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Moisture in timber

This Wood Information Sheet provides basic information for the specifier and user on the facts and importance of the moisture content of wood. A separate sheet, *Moisture content standards for timber*, WIS 4 – 27, gives details of the levels of moisture content recommended in various British Standards and outlines the results of research to establish more realistic recommendations.

Other TRADA Wood Information Sheets deal with specific uses of timber and give advice on the specification of moisture content.

Water and timber

Water in wood is not just a contaminant or a carry-over from water conduction in the tree, but a chemical constituent . About 25 to 30% of the water in wet wood is chemically bound in varying degrees to the wood fibres. Living trees and freshly-felled sawn timber can contain much more water than this - up to about 200%. The moisture content figure can be more than 100% because the weight of water in timber is expressed as a percentage of the oven dry weight (wt) of the wood:

$$mc\% = \frac{\text{wt wet wood - wt dried wood}}{\text{wt dried wood}} \times 100$$

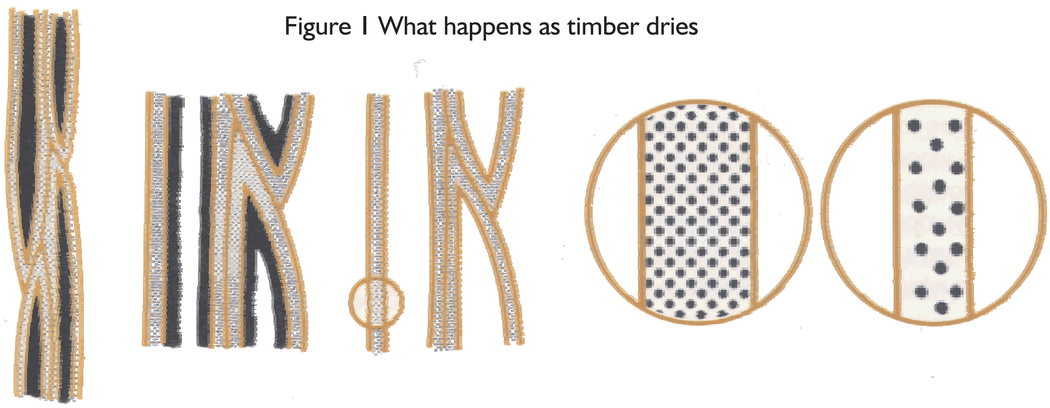
Thus a piece of wet timber whose weight is half dry wood and half water will have a moisture content of 100%.

Above the 25 - 30% moisture content level, water fills or partially fills the cavities of the wood fibres, see Figure 1. When wood dries, this water is lost first. This reduces the weight of the piece but does not change its dimensions. When the cell cavities are empty but the cell walls still retain their bound water, the wood is said to be at *fibre saturation point (fsp)*.

Further drying below fsp results in shrinkage of the wood as the walls of the fibres contract, see Figure 1. The process happens in reverse if dried wood is put into a wet or moist environment and it absorbs water.

It is usually necessary to dry wood before it is used or processed in some way, unless it is going to be used in water or in a very wet environment.

Figure 1 What happens as timber dries



There are two main reasons for needing to dry timber:

- wood of many species will decay if kept at high moisture contents for long periods. Some susceptible timbers will suffer from mould or staining even if they are kept wet for only a short time. Timber below about 20% moisture content is too dry to suffer such discolouration or decay (although damp surfaces of otherwise dry wood can develop mould/stain).
- wet wood will usually dry out in service. As it loses water below the 25 - 30% fibre saturation point it will shrink laterally. If the grain of the piece is not absolutely straight, distortion may occur. Pre-drying the wood allows these inevitable dimensional changes to be avoided in service and enables the production of accurately shaped and sized components.

Further reasons for drying that may be important in specific cases are:

- to save weight during transportation
- to facilitate machining
- to enable strong glue joints to be made
- to allow preservatives to penetrate
- to increase the loads that timber can carry.

Timber drying

The process of commercial timber drying involves evaporating moisture from the surface of the wood. This is usually carried out by heating the timber in a kiln. The surface layers dry by evaporation and the deep-seated moisture gradually moves towards the surface, setting up a moisture gradient in the piece - drier towards the outside and wetter towards the centre. During drying it is difficult therefore to define precisely what is meant by the 'moisture content' of a piece of wood since this will vary through the section. Timber drying is a relatively slow process which may take several days to several months, depending on the species of timber, its thickness and the drying facilities used. Drying is more rapid from the ends of boards or logs, unless they have been treated with an end grain sealing treatment. Timber which is dried in a kiln is usually given a 'conditioning treatment' at the end of the process to even-out the distribution of moisture in the pieces.

Moisture gradients

For many end uses the distribution of moisture in a piece of timber can be as important as its average moisture content. Lengthwise sawing or deep machining of pieces that have steep moisture gradients will result in distortion. This may occur immediately, due to the release of stresses set up during rapid drying, or more slowly as the new surfaces dry out. Moisture gradients are less significant in pieces which were dried in the shape in which they are to be used.

Equilibrium moisture content (emc)

The moisture content of wood changes in response to the temperature and humidity of its surroundings ie it is a 'hygroscopic' material.

In constant conditions of temperature and humidity, the timber will, in theory at least, eventually reach a constant moisture content - the so-called *equilibrium moisture content* for those conditions. In practice, such stability of conditions rarely occurs and therefore a true equilibrium moisture content is never reached.

The response of timber to changes in temperature and humidity is quite slow and tends to 'average out' minor fluctuations in conditions such as 24 hour variations in central heating. The outer layers of the timber respond more rapidly to changes than the inner sections of a piece. Protective or decorative coatings, such as paints, varnishes and exterior wood finishes slow down the response to a degree roughly related to the thickness of the coating. They will not prevent the moisture content of the timber from changing. In general terms, changes in moisture content of timber in buildings are measurable on a seasonal basis, rather than in terms of days or weeks.

The actual emc value varies slightly between different species of timber and also depends on whether the wood had to gain or lose moisture to reach the equilibrium level. Wood based boards, such as plywood, chipboard and fibre building board often have lower emc values than the timbers from which they were made.

The relationships between and temperature/humidity have, until now, been taken from a chart produced more than 30 years ago, designed for drying kiln operators (VA 2, see References). The data did not take account of species differences related to drying down from the 'green' condition and early editions included the wording "this chart is approximate only".

A TRADA Technology research project (supported by TRADA and DETR under the Partners in Technology programme) was undertaken to determine the emc values of 20 species of timber widely used in the UK over a temperature range of 10 - 30° C and a humidity range of 35 to 75% RH. Figure 2 presents this data, averaged for all 20 species, with limited extrapolation to 0° C and a wider range of relative humidity.

Emc as a diagnostic tool

The concept of emc is particularly useful when trying to diagnose moisture-related problems with timber. In reasonably stable temperature/ humidity conditions, the moisture content of a piece of timber should correspond, approximately, to the emc appropriate to these conditions. If it does not, then other explanations need to be investigated:

- has the timber been recently introduced to the environment and is still gaining or losing moisture?
- has it been treated with flame retardants such that the moisture meter is giving false readings?
- is there a source of moisture (or drying, such as an underfloor heating pipe) that is preventing equilibrium from being reached?

The availability of more accurate data in Figure 2 will assist in such investigations and analysis.

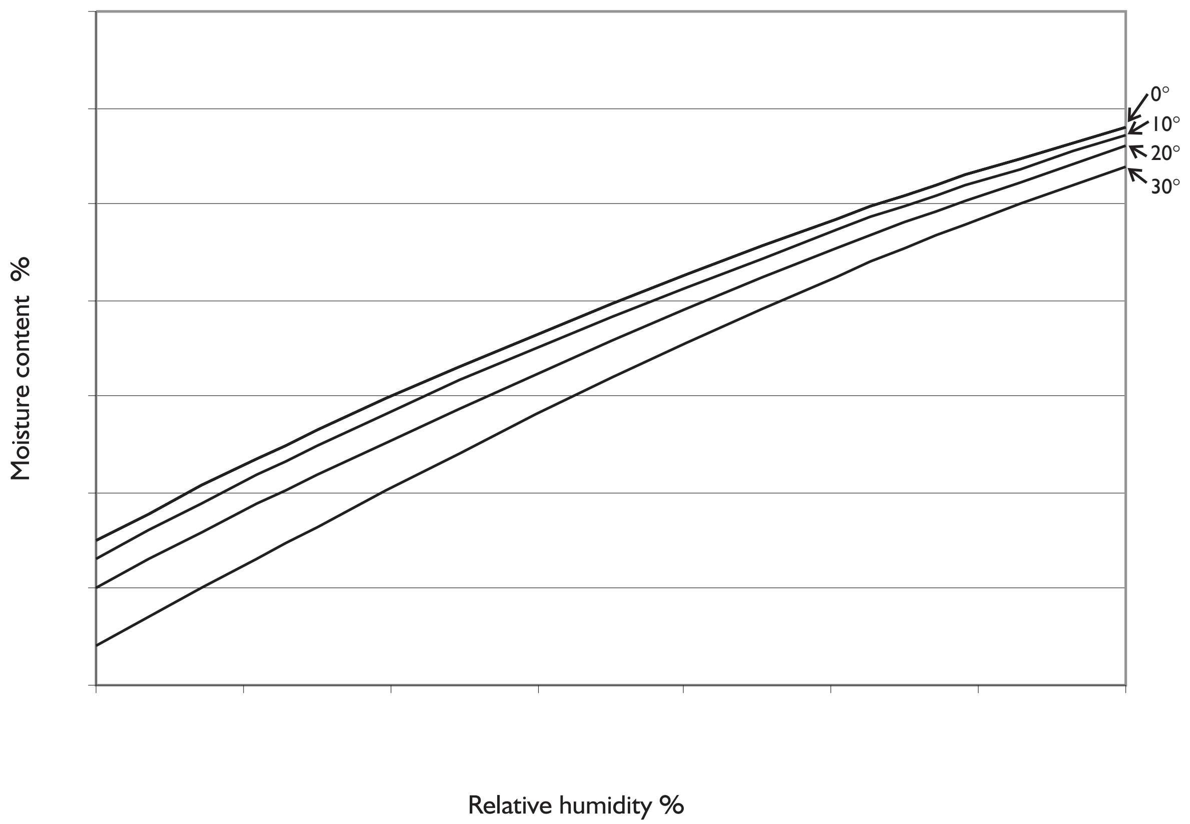


Figure 2 Average emc values derived from recent research on 20 species (temperatures in °C)

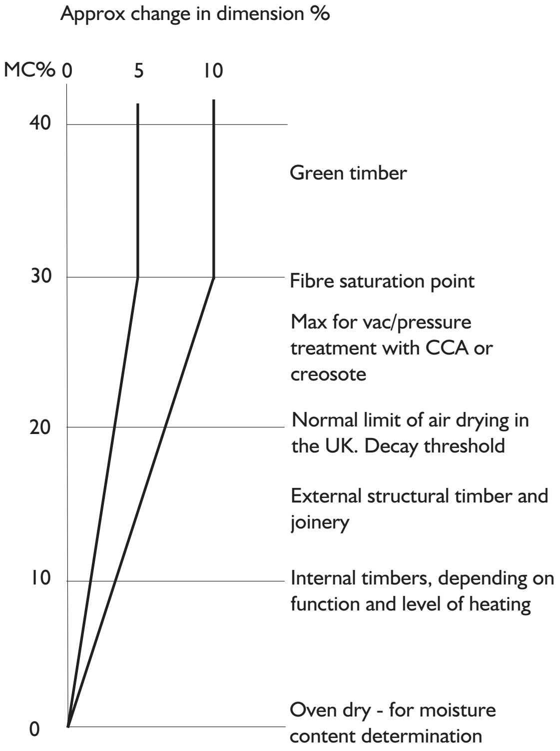


Figure 3 Emc values and shrinkage

Shrinkage

Figure 3 shows generalised swelling and shrinkage characteristics of wood. The characteristics are stable above fibre saturation point and are shown as a linear change in dimension as the moisture content reduces below this level. This is a very simple approximation of a complicated picture but is quite adequate for a 'rule of thumb' assessment. Actual shrinkage and movement values vary between species and can be influenced by mechanical restraint.

For most practical purposes the following assumptions should suffice:

- timber does not shrink or swell lengthwise along the grain.
- shrinkage starts as the timber dries below about 30% moisture content.
- it shrinks and moves almost twice as much across the width of a flat sawn board (ie in a tangential direction) as it does across a quarter sawn board (ie radially).
- tangential shrinkage or swelling can be estimated as roughly 1% for every 3% change in moisture content below 30%; radial shrinkage is about half this.

If timber is put into service at a moisture content higher than that which it is likely to reach in time (ie higher than the likely emc), two interrelated problems can occur. One is shrinkage and the other is distortion.

For example, if a piece of timber at 25% mc is put into a 16% emc environment it can be expected to shrink 3% tangentially and 1.5% radially. This may not seem much on a 25 x 25 mm batten but it represents 13 mm on a 600 mm deep laminated beam and 230 mm on a 10m wide floor.

Whilst it is unrealistic to apply high precision to matters involving moisture content, a severe mismatch between the moisture content of supply, storage or installation and the timber's eventual emc will often lead to problems in service.

Distortion is caused by the difference in shrinkage in a tangential direction compared with that radially, coupled with the fact that the grain of a piece of timber rarely runs true. Thus large changes in moisture content below fibre saturation point can result in the bowing or twisting of studs or the cupping of floor or cladding boards.

Careful design to accommodate anticipated movement, coupled with sensible moisture content specification will avoid such problems.

Movement

As explained above, a stable emc is never reached in practice. The change in dimension exhibited by timber after its initial drying shrinkage is termed *movement*. This varies between species. Table 1 indicates the movement values of a number of common species, based on a classification system devised by the Forest Products Research Laboratory (now part of the Building Research Establishment). The classes are based on the sum of the tangential and radial movements corresponding to a change in humidity conditions from 90% to 60% relative humidity at a constant temperature.

Small:	under 3%
Medium:	3.0 - 4.5%
Large:	over 4.5%

Where movement tolerances are critical, a timber with small movement characteristics should be considered.

Table 1 Movement values of some common species

SMALL				
abura	afzelia	agba	cedar, S American	Douglas fir
gedu nohor	guarea	hemlock, Western	idigbo	iroko
jelutong	lauan	limba	mahogany, African	mahogany, American
makoré	mengkulang	meranti	merbau	obeche
padauk	pine, Canadian red	pine, Corsican	pine, yellow	purpleheart
rosewood	sepetir	spruce, Canadian	spruce, Sitka	teak
walnut, African	wengé	western red cedar		
MEDIUM				
ash, American	ash, European	cherry, American	cherry, European	danta
elm, European,	elm, white	greenheart	jarrah	kapur
kempas	maple, rock,	maple, soft	niangon	nyatoh
oak, American red	oak, American white	oak, European	oak Japanese	parana pine
pine, radiata	pine, Scots	poplar, American yellow (tulipwood)		redwood
sapele	utile	walnut, American	walnut, European	whitewood,European
LARGE				
beech, European	birch, American	birch, European	chestnut, sweet	karri
keruing	ramin	rubberwood		

Measuring moisture content

There are two commonly used methods of measuring moisture content in wood.

One, using *moisture meters*, is a non- destructive test which is based on the fact that the electrical properties of timber vary with its moisture content. This method is particularly appropriate for routine checking (eg quality control) and site use.

The second method is destructive in that it involves taking the piece of timber (or a sample from it), weighing it to determine the mass of the wood plus water, drying it completely to obtain the dry weight, and using the formula on page 1 to calculate the moisture content. Known as the *oven dry* method, this is the more precisely defined and is often taken as the 'true' moisture content.

Moisture meters

Most common meters work on the principle that as the moisture content of a piece of timber increases, its electrical resistance decreases. Thus timber with a low moisture content has a high resistance. Conductivity is usually measured between two or more pin or blade-like electrodes which are pushed or hammered into the timber. Further information is given in the TRADA WI sheet *Moisture meters for wood*.

The main advantage of a moisture meter is that it gives instant readings which, although they may not be highly accurate, can be repeated many times to give an overall picture of moisture content and its distribution. The portability of the instrument is also a major advantage and moisture meters have gained wide acceptance in determining moisture content during the processing, storage, transportation, installation and in-service checking of timber and timber products.

Temperature and species corrections should be applied to improve the accuracy of the results. Even so, the values will not be completely accurate because the relationship between conductivity and moisture content is not precise. The usual standard expected of such meters is that most readings will be within +/- 2% moisture content of the true level between about 8 and 25%. Some meters have scales which suggest they can be used outside this range but such readings should be viewed as indicative only, unless proved by calibration against oven drying.

The readings given by moisture meters are influenced by the presence of salts in the wood, such as those from waterborne preservatives, flame retardant treatments and contamination by sea water. Such salts increase the conductivity of the wood, particularly at higher moisture contents, and give a falsely high reading for moisture content. The magnitude of the effect is variable and it is not usually possible to correct the readings. Therefore when the presence of such salts is suspected, moisture readings which are higher than expected should be treated with suspicion.

When using moisture meters on panel products, be aware that panels are not consistent between brands. Correction values are available for some board products from some meter manufacturers. For others, the moisture content readings obtained with resistance-type meters should not be treated with confidence. The effect with some varieties of exterior plywood can be particularly severe. In extreme cases, meters may indicate moisture values approximately double those obtained using the oven dry method. If high accuracy is required, advice should be sought from the board/meter manufacturer.

A small calibration device can be used to verify the correct operation of most types of resistance meters. These are available from meter manufacturers and independent suppliers.

Oven drying

The oven dry method provides a relatively accurate assessment of the moisture content of the sample or samples being tested. However, since it is a destructive test, its day to day use is largely confined to companies undertaking timber drying where it is used for monitoring moisture content during the drying process.

There are other situations where very accurate assessment of moisture content is necessary. In this case, specialist help, such as that available from TRADA Technology should be sought. Samples for checking should be taken at least 300 mm in from the ends of the piece of timber.

The method has some limitations. For example, volatile constituents found in resinous or oily timbers, or creosote or other solvents added to the timber can be driven off and wrongly counted as water. A distillation method of moisture content determination is available for such timber if high precision is required. Results are accurate for the samples being tested. However, it is not easy to define gradients of moisture or to assess batches of timber; it is destructive and time-consuming - hence its restriction to specialised applications.

Specifying moisture content

The appropriate moisture content may not always relate to the environment of use. For example, wooden handles for garden tools which will eventually reach equilibrium with conditions in the garden shed may spend many months in a centrally heated supermarket. The moisture content of manufacture should therefore be geared towards the supermarket conditions.

Wood products can be too dry for their service environment, although this is far less common than their being too wet. In these cases problems with swelling, as opposed to shrinkage can occur, usually with wood block flooring or panel products, particularly hardboard.

Many British Standards specify the moisture content of timber and panel products yet there is a marked lack of uniformity in both the requirements and the way in which they are defined.

There are three broad reasons for specifying the moisture content of timber in British Standards:

- to minimize in-service problems due to dimensional changes or distortion. This is the best represented category and includes items such as furniture, joinery, flooring etc
- to enable efficient processing, eg preservative treatment, gluing, machining and fabrication
- to prevent deterioration, minimize shrinkage and ensure adequate strength of timber and panel products.

A realistic specification of moisture content should include:

1. the average moisture content of the batch
2. the tolerance limits on the average moisture content of individual pieces within that batch
3. a limitation on the variability of moisture content within the individual pieces, either at different depths (ie moisture gradients) or at different positions along the length, or both
4. the method of measurement.

The appropriate British Standard will usually give the information necessary to specify 1. Items 2 and 3 will depend on the end use and whether variation from piece to piece or within pieces is critical.

A companion WI Sheet *The specification of kiln dried timber* defines three classes of kiln drying in terms of moisture content levels and variability. These classes should be used as guidance in drawing up moisture content specifications for common end uses and certainly where kiln drying is called for. It is, of course still open to the client and specifier to agree more, or less, stringent specifications, if appropriate.

Care of dried timber

Timber dried to a level appropriate to its end use must be stored so that moisture content changes are minimal. Wood, close piled under adequate cover may be stored for a week or two without major changes in moisture content. However, softwoods and permeable hardwoods at a low moisture content will take up moisture more quickly than some less permeable hardwoods.

Flooring, joinery, furniture and any wood supplied at the lower moisture contents should, as far as possible be delivered and installed after the building has dried out.

Guidance on site storage is given in TRADA WI Sheet *Care of timber and wood based products on building sites*.

References and further reading

TRADA Wood Information Sheets

Specification of kiln dried timber. WIS 2/3-24

Introducing wood. WIS 2/3-28

Care of timber and wood based products on building sites. WIS 4-12

Moisture meters for wood. WIS 4-18

Moisture content standards for timber. WIS 4 - 27

Wallcharts

Equilibrium moisture content and humidity chart for wet and dry bulb thermometers. VA 2

Timber drying. VA 5

Moisture content. VA 6

Prices and a list of publications are available on request from the TRADA Information Centre:

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