Eucalyptus brassiana)*	0.64	0.67	0.76	
Eucalyptus *(Eucalyptus citriodora)*	0.64	0.70	0.78	
Garjan, tellya *(Dipterocarpus turbinatus)*	0.65	0.71	0.78	
Garjan, baittya *(Dipterocarpus scaber)*	0.66	0.69	0.75	
Haritaki *(Terminalia chebula)*	0.64	0.74	0.78	
Jam *(Syzygium* sp.*)*	0.60	0.63	0.67	
Kanak *(Schima wallichii)*	0.61	0.66	0.72	
Kankra *(Bruguiera conjugata)*	0.71	0.77	0.81	
Mingiri *(Cassia siamea)*	0.67	0.73	0.75	

Table 1. Specific gravity of timber species of Bangladesh - Concld.

Species	Density based on ovendry weight and volume at			Grouping
	Green	Airdry	Ovendry	
Neem *(Azadirachta indica)*	0.69	0.74	0.76	Heavy
Passur *(Xylocarpus mollocensis)*	0.64	0.66	0.73	
Sal *(Shorea robusta)*	0.73	0.78	0.82	
Sil koroi *(Albizia procera)*	0.67	0.69	0.73	
Sissoo *(Dalbergia sissoo)*	0.65	0.71	0.74	
Tentul *(Tamarindus indica)*	0.69	0.76	0.79	
Batna *(Quercus* sp.*)*	0.78	0.85	0.94	Very heavy
Eucalyptus *(Eucalyptus tereticornis)*	0.75	0.82	0.87	
Goda *(Vitex penduncularis)*	0.84	0.89	0.94	
Gutguttya *(Protium serratum)*	0.75	0.84	0.88	
Homalium *(Homalium bhamoense)*	0.80	0.86	0.93	
Itchri *(Anogeissus acuminata)*	0.79	0.83	0.92	
Nageashwar *(Mesua ferrea)*	0.84	0.91	1.03	
Sundri *(Heritiera fomes)*	0.81	0.94	1.01	

Table 2. Shrinkage of timber species of Bangladesh

Species	Shrinkage (%)						
	Radial		Tangential		Volumetric		Grouping
	from green to mc level at						
	12%	OD	12%	OD	12%	OD	
Chickrassi	2.00	2.30	3.00	3.30	4.90	5.00	Very stable
Gamar	2.50	3.00	3.50	4.00	6.70	7.00	
Jackfruit	1.41	2.39	3.05	4.72	2.47	5.72	
Rain tree	1.05	2.41	1.57	3.90	4.20	5.80	
Sil koroi	2.80	3.00	4.20	5.80	6.30	7.00	
Teak	1.80	2.00	2.80	3.00	4.50	5.00	
Telsur	2.00	2.90	3.30	3.90	4.00	6.00	
Ambarela	1.48	2.70	3.78	5.98	5.12	8.24	Stable
Bandarhola	1.36	2.76	2.02	5.03	3.14	9.25	
Barela	1.54	2.97	4.47	6.09	5.62	9.02	
Baruna	2.16	3.50	2.77	5.48	4.58	8.47	
Bhui kadam	1.53	2.36	3.06	4.11	4.59	8.45	
Bonsimul	1.43	2.65	3.70	5.97	5.06	8.17	
Chakua koroi	1.75	3.16	3.63	4.85	4.28	8.68	
Champa	2.85	3.40	4.50	5.60	6.98	9.00	
Chapalish	2.90	3.45	4.55	5.00	6.00	9.00	
Chundul	1.62	2.60	2.83	4.83	4.72	8.61	
Dumur	1.42	2.16	2.98	3.92	3.80	6.02	
Kadam	1.52	3.20	2.91	5.31	3.05	9.60	
Mangium	2.01	2.63	3.52	6.66	7.01	8.25	
Mango	1.67	2.76	2.78	4.42	4.29	7.35	
Monkona	1.55	2.93	2.50	5.88	3.14	8.39	
Pitali	1.44	3.36	2.90	6.22	3.01	8.20	
Rubber	1.80	1.99	2.95	4.95	5.95	8.35	
Udal	1.50	2.24	3.01	4.03	4.14	7.32	
Uriam	2.05	3.13	3.24	6.08	5.25	9.61	
Akashmoni	1.90	2.05	3.76	4.75	8.01	12.42	Moderate
Banspata	2.04	4.05	3.81	6.96	5.39	10.03	stable
Barta	3.19	4.49	7.25	8.38	11.14	12.66	
Bhadi	2.54	5.21	4.52	8.34	6.22	12.20	
Bohera	2.97	4.78	4.87	7.92	5.89	12.75	
Chalta	3.05	3.53	6.70	7.95	9.80	12.96	

Table 2. Shrinkage of timber species of Bangladesh - Concld.

Species	Shrinkage (%)						
	Radial		Tangential		Volumetric		Grouping
	from green to mc level at						
	12%	OD	12%	OD	12%	OD	
Babla	2.71	3.64	4.13	6.71	7.93	13.59	Unstable
Baen	2.85	3.90	4.35	6.91	8.15	13.50	
Batna	2.77	5.31	4.83	7.82	7.98	14.34	
Eucalyptus camaldulensis	3.50	5.95	5.35	8.30	9.00	19.00	
Eucalyptus citriodora	3.40	6.00	5.30	8.15	8.95	19.00	
Eucalyptus brassiana	3.25	5.80	5.15	7.57	8.34	15.20	
Eucalyptus tereticornis	3.00	4.72	5.00	6.92	7.95	13.84	
Garjan, dholya	2.90	3.60	5.03	8.60	8.15	14.30	
Garjan, tellya	3.15	4.20	5.25	8.90	8.22	15.00	
Goda	2.38	5.84	4.12	8.78	7.32	15.31	
Gutguttya	3.26	4.66	5.27	7.37	8.77	14.19	
Haritoki	2.21	5.09	4.54	8.92	5.41	14.37	
Homalium	2.37	4.78	4.16	7.71	7.09	13.52	
Itchri	2.54	4.89	4.36	9.16	7.00	13.86	
Mandar	2.16	3.76	4.51	7.09	6.77	13.21	
Mingiri	3.05	4.00	6.15	7.83	11.83	13.87	
Nageshwar	2.47	6.18	4.06	8.89	8.45	19.02	
Sissoo	2.77	4.94	4.54	8.24	6.70	13.75	
Tentul	3.76	5.38	7.83	8.41	11.24	13.56	
Toon	3.80	5.70	8.01	8.64	12.34	16.00	

OD = Ovendry

Table 3. Mechanical properties of timber species of Bangladesh.

Species	Seasoning condition	Static bending (kg/cm^2)		Compression parallel to grain (kg/cm^2)	Compression perpendicular to grain (kg/cm^2)	Hardness (kg)		Nailwithdrawal (kg)		Grouping
		MOR	MOE	Max. crus.		Side	End	Side	End	
1	2	3	4	5	6	7	8	9	10	
Ambarela	Green	432	68	190	35	244	315	55	60	Weak
	Airdry	554	87	275	42	270	385	80	87	
Baruna	Green	355	55	165	32	227	300	52	55	
	Airdry	480	60	250	40	260	310	75	80	
Bandarhola	Green	475	70	219	36	249	318	58	62	
	Airdry	527	83	270	47	274	386	83	89	
Banspata	Green	325	71	300	45	262	300	60	65	
	Airdry	528	99	380	73	380	390	70	75	
Barela	Green	418	82	210	50	280	320	65	68	
	Airdry	637	90	301	79	400	420	79	82	
Barta	Green	513	63	210	48	310	320	58	60	
	Airdry	599	75	368	86	480	490	52	58	
Bhuikadam	Green	432	61	189	33	229	209	50	54	
	Airdry	585	78	395	66	281	286	53	59	
Bonsimul	Green	309	55	175	23	161	179	40	41	
	Airdry	378	68	305	38	209	186	43	44	
Chakua koroi	Green	380	50	180	49	202	220	42	45	
	Airdry	475	55	300	55	300	315	44	55	
Chapalish	Green	600	90	218	49	365	366	70	76	
	Airdry	661	120	311	81	466	464	83	98	
Chalta	Green	513	61	292	48	355	395	74	77	
	Airdry	662	80	493	93	450	510	84	88	
Chundal	Green	357	56	192	32	210	214	51	53	
	Airdry	415	60	371	53	255	346	55	58	
Dumur	Green	362	47	156	44	243	249	56	60	
	Airdry	433	36	203	46	265	285	58	61	
Gab	Green	363	33	195	40	215	220	50	52	
	Airdry	420	43	380	56	260	300	53	56	
Gamar	Green	512	75	221	42	361	327	86	50	
	Airdry	514	76	268	46	322	340	70	36	

MOR = Modulus of rupture, MOE = Modulus of elasticity
Max. crus. = Maximum crushing strength

Table 3. Mechanical properties of timber species Bangladesh - Contd.

Species	Seasoning condition	Static bending (kg/cm^2)		Compression parallel to grain (kg/cm^2)	Compression perpendicular to grain (kg/cm^2)	Hardness (kg)		Nail with drawal (kg)		Grouping
		MOR	MOE	Max. crus.		Side	End	Side	End	
1	2	3	4	5	6	7	8	9	10	
Ghora neem	Green	485	56	212	35	220	245	101	55	Weak
	Airdry	665	72	375	60	226	240	122	79	
Jhumka bhadi	Green	303	41	180	39	215	225	50	55	
	Airdry	465	56	290	55	230	240	52	57	
Kadam	Green	379	61	220	42	230	235	52	55	
	Airdry	472	74	310	52	300	315	65	68	
Kao	Green	437	54	225	43	220	230	54	55	
	Airdry	580	64	380	51	400	410	67	69	
Kanak	Green	440	63	210	47	225	230	55	57	
	Airdry	555	66	385	60	390	405	68	70	
Keora	Green	623	84	252	62	450	441	76	85	
	Airdry	699	95	375	81	396	484	81	98	
Mangium	Green	652	83	252	44	337	305	107	61	
	Airdry	656	88	277	55	318	313	54	29	
Mandar	Green	225	39	84	20	92	119	32	20	
	Airdry	345	42	115	40	105	149	38	34	
Mingiri	Green	390	45	222	35	100	145	50	50	
	Airdry	491	60	380	40	120	195	53	52	
Monkona	Green	269	53	215	34	115	220	58	56	
	Airdry	331	61	282	36	118	245	62	60	
Pairag	Green	486	87	250	38	130	160	54	52	
	Airdry	542	120	360	42	135	285	70	70	
Payna	Green	197	37	73	23	83	84	51	26	
Mandar	Airdry	206	38	80	25	114	110	39	26	
Pitali	Green	466	79	280	40	285	295	56	50	
	Airdry	557	93	385	44	350	360	71	70	
Raktan	Green	484	79	295	41	280	295	55	54	
	Airdry	505	88	405	45	400	410	69	67	
Rain tree	Green	481	58	300	58	470	452	113	90	
	Airdry	642	80	460	110	499	483	121	70	

Table 3. Mechanical properties of timber species Bangladesh - Contd.

Species	Seasoning condition	Static bending (kg/cm^2)		Compression parallel to grain (kg/cm^2)	Compression perpendicular to grain (kg/cm^2)	Hardness (kg)		Nailwithdrawal (kg)		Grouping
		MOR	MOE	Max. crus.		Side	End	Side	End	
1	2	3	4	5	6	7	8	9	10	
Rata	Green	529	61	300	44	315	335	78	75	Weak
	Airdry	630	75	405	47	460	475	105	95	
Rubber	Green	457	42	206	57	372	339	104	52	
	Airdry	610	56	344	132	562	679	200	44	
Toon	Green	470	84	211	25	279	304	98	41	
	Airdry	693	102	311	36	318	404	100	64	
Udal	Green	392	65	200	38	210	230	100	89	
	Airdry	533	76	340	40	380	400	130	105	
Uriam	Green	520	81	260	41	290	305	115	110	
	Airdry	646	85	430	44	400	440	120	115	
Akashmoni	Green	658	79	342	93	514	527	140	72	Moderate
	Airdry	701	86	350	117	572	554	115	71	strong
Baen	Green	592	76	285	61	389	480	77	94	
	Airdry	762	92	474	73	492	523	94	108	
Bhadi	Green	724	110	259	72	574	513	166	113	
	Airdry	788	128	366	96	535	590	143	104	
Chikrassi	Green	619	98	276	60	426	513	94	101	
	Airdry	888	117	413	109	592	685	147	153	
Civit	Green	568	111	247	40	383	386	125	64	
	Airdry	881	136	463	72	485	558	188	109	
Dakroom	Green	530	82	300	78	400	500	147	140	
	Airdry	850	100	485	85	470	510	150	155	
Dhaki Jam	Green	668	90	337	92	665	667	154	113	
	Airdry	805	112	458	105	703	821	225	154	
Eucalyptus camaldulensis	Green	720	91	295	60	473	493	169	111	
	Airdry	807	98	386	108	478	592	200	123	
Eucalyptus brassiana	Green	682	87	304	78	425	470	160	155	
	Airdry	799	95	316	101	465	505	175	165	
Garjan, dholya	Green	549	89	245	48	410	425	145	140	
	Airdry	650	120	250	70	455	460	170	181	

Table 3. Mechanical properties of timber species Bangladesh - Contd.

Species	Seasoning condition	Static bending (kg/cm^2)		Compression parallel to grain (kg/cm^2)	Compression perpendicular to grain (kg/cm^2)	Hardness (kg)		Nailwithdrawal (kg)		Grouping
		MOR	MOE	Max. crus.		Side	End	Side	End	
1	2	3	4	5	6	7	8	9	10	
Garjan,	Green	811	136	382	60	505	515	201	195	Moderate
bhaittya	Airdry	890	143	400	78	585	600	222	225	strong
Gutguttya	Green	720	85	385	70	485	500	205	200	
	Airdry	870	95	410	76	565	595	231	235	
Hansak	Green	637	100	370	71	490	505	200	205	
	Airdry	816	110	405	77	595	615	250	245	
Homalium	Green	705	96	300	78	428	420	112	90	
	Airdry	708	101	340	90	495	500	110	85	
Itchri	Green	665	98	285	80	380	390	100	95	
	Airdry	733	104	340	85	405	400	105	100	
Jackfruit	Green	481	58	195	65	408	405	113	90	
	Airdry	701	64	305	115	485	425	110	110	
Jam	Green	660	80	295	69	420	415	114	113	
	Airdry	805	100	330	100	495	490	105	107	
Jarul	Green	664	103	334	82	569	540	145	86	
	Airdry	887	106	461	101	558	676	238	150	
Kamdev	Green	476	77	260	60	270	360	100	100	
	Airdry	714	104	300	78	385	380	95	90	
Kerung	Green	710	70	295	73	400	400	122	120	
	Airdry	756	94	325	81	410	405	120	115	
Mango	Green	461	60	286	53	308	297	129	85	
	Airdry	775	68	390	72	410	463	182	145	
Moos	Green	543	90	200	56	297	295	100	105	
	Airdry	837	110	330	80	380	385	105	107	
Pitraj	Green	617	110	272	32	345	390	120	64	
	Airdry	822	113	368	67	440	517	145	91	
Sil koroi	Green	633	98	354	115	739	653	110	117	
	Airdry	805	113	504	146	705	730	160	169	
Teak	Green	867	120	383	67	506	494	138	95	
	Airdry	1008	131	513	119	540	531	79	68	

Table 3. Mechanical properties of timber species Bangladesh - Contd.

Species	Seasoning condition	Static bending (kg/cm^2)		Compression parallel to grain (kg/cm^2)	Compression perpendicula to grain (kg/cm^2)	Hardness (kg)		Nailwithdrawal (kg)		Grouping
		MOR	MOE	Max. crus.		Side	End	Side	End	
1	2	3	4	5	6	7	8	9	10	
Telsur	Green	839	108	405	99	509	585	111	122	Moderate
	Airdry	982	119	503	122	665	776	146	154	strong
Babla	Green	749	76	348	117	932	912	245	204	Strong
	Airdry	1002	99	515	118	968	946	250	211	
Champa	Green	703	101	295	50	415	464	101	107	
	Airdry	920	127	498	105	554	685	112	129	
Eucalyptus	Green	687	96	305	52	513	499	152	100	
citriodora	Airdry	976	139	499	86	665	581	122	91	
Eucalyptus	Green	911	114	431	86	649	623	173	93	
tereticornis	Airdry	1033	123	606	138	875	1005	164	127	
Garjan,	Green	603	117	302	44	361	345	102	59	
dholi	Airdry	916	158	530	70	476	485	113	73	
Garjan,	Green	692	122	347	49	501	422	134	73	
tellya	Airdry	1067	151	553	91	651	640	204	113	
Hargaja	Green	640	100	340	60	506	495	140	130	
	Airdry	950	120	513	114	542	532	85	85	
Kasturi	Green	523	94	335	61	500	500	135	130	
	Airdry	931	129	514	113	540	530	80	80	
Narikeli	Green	751	94	364	63	504	505	141	125	
	Airdry	1059	134	531	120	535	530	115	100	
Passur	Green	808	87	405	91	565	636	116	116	
	Airdry	997	137	448	200	773	801	119	128	
Sal	Green	863	117	390	114	798	748	104	115	
	Airdry	1035	129	531	170	903	885	144	143	
Sissoo	Green	560	65	302	80	659	591	156	83	
	Airdry	984	110	503	88	702	703	177	119	
Tali	Green	759	92	349	75	556	585	161	109	
	Airdry	977	110	482	84	617	762	211	159	

Table 3. Mechanical properties of timber species Bangladesh - Contd.

Species	Seasoning condition	Static bending (kg/cm^2)		Compression parallel to grain (kg/cm^2)	Compression perpendicula to grain (kg/cm^2)	Hardness (kg)		Nailwithdrawal (kg)		Grouping
		MOR	MOE	Max. crus.		Side	End	Side	End	
1	2	3	4	5	6	7	8	9	10	
Batna	Green	1040	130	404	108	606	649	236	177	Very
	Airdry	1260	165	592	148	1166	1639	283	236	strong
Bohera	Green	768	146	425	80	550	540	140	130	
	Airdry	1246	162	600	150	590	580	100	89	
Dharmara	Green	1043	127	523	113	580	575	145	135	
	Airdry	1499	139	660	169	610	605	115	110	
Goda	Green	1022	138	545	123	575	580	140	130	
	Airdry	1248	158	680	175	600	610	110	100	
Haritaki	Green	840	125	450	113	560	555	145	140	
	Airdry	1320	135	670	180	610	610	115	110	
Kankra	Green	922	138	450	96	658	740	114	138	
	Airdry	1381	182	536	177	911	993	142	182	
Nageshwar	Green	1053	144	520	125	585	575	145	138	
	Airdry	1711	203	690	185	625	630	120	170	
Neem	Green	929	135	405	90	735	740	148	110	
	Airdry	1014	149	484	128	853	824	183	150	
Sundri	Green	904	135	458	133	813	819	105	123	
	Airdry	1352	142	635	142	979	866	137	154	
Tentul	Green	959	145	393	85	676	608	140	98	
	Airdry	1192	176	595	128	703	695	146	105	

Table 3. Mechanical properties of timber species of Bangladesh - Contd.

Species	Seasoning condition	Shear parallel (kg/cm^2)		Cleavage (kg/cm of width)		Tension perpendicular (kg/cm^2)		Toughness (cm-kg/ specimen)		Tension parallel (kg/cm^2)	Grouping
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential		
1	2	11	12	13	14	15	16	17	18	19	
Ambarela	Green	40	55	38	42	27	29	287	295	631	Weak
	Airdry	59	62	43	44	26	27	255	261	686	
Baruna	Green	43	57	39	44	29	33	290	295	666	
	Airdry	58	63	45	48	27	31	260	269	700	
Bandarhola	Green	95	68	32	39	25	29	188	205	633	
	Airdry	177	118	77	89	61	72	399	388	1054	
Banspata	Green	77	79	35	45	29	33	202	210	755	
	Airdry	87	90	44	56	44	49	344	340	895	
Barela	Green	73	85	49	60	29	32	190	222	733	
	Airdry	80	90	58	66	28	34	180	210	900	
Barta	Green	79	87	60	65	42	40	215	230	695	
	Airdry	85	90	58	60	39	37	200	215	930	
Bhuikadam	Green	66	70	65	69	40	42	285	295	730	
	Airdry	79	83	64	65	39	41	270	280	900	
Bonsimul	Green	42	46	55	59	38	40	305	330	850	
	Airdry	49	52	55	58	39	39	295	310	1000	
Chakua koroi	Green	55	60	61	68	41	43	310	350	880	
	Airdry	69	75	60	72	40	44	295	310	1040	
Chapalish	Green	128	107	31	58	25	32	442	437	886	
	Airdry	158	107	34	68	28	44	371	351	1150	
Chalta	Green	66	83	61	65	50	64	310	350	886	
	Airdry	73	124	65	69	62	71	290	300	1150	
Chundal	Green	56	63	50	55	40	41	253	280	700	
	Airdry	61	69	54	62	38	40	296	310	890	
Dumur	Green	55	62	41	43	25	36	202	286	660	
	Airdry	50	58	43	46	23	41	235	295	850	
Gab	Green	71	84	40	42	30	30	237	280	690	
	Airdry	93	98	43	47	34	48	273	298	900	

Table 3. Mechanical properties of timber species of Bangladesh - Contd.

Species	Seasoning condition	Shear parallel (kg/cm^2)		Cleavage (kg/cm of width)		Tension perpendicular (kg/cm^2)		Toughness (cm-kg/specimen)		Tension parallel (kg/cm^2)	Grouping
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential		
1	2	11	12	13	14	15	16	17	18	19	
Gamar	Green	72	74	55	54	44	42	311	333	874	Weak
	Airdry	64	67	50	46	41	39	226	242	942	
Ghora neem	Green	68	68	66	63	30	34	205	231	605	
	Airdry	85	90	68	69	40	43	197	200	715	
Jhumka bhadi	Green	68	85	55	64	40	43	285	305	775	
	Airdry	82	97	54	68	38	40	277	300	990	
Kadam	Green	50	58	44	48	33	34	195	230	645	
	Airdry	55	66	40	60	30	31	257	225	785	
Kao	Green	58	65	53	63	39	41	285	295	830	
	Airdry	63	73	59	71	40	40	300	325	945	
Kanak	Green	70	88	59	66	43	48	305	330	915	
	Airdry	95	110	64	72	45	46	385	325	1010	
Keora	Green	133	70	57	64	41	48	331	265	865	
	Airdry	166	111	67	83	47	67	337	312	995	
Mangium	Green	57	64	47	51	40	44	307	314	915	
	Airdry	75	77	46	49	40	41	255	200	1103	
Mandar	Green	30	32	20	23	15	20	221	220	155	
	Airdry	44	45	22	18	22	21	213	207	205	
Mingiri	Green	52	58	54	62	38	44	205	210	670	
	Airdry	60	65	56	74	38	43	285	280	950	
Monkona	Green	50	58	56	60	40	45	235	230	775	
	Airdry	56	65	60	68	38	43	290	280	995	
Pairag	Green	60	65	58	59	41	48	255	270	800	
	Airdry	66	72	69	68	40	45	305	290	980	
Payna Mandar	Green	37	41	19	21	18	19	286	225	125	
	Airdry	45	47	25	28	21	23	280	215	200	
Pitali	Green	66	71	45	49	42	46	195	190	660	
	Airdry	70	81	49	58	39	42	235	230	780	

		R	gelitia	R	gelitia	F	gelitia	F	gelitia		
1	2	11	12	13	14	15	16	17	18	19	
Raktan	Green	48	55	40	44	34	36	200	225	670	Weak
	Airdry	55	63	41	50	33	35	205	220	800	
Rain tree	Green	92	102	47	50	41	42	301	308	790	
	Airdry	133	147	67	83	39	46	297	305	915	
Rata	Green	75	86	50	59	41	49	328	274	922	
	Airdry	100	108	64	71	52	67	238	260	983	
Rubber	Green	83	85	41	66	37	51	324	251	492	
	Airdry	113	122	72	100	51	69	194	230	691	
Toon	Green	59	65	46	50	30	37	261	264	808	
	Airdry	81	90	55	63	44	53	237	241	939	
Udal	Green	30	35	40	43	34	35	190	185	600	
	Airdry	32	33	45	46	33	40	180	180	715	
Uriam	Green	50	60	58	65	38	39	235	230	885	
	Airdry	55	65	63	70	35	38	215	210	965	
Akashmoni	Green	83	92	55	66	36	39	321	160	857	Moderate
	Airdry	94	102	51	54	40	45	162	186	1018	strong
Baen	Green	140	114	52	55	26	40	324	353	990	
	Airdry	193	118	56	60	42	38	359	370	1230	
Bhadi	Green	101	108	61	75	52	60	219	254	794	
	Airdry	94	109	64	79	51	67	210	228	871	
Chikrassi	Green	152	73	59	70	37	46	313	331	735	
	Airdry	186	109	77	88	62	70	343	351	1125	
Civit	Green	73	86	50	66	35	51	317	342	905	
	Airdry	115	141	70	84	39	58	269	274	1334	
Dakroom	Green	86	104	50	54	40	41	340	330	890	
	Airdry	86	99	55	60	38	40	280	295	1020	
Dhaki Jam	Green	108	115	68	80	52	62	314	350	692	
	Airdry	134	138	63	77	45	58	287	239	913	

Table 3. Mechanical properties of timber species of Bangladesh - Contd.

Species	Seasoning condition	Shear parallel (kg/cm^2)		Cleavage (kg/cm of width)		Tension perpendicular (kg/cm^2)		Toughness (cm-kg/specimen)		Tension parallel (kg/cm^2)	Grouping
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential		
1	2	11	12	13	14	15	16	17	18	19	
Raktan	Green	48	55	40	44	34	36	200	225	670	Weak
	Airdry	55	63	41	50	33	35	205	220	800	
Rain tree	Green	92	102	47	50	41	42	301	308	790	
	Airdry	133	147	67	83	39	46	297	305	915	
Rata	Green	75	86	50	59	41	49	328	274	922	
	Airdry	100	108	64	71	52	67	238	260	983	
Rubber	Green	83	85	41	66	37	51	324	251	492	
	Airdry	113	122	72	100	51	69	194	230	691	
Toon	Green	59	65	46	50	30	37	261	264	808	
	Airdry	81	90	55	63	44	53	237	241	939	
Udal	Green	30	35	40	43	34	35	190	185	600	
	Airdry	32	33	45	46	33	40	180	180	715	
Uriam	Green	50	60	58	65	38	39	235	230	885	
	Airdry	55	65	63	70	35	38	215	210	965	
Akashmoni	Green	83	92	55	66	36	39	321	160	857	Moderate
	Airdry	94	102	51	54	40	45	162	186	1018	strong
Baen	Green	140	114	52	55	26	40	324	353	990	
	Airdry	193	118	56	60	42	38	359	370	1230	
Bhadi	Green	101	108	61	75	52	60	219	254	794	
	Airdry	94	109	64	79	51	67	210	228	871	
Chikrassi	Green	152	73	59	70	37	46	313	331	735	
	Airdry	186	109	77	88	62	70	343	351	1125	
Civit	Green	73	86	50	66	35	51	317	342	905	
	Airdry	115	141	70	84	39	58	269	274	1334	
Dakroom	Green	86	104	50	54	40	41	340	330	890	
	Airdry	86	99	55	60	38	40	280	295	1020	
Dhaki Jam	Green	108	115	68	80	52	62	314	350	692	
	Airdry	134	138	63	77	45	58	287	239	913	

Table 3. Mechanical properties of timber species of Bangladesh - Contd.

Species	Seasoning condition	Shear parallel (kg/cm^2)		Cleavage (kg/cm of width)		Tension perpendicular (kg/cm^2)		Toughness (cm-kg/ specimen)		Tension parallel (kg/cm^2)	Grouping
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential		
1	2	11	12	13	14	15	16	17	18	19	
Eucalyptus camaldulensis	Green	88	92	53	52	45	42	359	414	895	Moderate strong
	Airdry	95	105	56	59	46	54	302	311	1020	
Eucalyptus brassiana	Green	85	90	54	53	44	43	340	395	900	
	Airdry	90	103	58	57	45	50	290	265	1080	
Garjan, dholya	Green	77	82	65	70	47	46	335	330	915	
	Airdry	95	99	70	75	46	48	285	265	1285	
Garjan, bhaittya	Green	90	100	67	75	49	51	315	300	900	
	Airdry	105	130	69	76	50	53	275	275	1240	
Gutguttya	Green	92	105	68	77	50	55	285	275	1100	
	Airdry	107	130	70	78	55	60	270	260	1310	
Hansak	Green	60	65	55	61	47	49	295	290	735	
	Airdry	65	71	56	63	46	47	265	260	895	
Homalium	Green	85	95	62	66	53	55	315	300	955	
	Airdry	93	105	69	73	55	61	285	265	1200	
Itchri	Green	87	97	64	68	55	61	330	300	1100	
	Airdry	99	110	71	75	60	66	295	285	1340	
Jackfruit	Green	103	123	43	49	22	29	291	321	905	
	Airdry	145	172	56	76	28	33	287	300	1300	
Jam	Green	104	116	64	69	49	53	295	310	935	
	Airdry	112	117	66	76	48	54	288	305	1295	
Jarul	Green	101	103	66	64	57	58	334	351	978	
	Airdry	124	123	64	63	60	61	261	273	1148	
Kamdev	Green	77	88	68	74	37	41	330	350	990	
	Airdry	90	108	73	79	65	66	260	285	1210	
Kerung	Green	60	66	60	66	44	46	310	300	755	
	Airdry	65	73	62	74	42	43	270	280	935	
Mango	Green	80	90	47	56	40	45	281	295	611	
	Airdry	96	107	57	60	40	40	279	293	815	

Table 3. Mechanical properties of timber species of Bangladesh - Contd.

Species	Seasoning condition	Shear parallel (kg/cm^2)		Cleavage (kg/cm of width)		Tension perpendicular (kg/cm^2)		Toughness (cm-kg/specimen)		Tension parallel (kg/cm^2)	Grouping
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential		
1	2	11	12	13	14	15	16	17	18	19	
Moos	Green	75	79	55	60	43	50	295	345	895	Moderate
	Airdry	103	120	60	65	44	53	200	315	1130	strong
Pitraj	Green	75	86	50	59	41	49	328	274	922	
	Airdry	100	108	64	71	52	67	238	260	983	
Sil koroi	Green	193	127	63	71	53	63	424	370	945	
	Airdry	218	150	70	84	48	69	256	270	1230	
Teak	Green	86	103	68	77	44	49	387	418	1036	
	Airdry	97	115	66	79	41	47	320	326	1176	
Telsur	Green	163	95	71	82	59	72	461	417	865	
	Airdry	172	141	59	82	38	51	441	433	1100	
Babla	Green	135	149	88	84	65	75	311	396	723	Strong
	Airdry	168	227	192	108	73	88	304	388	855	
Champa	Green	153	83	60	69	46	51	350	359	1140	
	Airdry	153	93	61	73	44	60	341	354	1360	
Eucalyptus citrodora	Green	55	61	52	57	45	43	330	377	794	
	Airdry	87	92	64	75	42	53	275	288	1174	
Eucalyptus tereticornis	Green	104	107	49	57	44	48	420	499	1597	
	Airdry	111	110	62	65	36	46	355	362	2164	
Garjan dholi	Green	72	76	55	63	39	47	256	261	1054	
	Airdry	98	105	66	77	40	53	350	353	1320	
Garjan tellya	Green	78	96	55	88	50	75	237	392	1421	
	Airdry	118	141	84	116	71	75	330	353	1609	
Hargaja	Green	77	94	57	63	44	48	325	330	1065	
	Airdry	94	117	62	70	46	52	285	290	1275	
Kasturi	Green	63	85	66	77	45	49	345	340	1010	
	Airdry	77	118	68	80	50	55	315	296	895	
Narikeli	Green	70	95	64	76	44	48	295	300	895	
	Airdry	90	117	66	78	43	52	275	290	1100	

Table 3. Mechanical properties of timber species of Bangladesh - Concld.

Species	Seasoning condition	Shear parallel (kg/cm^2)		Cleavage (kg/cm of width)		Tension perpendicular (kg/cm^2)		Toughness (cm-kg/specimen)		Tension parallel (kg/cm^2)	Grouping
-		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential		
1	2	11	12	13	14	15	16	17	18	19	
Passur	Green	119	100	55	70	38	47	213	201	1230	Strong
	Airdry	218	180	72	80	43	51	208	247	1410	
Sal	Green	177	118	77	89	61	72	391	388	1054	
	Airdry	166	132	64	71	46	59	371	360	1172	
Sissoo	Green	110	106	69	64	55	62	365	403	800	
	Airdry	136	118	95	79	68	66	360	393	1200	
Tali	Green	103	110	64	66	58	65	352	345	965	
	Airdry	146	163	88	107	65	84	260	290	944	
Batna	Green	118	141	73	109	61	92	326	320	1226	Very
	Airdry	169	186	68	102	60	94	493	234	1699	strong
Bohera	Green	91	131	78	105	60	75	340	325	1340	
	Airdry	134	140	79	110	61	80	400	380	1480	
Dharmara	Green	103	114	81	107	55	80	340	355	1380	
	Airdry	106	116	88	119	65	83	289	325	1495	
Goda	Green	115	121	85	110	66	85	387	405	1390	
	Airdry	123	130	91	121	69	91	370	380	1490	
Hariroki	Green	101	103	80	91	60	66	330	410	1195	
	Airdry	107	131	83	105	67	73	320	390	1350	
Kankra	Green	200	133	50	71	36	54	311	312	970	
	Airdry	236	143	52	73	37	52	421	359	1290	
Nageshwar	Green	111	113	83	94	60	63	324	410	1290	
	Airdry	155	161	87	107	61	67	300	400	1400	
Neem	Green	125	150	66	68	32	38	391	421	1015	
	Airdry	155	196	72	82	40	49	372	390	1410	
Sundri	Green	190	157	98	106	43	70	555	480	1310	
	Airdry	312	259	115	93	45	63	606	580	1495	
Tentul	Green	102	109	72	78	46	56	312	321	1015	
	Airdry	110	130	76	80	47	59	285	291	1200	

Table 4. Mechanical properties of timber species relative to teak.

Species	Seasoning condition	Static bending		Compression parallel	Compression perpendicular	Hardness		Nailwithdrawal	
		MOR	MOE	Max. crus.		Side	End	Side	End
1	2	3	4	5	6	7	8	9	10
Teak	**Green**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
	Airdry	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Akashmoni	Green	76	66	89	139	102	106	101	76
	Airdry	70	66	68	98	106	104	145	104
Ambarela	Green	50	57	50	52	48	64	40	63
	Airdry	55	66	54	35	50	73	101	128
Babla	Green	86	63	91	145	184	185	178	215
	Airdry	99	76	100	99	179	178	314	310
Baen	Green	68	63	74	91	77	97	56	99
	Airdry	76	70	92	61	91	98	119	159
Baruna	Green	41	46	43	48	45	61	38	58
	Airdry	48	46	49	34	48	68	95	117
Bandarhola	Green	55	63	57	54	49	64	42	65
	Airdry	52	63	53	39	51	73	105	131
Banspata	Green	37	59	78	67	52	73	43	68
	Airdry	52	76	74	61	70	73	89	110
Barela	Green	48	68	55	75	55	65	45	72
	Airdry	63	69	59	66	74	79	100	121
Barta	Green	59	53	55	72	61	65	42	63
	Airdry	59	57	72	72	89	92	66	85
Bhui kadam	Green	50	51	49	49	45	42	36	57
	Airdry	58	60	77	55	52	54	67	87
Bhadi	Green	64	57	68	107	113	104	120	119
	Airdry	77	98	71	81	99	111	181	132
Batna	Green	111	124	105	161	120	131	171	186
	Airdry	125	126	115	124	216	309	358	347
Bonsimul	Green	36	46	46	34	32	36	29	43
	Airdry	38	52	59	32	39	35	54	65
Bohera	Green	89	122	111	119	109	109	101	137
	Airdry	124	124	117	126	109	109	127	131
Chakua koroi	Green	44	42	47	73	40	45	30	47
	Airdry	47	42	58	38	56	59	56	81
Chundal	Green	41	46	50	48	42	43	37	56
	Airdry	41	46	72	45	47	65	70	85

Table 4. Mechanical properties of timber species relative to teak. - Contd.

Species	Seasoning condition	Static bending		Compression parallel	Compression perpendicular	Hardness		Nailwithdrawal	
		MOR	MOE	Max. crus.		Side	End	Side	End
1	2	3	4	5	6	7	8	9	10
Chalta	Green	59	51	93	72	70	80	54	81
	Airdry	66	61	96	78	83	96	106	129
Champa	Green	81	84	77	75	82	94	73	113
	Airdry	91	97	97	88	103	129	142	190
Chapalish	Green	69	72	57	73	72	74	51	80
	Airdry	66	92	61	68	80	87	105	144
Chickrassi	Green	71	82	72	90	84	104	68	106
	Airdry	88	89	81	92	110	129	186	228
Civit	Green	66	93	64	60	76	78	91	67
	Airdry	87	104	90	61	90	91	238	160
Dumur	Green	42	39	41	66	48	50	41	63
	Airdry	43	27	40	39	49	54	73	90
Dakroom	Green	61	68	78	116	79	81	107	147
	Airdry	84	76	95	71	87	89	190	228
Dhaki jam	Green	77	75	88	137	131	135	112	119
	Airdry	80	85	89	88	130	132	285	226
Dharmara	Green	120	106	137	169	115	116	105	142
	Airdry	149	106	129	142	113	114	146	162
Eucalyptus brassiana	Green	79	73	79	116	84	86	116	163
	Airdry	79	73	62	85	86	88	222	243
Eucalyptus camaldulensis	Green	83	76	77	90	93	96	122	117
	Airdry	80	75	75	91	89	90	253	181
Eucalyptus citriodora	Green	79	80	80	78	101	101	110	105
	Airdry	97	106	97	72	123	109	154	134
Eucalyptus tereticornis	Green	105	95	113	128	128	126	125	98
	Airdry	102	94	118	116	162	189	208	187
Gab	Green	42	28	51	40	42	45	36	55
	Airdry	42	33	74	47	48	56	67	82
Gamar	Green	59	63	58	63	71	66	62	53
	Airdry	55	53	52	53	60	64	89	53
Garjan, dholi	Green	70	98	79	66	71	70	74	62
	Airdry	71	121	103	59	88	90	143	107
Garjan, teflya	Green	80	102	91	73	99	85	97	77
	Airdry	106	115	108	76	121	121	258	166

Table 4. Mechanical properties of timber species relative to teak. - Contd.

Species	Seasoning condition	Static bending		Compression parallel	Compression perpendicular	Hardness		Nailwithdrawal	
		MOR	MOE	Max. crus.		Side	End	Side	End
1	2	3	4	5	6	7	8	9	10
Garjan, dholya	Green	63	74	64	72	81	83	105	147
	Airdry	64	92	49	59	84	86	215	266
Garjan, baittya	Green	94	113	100	90	100	102	146	205
	Airdry	88	109	78	66	108	110	281	331
Ghora neem	Green	56	47	55	52	44	49	74	58
	Airdry	66	55	73	50	42	45	153	87
Gutguttya	Green	83	71	101	104	96	98	149	211
	Airdry	86	73	80	64	105	106	292	346
Goda	Green	118	115	142	184	114	117	101	137
	Airdry	124	121	133	147	111	115	139	147
Hansak	Green	73	83	97	106	97	102	145	216
	Airdry	81	84	79	65	110	116	316	360
Hargaza	Green	74	83	89	90	100	100	101	137
	Airdry	94	92	100	96	100	100	108	125
Homalium	Green	81	80	78	116	85	85	81	94
	Airdry	70	77	66	76	92	94	139	125
Horitaki	Green	97	104	117	169	111	112	105	147
	Airdry	131	103	131	151	113	115	146	162
Itchri	Green	77	82	74	119	75	79	72	100
	Airdry	73	79	66	71	75	75	133	147
Jhumka	Green	35	34	47	58	42	46	36	58
Bhadi	Airdry	46	43	57	46	43	45	66	84
Jackfruit	Green	55	48	51	97	81	82	82	95
	Airdry	70	49	59	97	90	80	138	162
Jam	Green	76	67	77	103	83	84	83	119
	Airdry	80	76	64	84	92	92	133	157
Jarul	Green	77	86	87	122	112	109	105	91
	Airdry	88	81	90	85	103	127	301	221
Kadam	Green	44	51	57	63	45	48	38	58
	Airdry	47	56	60	44	56	59	82	100
Kao	Green	50	45	59	64	43	47	39	59
	Airdry	58	49	74	43	74	77	85	101
Kanak	Green	51	53	55	70	44	47	40	60
	Airdry	55	50	75	50	72	76	86	103

Table 4. Mechanical properties of timber species relative to teak. - Contd.

Species	Seasoning condition	Static bending		Compression parallel	Compression perpendicular	Hardness		Nailwithdrawal	
		MOR	MOE	Max. crus.		Side	End	Side	End
1	2	3	4	5	6	7	8	9	10
Kankra	Green	106	115	117	143	130	150	83	145
	Airdry	137	139	104	149	169	187	180	268
Kamdev	Green	55	64	68	90	73	73	72	105
	Airdry	71	79	58	66	71	72	120	132
Kasturi	Green	60	78	87	91	99	101	98	137
	Airdry	92	99	100	95	100	100	101	118
Kerung	Green	82	58	77	109	79	81	88	126
	Airdry	75	72	63	68	76	76	152	169
Keora	Green	72	70	66	93	89	89	55	89
	Airdry	69	73	73	68	73	91	103	144
Mandar	Green	26	33	22	30	18	24	22	21
	Airdry	34	32	22	34	19	28	48	50
Mangium	Green	75	69	66	66	67	62	78	64
	Airdry	65	67	54	46	59	59	68	43
Mango	Green	53	50	75	79	61	60	93	89
	Airdry	77	52	76	61	76	87	228	213
Minjiri	Green	45	38	58	52	20	29	36	53
	Airdry	49	46	74	34	22	37	67	76
Monkona	Green	31	44	56	51	23	45	42	59
	Airdry	33	47	55	30	22	46	78	88
Moos	Green	63	75	52	84	59	60	72	111
	Airdry	83	85	64	67	70	73	133	157
Narkeli	Green	87	78	95	94	100	102	102	132
	Airdry	105	102	104	101	99	100	146	147
Nageshwar	Green	121	120	136	187	116	116	105	145
	Airdry	170	155	135	155	116	119	152	250
Neem	Green	107	112	106	134	145	149	107	116
	Airdry	101	114	95	108	158	155	230	221
Pairag	Green	56	73	65	57	26	32	39	55
	Airdry	54	92	70	35	25	54	89	103
Painya mandar	Green	23	31	19	34	17	17	37	27
	Airdry	20	29	16	21	21	21	48	38
Passur	Green	93	73	106	136	112	129	84	122
	Airdry	99	105	87	168	143	151	151	188

Table 4. Mechanical properties of timber species relative to teak. - Contd.

Species	Seasoning condition	Static bending		Compression parallel	Compression perpendicular	Hardness		Nailwithdrawal	
		MOR	MOE	Max. crus.		Side	End	Side	End
1	2	3	4	5	6	7	8	9	10
Pitali	Green	54	66	73	60	56	60	41	53
	Airdry	58	71	75	37	65	68	90	103
Pitraj	Green	71	92	71	48	68	79	88	67
	Airdry	82	86	72	56	81	97	184	134
Raktan	Green	56	66	77	61	55	60	40	57
	Airdry	50	71	79	38	74	77	87	99
Rain tree	Green	55	48	78	87	93	91	82	95
	Airdry	64	61	90	92	93	91	153	103
Rata	Green	61	51	78	66	62	68	57	79
	Airdry	62	57	79	39	85	89	133	140
Rubber	Green	53	35	54	85	74	69	75	55
	Airdry	61	43	67	111	104	128	253	65
Sal	Green	100	98	102	170	158	151	75	121
	Airdry	103	98	104	143	167	167	182	210
Sil koroi	Green	73	82	92	172	146	132	80	123
	Airdry	80	86	98	123	131	137	202	249
Sissoo	Green	65	54	79	119	130	119	113	87
	Airdry	98	84	98	74	130	132	222	175
Sundri	Green	104	113	120	199	161	166	76	129
	Airdry	134	108	124	119	181	163	173	226
Tali	Green	88	77	91	112	110	118	117	115
	Airdry	97	84	94	70	114	144	267	234
Telsur	Green	97	90	106	148	101	118	80	128
	Airdry	97	91	98	103	123	146	185	226
Tentul	Green	111	121	103	127	134	123	101	103
	Airdry	118	134	116	108	130	131	190	154
Toon	Green	54	70	55	37	55	62	71	43
	Airdry	69	78	61	30	59	76	127	94
Udal	Green	45	54	52	57	42	47	72	94
	Airdry	53	58	66	34	70	75	165	154
Urium	Green	60	68	68	61	57	62	83	116
	Airdry	64	64	84	37	74	83	152	169

Table 4. Mechanical properties of timber species relative to teak. – Contd.

Species	Seasoning condition	Shear parallel		Cleavage		Tension perpendicular		Toughness		Tension parallel
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential	
1	2	11	12	13	14	15	16	17	18	19
Teak	**Green**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
	Airdry	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Akashmoni	Green	97	89	81	86	82	80	83	62	83
	Airdry	88	89	77	68	98	96	51	57	86
Ambarela	Green	47	53	56	55	61	59	74	71	61
	Airdry	61	54	65	56	63	57	80	82	58
Babla	Green	156	145	129	109	147	153	80	94	70
	Airdry	173	197	139	137	178	187	95	119	73
Baen	Green	163	111	76	71	59	82	84	91	96
	Airdry	147	103	85	76	102	81	112	113	105
Baruna	Green	50	55	57	57	66	67	75	71	64
	Airdry	60	55	68	61	66	66	81	83	60
Bandarhola	Green	114	44	53	47	57	57	56	56	51
	Airdry	98	59	48	49	61	62	59	63	43
Banspata	Green	90	77	51	58	66	67	52	50	73
	Airdry	90	78	67	71	107	104	108	104	76
Barela	Green	85	83	72	78	66	65	49	53	71
	Airdry	82	78	88	84	68	72	56	64	77
Barta	Green	92	84	88	84	95	82	56	55	67
	Airdry	88	78	88	76	95	79	63	66	79
Bhui kadam	Green	77	68	96	90	91	86	74	71	70
	Airdry	81	72	97	82	95	87	84	86	77
Bhadi	Green	117	105	90	97	118	122	57	61	77
	Airdry	97	95	97	100	124	143	66	70	74
Batna	Green	137	137	107	142	139	188	84	77	118
	Airdry	174	162	103	129	146	200	154	72	144
Bonsimul	Green	49	45	81	77	86	82	79	79	82
	Airdry	51	45	82	73	95	83	92	95	85
Bohera	Green	106	127	115	136	136	153	88	78	129
	Airdry	138	122	120	139	149	170	125	116	126
Chakua koroi	Green	64	58	90	88	93	88	80	84	86
	Airdry	71	65	91	91	98	94	92	95	89
Chundal	Green	65	61	74	71	91	84	65	67	68
	Airdry	63	60	82	78	93	85	93	95	76

Table 4. Mechanical properties of timber species relative to teak. – Contd.

Species	Seasoning condition	Shear parallel		Cleavage		Tension perpendicular		Toughness		Tension parallel
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential	
1	2	11	12	13	14	15	16	17	18	19
Chalta	Green	77	81	90	84	114	131	80	84	86
	Airdry	75	108	98	87	151	151	91	92	98
Champa	Green	178	81	88	90	105	104	90	86	110
	Airdry	158	81	92	92	107	128	107	109	116
Chapalish	Green	149	104	46	75	57	65	114	105	85
	Airdry	163	93	52	86	68	94	116	108	88
Chickrassi	Green	177	71	87	91	84	94	81	79	71
	Airdry	192	95	117	111	151	149	107	108	96
Civit	Green	85	83	74	86	80	104	82	82	87
	Airdry	119	123	106	106	95	123	84	84	113
Dumur	Green	64	60	60	56	57	73	53	68	64
	Airdry	52	50	65	58	56	87	73	90	72
Dakroom	Green	100	101	74	70	91	84	88	79	86
	Airdry	89	86	83	76	93	85	88	90	87
Dhaki jam	Green	126	112	100	104	118	127	81	84	67
	Airdry	138	120	95	97	110	123	90	73	78
Dharmara	Green	120	111	119	139	125	163	88	85	133
	Airdry	109	101	133	151	159	177	90	100	127
Eucalyptus	Green	99	87	79	69	100	88	88	94	87
brassiana	Airdry	93	90	88	72	110	106	91	81	92
Eucalyptus	Green	102	89	78	68	102	86	93	99	86
camaldulensis	Airdry	98	91	85	75	105	115	94	95	87
Eucalyptus	Green	64	55	76	74	102	88	85	90	77
citriodora	Airdry	90	80	97	95	102	113	86	88	100
Eucalyptus	Green	121	104	72	74	100	98	109	119	154
tereticornis	Airdry	114	96	94	82	88	98	111	111	184
Gab	Green	83	82	59	55	68	61	61	67	67
	Airdry	96	85	65	59	83	102	85	91	77
Gamar	Green	84	72	81	70	100	86	80	80	84
	Airdry	66	58	76	58	100	83	71	74	80
Garjan, dholi	Green	84	74	81	82	89	94	66	62	102
	Airdry	101	91	100	97	98	113	109	108	112
Garjan, tellya	Green	90	93	81	114	114	153	61	94	137
	Airdry	122	123	127	147	173	160	103	108	138

Table 4. Mechanical properties of timber species relative to teak. – Contd.

Species	Seasoning condition	Shear parallel		Cleavage		Tension perpendicular		Toughness		Tension parallel
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential	
1	2	11	12	13	14	15	16	17	18	19
Garjan, dholya	Green	90	80	96	91	107	94	87	79	88
	Airdry	98	86	106	95	112	102	89	81	106
Garjan. baittya	Green	109	97	99	97	111	104	81	72	87
	Airdry	108	113	105	96	122	113	86	84	105
Ghora neem	Green	79	66	97	82	68	69	53	55	58
	Airdry	88	78	103	87	96	91	61	61	61
Gutguttya	Green	107	102	100	100	114	112	74	66	106
	Airdry	110	113	106	99	134	128	84	80	111
Goda	Green	134	117	125	143	150	173	100	97	134
	Airdry	127	113	138	153	168	194	116	117	127
Hansak	Green	70	63	81	79	107	100	76	69	71
	Airdry	67	62	85	80	112	100	83	80	76
Hargaza	Green	90	91	84	82	100	98	84	79	103
	Airdry	97	102	94	89	112	111	89	89	108
Homalium	Green	99	92	91	86	120	112	81	72	92
	Airdry	96	91	105	92	134	130	89	81	102
Horitaki	Green	117	100	118	118	136	135	85	98	115
	Airdry	110	114	126	133	163	155	100	120	115
Itchri	Green	101	94	94	88	125	124	85	72	106
	Airdry	102	96	108	95	146	140	92	87	114
Jhumka Bhadi	Green	79	83	81	83	91	88	74	73	76
	Airdry	85	85	82	86	93	85	87	92	84
Jackfruit	Green	120	119	63	64	50	59	75	72	95
	Airdry	149	150	85	96	68	70	89	92	111
Jam	Green	121	113	94	90	111	108	76	74	90
	Airdry	115	102	100	96	117	115	90	94	110
Jarul	Green	117	100	97	83	130	118	86	84	94
	Airdry	128	107	97	80	146	130	82	84	98
Kadam	Green	58	56	65	62	75	69	58	55	62
	Airdry	57	57	61	76	73	66	80	69	67
Kao	Green	67	63	78	82	89	84	74	71	80
	Airdry	65	63	89	90	96	85	94	100	80
Kanak	Green	81	85	87	86	98	98	79	79	88
	Airdry	98	96	97	91	110	98	120	100	86

Table 4. Mechanical properties of timber species relative to teak. – Contd.

Species	Seasoning condition	Shear parallel		Cleavage		Tension perpendicular		Toughness		Tension parallel
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential	
1	2	11	12	13	14	15	16	17	18	19
Kankra	Green	233	129	74	92	82	110	80	75	94
	Airdry	243	124	79	92	90	111	109	110	100
Kamdev	Green	90	85	100	96	84	84	85	84	96
	Airdry	93	94	111	100	159	140	81	87	103
Kasturi	Green	73	83	97	100	102	100	89	81	85
	Airdry	79	103	103	101	122	117	98	91	86
Kerung	Green	70	64	88	86	100	94	80	72	73
	Airdry	67	63	94	94	102	91	84	86	80
Keora	Green	155	68	84	83	93	98	86	63	83
	Airdry	171	97	102	105	115	143	105	96	85
Mandar	Green	35	31	29	30	34	41	57	57	15
	Airdry	45	37	33	23	54	45	66	64	17
Mangium	Green	66	62	69	66	91	90	79	75	88
	Airdry	77	67	70	62	98	87	79	61	94
Mango	Green	93	87	69	73	91	92	72	70	59
	Airdry	99	93	86	76	98	85	87	90	69
Minjiri	Green	60	56	79	81	86	90	53	50	65
	Airdry	62	57	85	94	93	91	89	86	81
Monkona	Green	58	56	82	78	91	92	61	55	75
	Airdry	58	57	91	86	93	91	91	86	85
Moos	Green	87	77	81	78	98	102	76	83	86
	Airdry	106	104	91	82	107	113	63	97	96
Narkeli	Green	81	92	94	99	100	98	76	72	86
	Airdry	93	102	100	99	105	111	86	89	94
Nageshwar	Green	129	110	122	122	136	129	84	98	125
	Airdry	160	140	132	135	149	143	94	123	119
Neem	Green	145	146	97	88	73	78	101	100	98
	Airdry	160	170	109	104	98	100	116	120	120
Pairag	Green	70	63	85	77	93	98	66	65	77
	Airdry	68	63	105	86	98	96	95	83	83
Painya	Green	43	40	28	27	41	39	74	54	12
mandar	Airdry	47	41	38	35	51	49	87	66	17
Passur	Green	138	97	81	91	86	96	55	48	119
	Airdry	225	157	109	101	105	109	65	76	120

Table 4. Mechanical properties of timber species relative to teak. – Concld.

Species	Seasoning condition	Shear parallel		Cleavage		Tension perpendicular		Toughness		Tension parallel
		Radial	Tangential	Radial	Tangential	Radial	Tangential	Radial	Tangential	
1	2	11	12	13	14	15	16	17	18	19
Pitali	Green	77	69	66	64	95	94	50	45	64
	Airdry	72	70	74	73	95	89	73	71	66
Pitraj	Green	87	83	74	77	93	100	85	66	89
	Airdry	104	94	97	90	127	143	74	80	84
Raktan	Green	56	53	59	57	77	73	52	54	65
	Airdry	57	55	62	63	80	74	64	67	68
Rain tree	Green	107	79	69	65	93	86	78	73	76
	Airdry	137	128	102	105	95	98	93	94	78
Rata	Green	87	83	74	77	93	100	85	66	89
	Airdry	103	94	97	90	127	143	74	80	84
Rubber	Green	97	83	60	86	84	104	84	84	47
	Airdry	116	106	109	127	124	147	61	71	59
Sal	Green	206	115	113	116	139	147	101	93	102
	Airdry	171	115	97	90	112	126	116	110	100
Sil koroi	Green	224	123	93	92	120	129	110	89	91
	Airdry	225	130	106	106	117	146	80	83	105
Sissoo	Green	128	103	101	83	125	127	94	96	77
	Airdry	140	103	143	100	166	140	112	120	102
Sundri	Green	221	152	144	138	98	143	143	115	126
	Airdry	322	225	174	118	110	134	189	178	127
Tali	Green	120	107	94	86	132	133	91	83	93
	Airdry	151	142	133	135	159	179	81	89	80
Telsur	Green	190	92	104	106	134	147	119	100	83
	Airdry	177	123	89	104	93	109	138	133	94
Tentul	Green	119	106	106	101	105	114	81	77	98
	Airdry	113	113	115	101	115	126	89	89	102
Toon	Green	69	63	68	65	68	76	67	63	78
	Airdry	84	78	83	80	107	113	74	74	80
Udal	Green	35	34	59	56	77	71	49	44	58
	Airdry	33	29	68	58	80	85	56	55	61
Urium	Green	58	58	85	84	86	80	61	55	85
	Airdry	57	57	95	89	85	81	61	54	82

APPENDIX - 1

DETAILS OF TESTS AND PROPERTIES OF WOOD

Whenever wood is used, either in the manufactured state or unmanufactured state, a physical characteristic, a mechanical property, or a combination of both of the two, influences its selection. Some of the physical characteristics of wood, such as colour, lustre, odour, taste, figure and grain may be ascertained readily by physical inspection. For the more complicated physical properties, such as moisture content, shrinkage, specific gravity and for all the mechanical properties, it is necessary to conduct many laboratory tests for the determination of these properties. A general understanding of the basic physical and mechanical properties and methods of their evaluation are given below:

PHYSICAL PROPERTIES

1. Moisture content

Moisture content is the amount of water in wood expressed as a percentage of its ovendry weight.

The ovendrying method is the standard method for determination of moisture content. It is accurate throughout the whole range of moisture content. It consists of the following steps:

a) Select a representative wood piece, and cut a cross-section of 2.5 X2.5 cm along the grain.

b) Immediately after cutting, remove all loose splints and weigh the sample.

c) Place the sample in an oven maintained at a temperature of 103 ± 2^{o} C and dry until a constant weight is attained (i.e. about 24 hours).

d) Weigh the sample to obtain the ovendry weight.

$$\text{Moisture content}(\%) = \frac{\text{Original weight - Ovendry weight}}{\text{Ovendry weight}} \text{ X } 100$$

This is the most accurate method, but it takes at least 24 hours to determine its value. For instant determination, moisture meter may be used. It makes use of the certain electrical properties, such as conductivity or resistivity of wood. However, this method is not accurate, and is valid for below the fibre saturation point (i.e. below 30% moisture content).

2. Density and specific gravity

Density is the mass or weight of any substance per unit of volume. Specific gravity, in comparison of density, is the ratio of the density of a material to the density of a standard substance taken at a specific temperature. Water at its greatest density at 4^{o}C has become practically universal standard substance in determining specific gravity. Specific gravity of wood is generally

determined at green, airdry (i.e. 12% moisture content), and in ovendry conditions. It involves the following steps :

a) Prepare specimens of 2.5 x 2.5 cm dimension along the grain.

b) Weigh the specimens when green, and find out the volume by the immersion method.

c) After immersion, open-pile the green specimens and allow to airdry under room conditions to a uniform moisture content of about 12%. Then weigh the specimens and measure the dimensions of the specimens in three directions. Determine the airdry volume by multiplying the length, breadth and height of the specimens.

d) Pile the airdried specimens in an oven and dry at 103 ± 2^{O} C until constant weight is obtained.

e) After ovendrying, weigh the specimens and immerse in a hot paraffin bath while still warm. Take care to remove quickly to ensure a thin coating.

f) Determine the volume of the paraffin-coated specimens by immersion method as before.

g) Determine the specific gravity by using the formula

$$\text{Specific gravity} = \frac{\text{Ovendry weight}}{\text{Volume at green or airdry or ovendry condition}}$$

3. Shrinkage

Wood shrinks as it loses moisture. Wood from the tree may contain 50 to 300% moisture content based on weight of the ovendry wood. This water may be separated into two parts: (a) that contained as free water in the cell cavities and intercellular spaces of wood, and (b) that held as absorbed or bound water in the capillaries of the walls of wood elements. The bound water is of primary importance in the consideration of shrinkage. When all the free water is removed, but there is bound water in the wood, wood is said to have reached the fibre saturation point(fsp). It ranges from 25-30% moisture content. Shrinkage occurs if the moisture content is reduced below this fsp, and is proportional to the amount of water lost. It is expressed as percentage based on the green dimension of the wood. It is determined in three grain directions of wood i.e. radial, tangential and longitudinal, and generally at airdry and ovendry conditions. It is determined by use of the formula :

$$\text{Shrinkage (\%)} = \frac{\text{Green dimension - Airdry dimension or Ovendry dimension}}{\text{Green dimension}} \times 100$$

MECHANICAL PROPERTIES

Mechanical properties of wood is its fitness and ability to resist external or applied forces. By external force is meant any action outside of a given piece of material that tends to change its size or shape or deform in any manner. A force may act on a wooden piece to cause

a) pull and produce tension,

b) push and result in compression,

c) slide along the plane parallel to the line of action and result shear, and

d) twist result in torsion.

These are the forces one or combination of which come into play whenever wood is so used that its strength is invovled. A wood cannot be said to be strong or weak unless the forces imposed on it and their magnitude are known.

Small clear specimens have been tested for the evaluation of mechanical properties. A test of a large timber would yield results applicable only to the particular set of variables involved. Testing of small clear specimens permits the evaluation of the average properties for the species.

The tests have been conducted with the help of timber testing machines. The tests, methods of tests and properties evaluated are mentioned below :

1. Static bending

It furnishes data on bending strength and stiffness for such uses as beams, joists, etc.

Data on work absorption may also be obtained to furnish information on resistance to impact.

Method of test

A specimen of 2x2x30 inches is tested on a 28-inch span with centre loading. Supports are adjustable laterally to provide full loading at supports and loading block. Rollers are placed under ends to prevent longitudinal resraint. Load is applied with a rate of head movement of 0.1 inch per minute. Deflection of centre with respect to ends of the span is measured with a dial gauge. Simultaneous readings of the load and deflection are plotted on a graph.

Properties

a) **Stress at proportional limit**

It is the stress in the extreme fibre computed for the load at which load

and deflection cease to be proportional. Loads beyond the proportional limit, if continued for a longer period, will cause failure.

b) **Modulus of rupture**

It is the computed stress in the extreme fibre at maximum load. It is generally used for comparing the bending strength of various species, and is the basis for the working stress for extreme fibre in bending.

c) **Modulus of elasticity**

It is based on the slope of the straight portion of the load-deflection curve. It is a measure of the resistance to deflection of a beam.

d) **Work to proportional limit and maximum load or total load**
These are all measures of stress absorbed by the beam in bending and thus of resistance to impact. These are based on the area under the load-deflection curve.

2. Compression parallel to grain

It furnishes data on strength and resistance to deformation when loaded in compression parallel to grain in a short post.

Method of test

A specimen of 2x2x8 inches is compressed in the direction of its length. Load is applied through a spherical bearing block to insure uniform distribution of stress. The test is discontinued when the maximum load is passed and the failure appears.

Properties

a) **Stress at proportional limit**

It is the greatest stress at which the compressive load remains proportional to the shortening of the specimen. It averages about 75% of the maximum crushing strength for hardwoods and 80% for softwoods.

b) **Maximum crushing strength**

It is the maximum ability of a short column to sustain a slowly applied end load for a short period. It is taken into account in arriving at safe stresses for short columns and other compression members.

3. Compression perpendicular to grain

It furnishes data necessary in computing the bearing area required at the ends of beams or joists or under loads applied over limited areas.

Method of test

A specimen of 2x2x 6 inches is loaded through a plate 2 inches wide placed at the centre of the length, with the plate descending at a rate of 0.012 inch per minute. Load and compression on the two sides of the specimen are read simultaneously until the test is discontinued at 0.1-inch compression.

Property

Stress at proportional limit

It is the maximum across-the-grain stress that can be applied without injury in the method of test used. It is useful in deriving safe working stresses perpendicular to grain.

4. Tension parallel to grain

It furnishes data on maximum tensile strength along the grain. Because of difficulty in designing joints adequate to develop the full tensile strength of the member, this property generally does not govern in design.

Method of test

A specimen of 1x1x18 inches is reduced to 3/16x3/8 inch over the central 2.5 inches of length. Load is applied through shoulders 4 inches from the ends at a rate of 0.05 inch per minute. Simultaneous readings of load and of deformation over a 2-inch gauge length are taken.

Property

Tension parallel to grain

It is the maximum tensile stress sustained parallel to grain. It is generally higher than the modulus of rupture. Because it is affected to such as extent by cross grain, concentration of stress, etc., and because it is so difficult to design a fastening which will develop the full tensile strength of a member, design values based on modulus of rupture are generally used.

5. Tension perpendicular to grain

It furnishes data on maximum tensile strength at right angles to the grain direction. This property is quite low in value and variable, but it is generally not a controlling factor in design.

Method of test

The specimen is of 2x2x2.5 inches. Holes of 0.5 inch radius are

centred 1/4 inch from each end. with the axis of the holes parallel to a 2-inch dimension. Tension forces are applied through special grips acting in the drilled holes.

Property

Tension perpendicular to grain

It is the average maximum tensile stress sustained across the grain of the wood. The stress is not uniformly distributed so that the values are not true values, but are useful in comparing species

6. Hardness

It furnishes a measure of resistance to indentation and wear which is useful in selecting species for flooring, trim, etc. The data are not usable in design.

Method of test

The specimen size is of 2x2x6 inches. A rod whose end is formed into a hemisphere of 0.444-inch specimen at a rate of 0.25 inch per minute to a depth of 0.222 inch. Two penetrations are made on each end, two on a radial and two on a tangential surface. Hardness is taken as the load required to embed the ball to the required depth.

Property

(a) **Hardness**

It is arbitrarily taken as the load required to embed a ball of 0.4444 inch diameter to one-half its diameter. It affords a measure of resistance to indentation and wear.

7. Nail withdrawal

It furnishes data on resistance of nails to direct withdrawal.

Method of test

The specimen size is of 2x2x6 inches. Two inches common nails are driven to a penetration of 1.25 inches, on tangential surface, radial suface and on each end. Nails are withdrawn immediately after driving with special grips at a rate of 0.075 inch per minute.

Property

Nail withdrawal

It shows the maximum withdrawal resistance of the nails driven into the test specimen. The result is useful in establishing nailing requirements for different species where the nails will be subjected to withdrawal forces, and comparing the relative nail holding ability of various wood.

8. Shear

It furnishes data on the ability of timber to resist the slipping one part on another along the grain. It is useful in the design of joints and also in the design of beams where there is a tendency for the upper part to slide upon the lower.

Method of test

The specimen is 2x2x2.5 inches with a projecting 0.75 inch from a 2.5 inch long side. The specimen is placed in a special tool having a plate that is seated on the lip and moved downward at a rate of 0.024 inch per minute. Some specimens are cut so that the plane of failure is radial, while other is tangential.

Property

Shear

It is the average stress required to shear the lip from the standard specimen. It represents a measure of the ability of timber to resist slipping one part on another. This property is important in beams and in various types of joists.

9. Cleavage

It furnishes data on resistance to splitting. Data are not usable in design, but these are useful in the selection of species for uses in which resistance to splitting is required.

Method of test

The specimen is of 2x2x3.75 inches with a 0.5 inch radius hole drilled parallel to a 2-inch dimension and centred 1.25 inch from the end, leaving a 3-inch cleavage section. Cleavage forces are applied at a rate of 0.10 inch per minute through special grips acting in the drilled hole. Some specimens are cut to give a radial, others to give tangential surface of failure.

Property

Cleavage

It is the maximum stress required to cause splitting of the standard specimen.

Because its value depends upon the form of the specimen, it is useful only as an index.

10. Toughness

It furnishes data on impact resistance in bending. Although a number of other tests give data on toughness or resistance to impact, special test has been devised to give toughness value directly.

Method of test

A specimen of 2x2x28 cm is tested over a 24 cm span. A pendulum blow is transmitted through a chain and upto the centre of the specimen. Stress sustained by the specimen is indicated by the initial and final angles of swing of the pendulum, which are converted by means of tables to work values.

Property

Toughness

Data on impact resistance in bending can be approximated from properties obtained by several test methods. The toughness test, however, provides a simple method of obtaining toughness values from small specimens. It affords a rapid method of comparing species and a basis of selecting timber of known properties.

APPENDIX- 2

FACTORS AFFECTING THE STRENGTH OF WOOD

There are many factors which affect the mechanical properties i.e. strengths of wood. An understanding of these factors is useful in proper designing of various wooden structures. Here are the important factors.

1. Moisture content

Strength of timber above the fibre saturation point(fsp) does not show any significant variation. But below the fibre saturation point, strength increases with decreasing moisture content. This increase results from (a) actual strengthening and stiffening of the cell walls as these dry out, and (b) increase in compactness or amount of wood substance in a given volume because of the shrinkage that accompanies drying below fsp. All strength properties are not, however, affected equally by the changes in moisture content. While bending strength and crushing strength increase greatly with decrease in moisture, other properties such as stiffness decrease only moderately and shock resistance may decrease slightly.

2. Specific gravity

The specific gravity of wood substance, regardless of species, is constant which is approximately 1.5. The density of a piece of wood, therefore, is a good index of the amount of wood substance present, the balance of the volume being occupied by cell cavities, pores, resin ducts, etc.

Woods with higher specific gravity (i.e. denser woods) are, as usual, heavier. Heavier wood is, in general, stronger than lighter wood.

However, differences in structure between species and in the amount and character of the extractives in the heartwood may cause species of same specific gravity to have different strengths. Similarly, some species are equal in some properties to others of higher specific gravity. Inspite of this, specific gravity is generally considered the best criterion of the strength of clear wood aside from actual strength tests.

3. Temperature

a) Immediate effect

As temperature is raised, wood becomes weaker in most strength properties, and as temperature is lowered, it becomes stronger again. Within the usual range of temperature in service, the effect is not significant and the original strength will return when the temperature comes to normal.

B) Permanent effect

Heating wood above 150^{O}F for a extended period of time will cause a permanent weakening. The permanent strength loss depends on moisture content, temperature and time of exposure, heating medium and other factors.

4. Rate and method of loading

Wooden pieces at a very rapid rate will withstand stresses considerably greater than those loaded at a slower rate. Impact bending tests shows that a stick will resist a force more than double that it would have sustained in a standard static bending test. Pieces loaded continuously for a long period will fail at loads considerably lower than those causing failure in a few minutes. Beams under continuous loading will fail at loads one-half to three-fourths those causing failure in a standard test.

5. Position of growth rings in timber

The position of growth ring in a piece of timber may vary considerably, depending on the way the timber is sawn. Properties in compression perpendicular to the grain are affected by the orientation of the rings. In the toughness test, some species, when loaded on the tangential face, give average 50% higher than when loaded on the radial face. It is not important on other properties.

6. Heartwood and sapwood

The conditions of growth at the time the wood is formed are the controlling factors of wood strength. Heartwood is merely sapwood which has been transformed by the infiltration of various substances, and in general, heartwood is neither intrinsically stronger nor weaker than sapwood.

7. Locality of growth

In general, conditions of growth, such as site, soil moisture, climatic conditions, etc. are of more importance in determining the strength of wood than in locality alone.

8. Rate of growth

Among the ring-porous hardwoods, fast growth (few rings per inch) is generally indicative of good strength, but slow growth does not necessarily mean poor strength. Among the diffuse-porous hardwoods there appears to no general relation between strength and rate of growth. Among the softwoods, the strongest is generally associated with a normal growth ring. Exceptionally rapid or slow growth is generally attended by low density and thus low strength.

9. Live *versus* dead trees

Wood from dead trees, if not deteriorated by fungi or insects, is as good for structural purposes as trees alive when cut. However, trees left standing too long after being dead may seriously be deteriorated due to weather conditions or insect or fungus attack. At this stage, the dead timbers may be less strong than the living one.

10. Time or season of felling

It has very little direct effect on the characteristics of wood on the time or season of felling if proper handling methods are used.

11. Airdried or kilndried wood

Comparative tests indicate that proper kiln drying and air drying produce the same effect.

12. Preservative treatment

Wood preservative chemicals in themselves are regarded not harmful to strength. However, the treating process may result in considerable loss of strength if not properly carried out.

13. Defects and blemishes

Defects exert considerable influence on the strength of a wood depending on the type of defect, the property being considered, and the size and position of the defect. Blemishes only mar the appearance and are not necessarily a defect.

14. Extractives

Extractives appear to increase the strength properties of wood. Their effect on strength depends on the amount and nature of the extractives, species, moisture content and the strength property considered. Maximum crushing strength showed the greatest increase as a result of infiltration of extractives accompanying the change from sapwood to heartwood, shock resistance the least, with modulus of rupture intermediate.