PROPERTIES AND UTILIZATION OF TROPICAL WOODS IN BUILDINGS

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Before saying some words about the properties and utilization of tropical woods, I would like to mention that I am not a specialist in preservation of monuments, but simply a wood technologist.

Therefore, one of my principal task is : to take care that the natural material wood, which is an unique material with remarkable physical properties and also of outstanding beauty, is utilized as optimal as possible in any field of application.

Consequently, it is necessary to use the wood according to its properties in such a way that the wood properties meet all requirements of utilization. In any case, we have to avoid the use of wood or products made of wood in a wrong way or in a filed of application where wood cannot bear the mechanical, chemical or biological conditions with the result that the wood is destroyed or deteriorated after a short time.

A wrong use of wood or the choice of the wrong kind of wood or wood species will discriminate the material wood on the whole. Therefore, the correlation between wood properties on one hand and the requirements of the use on the other hand is of fundamental importance to the wood technologist in order to use the wood in the best way. In this connection I am first of all interested in the natural properties of untreated wood and in the range of variability of wood properties. Of further interest to the wood technologist is : how and by what means and treatments those natural properties which are unfavourable for a special use can be improved. Here I think of methods for a dimensional stabilization of wood under changing conditions of moisture or of methods to improve the durability of wood against organisms, such as fungi and insects, of methods to improve the strength properties, and so on.

When discussing the properties and utilization of tropical woods in detail we will soon recognize that this is a very wide field because of the large diversity and heterogenity of the different wood species. There are several thousand of tropical wood species with rather different wood properties. Only if we consider the anatomical wood structure and the density of tropical woods, we know that the lightest wood species, such as BALSA wood (Ochroma lagopus) or the wood of the UMBRELLA TREE (Musanga smithii) have a very low density of only 0.1 to 0.2 g/cm^3, whereas the heaviest and most dense wood species, such as SNAKE WOOD (Piratinera guianensis) or AFRICAN BLACKWOOD (GRENADILL, SENEGAL EBONY) (Dalbergia melanoxylon) have a density of 1.2 to 1.3 g/cm^3, that means they are much heavier than water. Consequently, the tropical forests produce wood the density of which varies in the very large range from 0.1 to 1.3 g/cm^3, and we know no other natural material of such heterogenity.

Wood species of light density consist to a rather large percentage of air in form of pores and cell lumina. This can be demonstrated in the best way by showing a cross section perpendicular to the grain of wood under the microscope. A rather light tropical hardwood, for instance, is BATAI (Albizzia falcata) shown here, with a density of 0.4 g/cm^3, and here you see that the

air volume or pore volume of the wood is in the order of 75%, that means that 3/4 of a macrosopical wood piece consists of air, and only 1/4 of cell wall substance or real wood substance. Nearly the same density have the well-known AFRICAN (0.45) and AMERICAN MAHOGANY (0.5) (Khaya ivorensis and Swietenia macrophylla).
Here is another cross section of a light wood species, this time of a softwood, namely WESTERN RED CEDAR, with a density of 0.34 g/cm^3, which has an air volume of nearly 80%.

On the contrary to these rather light wood species, the cross section of the very dense and heavy MANGROVE WOOD (Rhizophora sp.) with a density of more than 1.0 g/cm^3 is shown now, and here you see the thick cell walls of the wood fibres and only a few big pores, which the wood needs for the water transportation, the so-called vessels. The total air volume of this dense wood species is only in the order of 25%, whereas 3/4 of a piece of wood consists of cell wall, i.e. of pure wood substance, which for itself has a density of 1.5 g/cm^3. If we compress the wood in such a way that no pores or air volumes are left, which is a common procedure in the production of staypack made of European beech wood, then we get a density of the compressed wood of about 1.4 g/cm^3. Consequently, this densified wood has very high strength properties and, therefore, is used for high-stressed parts and articles such as shuttles, supports of machines etc...

In fact, the density of tropical wood species ranges from the extremes of 0.1 to 1.3 g/cm^3, but the most commercial wood species used in buildings have a medium density between 0.6 and 0.8 g/cm^3.
Many well-known tropical wood species, such as TEAK (Tectona grandis), AFZELIA/DOUSSIE (Afzelia sp.), ANGELIQUE/BASRALOCUS (Dicorynia guanensis), SIPO/UTILE (Entandrophragma utile), IROKO/KAMBALA (Chlorophora excelsa), NIANGON (Tarrietia utilis; distinctive, interlocked grain), RAMIN (Gonystylus bancanus) and MAKORE (Tieghemella heckelii) as well as AFRORMOSIA (Pericopsis elata) belong to this group of medium density timbers; our EUROPEAN BEECH (Fagus sylvatica) and OAK Wood (Quercus robur), for instance, have comparable densities, too.

Tropical wood species which belong to the group of light woods with low densities between 0.4 and 0.6 g/cm^3 are : AGBA/TOLA BRANCA (Gossweilerodendron balsamiferum), AMERICAN and AFRICAN MAHOGANY (Swietenia macrophylla and Khaya ivorensis), LIGHT RED MERANTI (shora sp.), LIMBA (Terminalia superba), FRAMIRE (Terminalia ivorensis). Softwoods of corresponding densities are FIR (Abies sp.), SPRUCE (Picea abies) and PINE (Pinus sylvestris) whereas very dense and very hard wood species with a density of more than 0.8 g/cm^3 are : GREENHEART (Ocotea rodiei), BONGOSSI/AZOBE (Lophira alata), NIOVE (Staudtia stipitata), LIGNUM VITAE (Pockholz) (Guiaiacum officinale), (TALI) Erythophleum ivorense.

Two characteristical properties of wood which determine its suitability for building pruposes essentially and which on the other hand are strongly affected by the wood density are :

Firstly, the strength properties and
secondly, the dimensional stability, that means the shrinkage and swelling bahaviour of wood with changes of the relative humidity of the surrounding climate.

Concerning the strength properties of wood we can make the general trivial statement that, in principle, all strength properties raise with increasing density, because in more dense wood there is more wood substance available to take up the stresses. In this connection I cannot discuss all those factors which reduce the strength properties of wood significantly, such as knots, slope of grain, interlocked grain, gungal decay and so on, because of the lack of time. But from the point of view of strength properties it would generally be advisable to use as heavy and dense timbers as possible in building constructions.

The second group of wood properties which in principle is also dependant on wood density is the dimensional stability. Concerning the shrinkage and swelling of the wood perpendicular to the grain, there is unfortunately, the general correlation with density that wood changes its dimensions the more the higher the density of wood is. The danger that beams or other timber in buildings check and warp when drying out or that cross sections of wooden parts distort with a change of the moisture content is far greater when using very dense woods instead of light timbers. From the point of view of dimensional stability it is, therefore, advisable to use light or medium dense wood species.

The strength properties and the dimensional stability of natural wood are to a certain degree countercurrent with respect to density, and it is a great fortune that there are some tropical wood species - especially those with high contents of extractives and coloured heartwood substances, which show little shrinkage and swelling despite the fact that they possess a relatively high density. Those wood species are strongly demanded for the use in buildng constructions, especially for windows and other frame constructions, especially for windows and other frame constructions. Those tropical wood species with favourable properties of dimensional stability are for instance : TEAK, SIPO, AFZELIA.

Two other wood properties which are important to the use of wood in buildings are :

at first, the colour of the wood, and
secondly, and mostly much more important, the natural resistance of wood against attack of fungi and insects.

The colour of the wood is determined by the kind and type of extractives, resins, tannins, gums, and other substances which are often - besides the structure and texture of the grain of the wood - also responsible for the decorative character of many wood species.

Also with regard to the colour of the wood which ranges from white (BALSA) over yellow (OAK, IROKO), reddish (MAHOGANY) and brownish (TEAK, AFZELIA, BONGOSSI) colour tones up to dark black (AFRICAN EBONY) there is an extremely great variation between wood species and a remarkable variety within wood species, too.

Very light-coloured woods, which do not contain larger quantities of extractives, as for instance RAMIN or SPRUCE, are normally not very durable or not durable at all against beatles such ANOBIUM PUNCTATUM and against blue stain; therefore, special treatments with preservatives to avoid these defects are necessary if those wood species are used. Furthermore, one must take into consideration that the most light-coloured wood species darken in the course of time considerably.

A lot of brownish or dark-coloured wood species contain large quantities of extractives which leach out in moist atmospheres, for instance if they are not protected against weather and rain in exterior use. Ugly discolourations are the result, and if the wood contains larger quantities of tannins, then dark blue ink-discolourations may occur when the wet wood is in contact with iron parts, such as nails or screws, because of iron-tannin-reactions.

At last, I would like to come back to the second wood properties which is very important regarding the use of wood in buildings, namely the natural durability. This is a property where a lot of tropical woods have great advantages compared with our European wood species. Whereas only one species of our local woods, namely OAK, can be indicated as resistant (the heartwood of PINE on the contrary can only be classified as moderately resistant), many tropical wood species are very resistant or resistant against fungi and insects. Wood species which are very resistant are for instance :

TEAK, ANGELIQUE, AFZELIA, IROKO, MAKORE, (MERBAU), (BILINGA).

The following wood species can be classified as resistant :

WESTERN RED CEDAR, (CEDRO), AGBA, (FREIJO), AMERICAN MAHOGANY, SIPO, IROKO, MAKORE, OAK, NIANGON, (KOSIPO), DARK RED MERANTI, KOTIBE, (OVENGKOL, MERBAU).

The high natural durability is one of the greatest advantages of the use of many tropical wood species.

If on the other hand the natural durability of a wood species is too low and if an attack of microorganisms has to be taken into account, only those wood species are of interest to the user which are relatively permeable so that they can be impregnated with suitable preservatives.

In relation to permeability there are a number of wood species which are very difficult to impregnate. The reason for that may be that the pits and pit membrane openings which connect the different cells in the wood are extremely narrow or closed (as in SPRUCE) or that the larger cell lumina of the vessels are filled with an completely blocked by tyloses, as for instance in OAK wood.

Therefore, to the user of wood two alternatives are often of great importance :

Either to have a wood species with a high natural durability so that an impregnation with preservations is not necessary,
or to have a wood with a permeable structure which can be impregnated with preservatives rather easily.

If we consider all wood properties discussed so far, such as :

Density in relation to strength properties and dimensional stability
as well as colour and discolourations of wood and natural durability
or permeability of the wood, respectively

then we can draw a number of conclusions in relation to the use of wood in buildings in general and to the use of wood for restorations or preservations of ancient buildings.

For heavy constructions and for high-stressed timber frame-work tropical wood species, such as AFZELIA, SIPO, IROKO (instead of OAK), and NIANGON can be recommended. For lighter building constructions tropical wood species, such as SIPO, RED MERANTI, KHAYA, and TOLA BRANCA can be used. Very dense, heavy and durable wood species, such as GREENHEART, and AZOBE as well as BASRALOCUS are recommended for foundations, pilework and harbour constructions.

For the facing of outside walls, for weather boarding with solid woods and for wooden shinghles only light-weight soft-woods of good durability are used, such as WESTERN RED CEDAR (Thuja plicata) or CALIFORNIAN REDWOOD (Sequoia sempervirens).

If we are looking for tropical wood species which shall be used for interior work in buildings, the scale of wood species is much broader, and it is more a question of decorative effects, colour and strength properties which kind of wood we choose. Decorative wood species with a red-brown colour which can be used for constructional work are : SIPO, DARK RED MERANTI, and for lighter constructions AMERICAN MAHOGANY. Wood species with a light colour which can be used for light constructions in buildings are : LIMBA, FRAMIRE, LIGHT RED MERANTI, TOLA BRANCA, and the softwood PARANA PINE (Araucaria angustifolia). For the manufacture of stairs harder wood species are preferred, such as : IROKO (yellow colour), AFZELIA (dark brown), MERBAU (Intsia bijuga), ANGELIQUE, and again the softwood PARANA PINE.

These are only a few examples of utilization of tropical woods in buildings as a result of their wood properties. But I hope I could give you some general information and ideas which are valuable for you and which may give you some new suggestions regarding the utilization of those wood species that may have some advantages compared with our local woods.

Perhaps I might have the opportunity to explain the one or other question and to go more into detail in a special problem during the discussion.

RESUME

PROPRIETES ET UTILISATION DES BOIS TROPICAUX

Il est nécessaire de connaître les propriétés des bois tropicaux pour répondre adéquatement aux exigences de leur utilisation. Le technologue ne peut ignorer la corrélation étroite entre les propriétés et l'utilisation du bois, même si son travail n'est pas facilité par l'hétérogénéité des essences.

Les propriétés du bois les plus adéquates à la construction sont les suivantes :

- la densité comprenant la propriété de "force" et la "stabilité" relative aux changements de dimension
- la couleur du bois
- la résistance naturelle aux attaques des insectes et champignons ou la perméabilité.

La durabilité naturelle du bois est la propriété essentielle de beaucoup d'expèces de bois tropicaux.