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Timber Flooring

Design guide for installation

Technical Design Guide issued by Forest and Wood Products Australia



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Table of Contents

Introduction	4
1. Timber Flooring and Floor Finishes	6
1.1 Movement in Timber Floors	6
1.2 Timber Species and Characteristics	6
1.3 Floors Over Different Sub-Floors	10
1.4 Floor Finish Types and Characteristics	10
2. Pre-Installation Requirements	13
2.1 Storage and Handling Procedures	13
2.2 Timber Flooring Standards and Specifications	13
2.3 Evaluating Site Conditions and the Installation Environment	14
2.4 Considering the Likely Movement After Installation	17
2.5 Installation Moisture Content and Acclimatisation	17
3. Installation to Timber and Sheet Sub-Floors	19
3.1 Sub-Floor Ventilation	19
3.2 Assessing Fixing Requirements	21
3.3 Allowance for Expansion in Floors	22
3.4 Floor Laying Practices	22
3.5 Installation of Strip Flooring Direct to Joists	23
3.6 Installation of Strip Flooring over Existing Timber and Sheet Floors on Joists	25
3.7 Installation of Strip Flooring over Plywood and Battens on Concrete Slabs	27
4. Installation by Direct Adhesive Fix to Slabs	32
4.1 Assessing and Preparing the Slab	32
4.2 Moisture Vapour Barriers	33
4.3 Adhesives	34
4.4 Direct Stick Installation Practices	35
5. Sanding and Finishing Timber Floors	38
5.1 Assessing the Floor Prior to Sanding	38
5.2 Preparation for Sanding	38
5.3 Sanding	39
5.4 Coating System Application	42
6. Overall Appearance to be Expected	45
6.1 Acceptable Appearance	45
7. Care and Maintenance	49
7.1 A Newly Finished Floor	49
7.2 Ongoing Care and Maintenance	49
Appendices	
Appendix A – Moisture Content and Timber Movement	51
Appendix B – Measuring Moisture Content of Timber and Sheet Products	55
Appendix C – Slab Moisture Assessment	62
Appendix D – Acoustic Performance	65
Appendix E – Underfloor Heating	68
Appendix F – Installation Checklist	72
Appendix G – Troubleshooting Guide	75

Introduction

Scope

This publication provides a reference guide for the installation of solid timber strip flooring over bearers and joists, timber-based sheet flooring products and concrete slabs. Generally, floors of this type are of solid timber or a laminated product made from layers of timber, bonded together. Flooring fits together with a tongue and groove joint. After the flooring is in place, the floor is sanded and finished. There are a number of other timber flooring products that are not of this type and are not covered by this guide. These include parquetry, pre-finished floors and 'floating' timber floor systems. When installing a strip timber floor, many aspects must be considered, including the house design, environment in which the floor is to be laid and the desired appearance of the finished floor. Such aspects influence the choice of species, cover width, fixings and finish to be applied. Information relating to product selection, assessing the installation environment, floor installation, sanding and finishing are provided in the guide, together with additional information of importance to the floor installer, sander and finisher.

The Flooring Process

Strip timber flooring is available in a wide range of species and colours, from harder and softer timbers and a variety of profiles and cover widths. Prior to the finished floor being handed over, there are a number of processes that must be correctly undertaken to achieve a floor with the performance and appearance that is of a professional standard. Each stage generally involves different sectors of the industry, each having specific skills. Each stage is of equal importance, with defined responsibilities. A lack of attention at any particular stage can adversely affect the finished floor. The stages are as follows:

- Manufacture – Usually carried out by a sawmiller, however, dried rough sawn boards may be machined into finished floor boards undertaken by a separate operation.
- Distribution – Flooring is often sold to timber merchants who on-sell to the installer.
- Specification – Architects, designers and owners usually specify the product to be installed.
- Sub-floor – Builders provide the joists and bearers or slab over which a floor is laid.
- Installation – Specialist floor installers and carpenters install floors over the sub-floor.
- Sanding and Finishing – Generally undertaken by professional floor sanders and finishers.

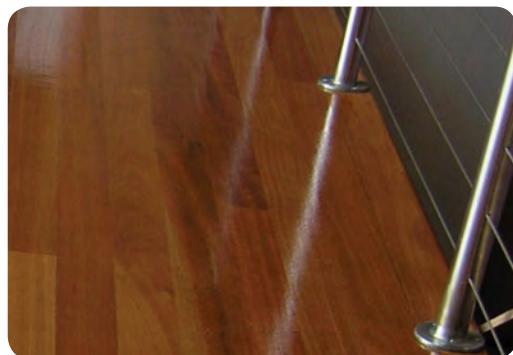


Selective logging from sustainable managed forests often starts the process.

The Owner's Choice

Aspects relating to what customers desire are of paramount importance and should not be taken lightly. They are relying on the expertise of those in the six stages outlined above and each area can influence the owner's satisfaction with their floor. Each floor is unique and is often seen by the owner as a focal point of the interior design. Those selecting a timber floor will often choose on colour, with board width influencing how the natural colours are blended. Timber hardness, or matching to an existing floor, can also be of prime importance. Aspects such as the origin of the flooring in terms of country, forest type or recycled, can also be of importance to the owner.

Owners are more aware and have more access to information than ever before, however they are unlikely to have the same depth of knowledge as those dealing with timber flooring on a day-to-day basis. It is important to accommodate customer preferences, however this should not be to the detriment of the performance of the floor or its final appearance. Where customer preferences cannot be accommodated, this needs to be brought to their attention. Where their choices can be accommodated but may affect the appearance of the floor, then this too needs to be brought to their attention and followed up in writing. Colour variation between showroom samples and the product provided, provision of expansion joints and high levels of sun exposure on an area of the floor are all areas that affect appearance and may necessitate specific discussion with the owner.



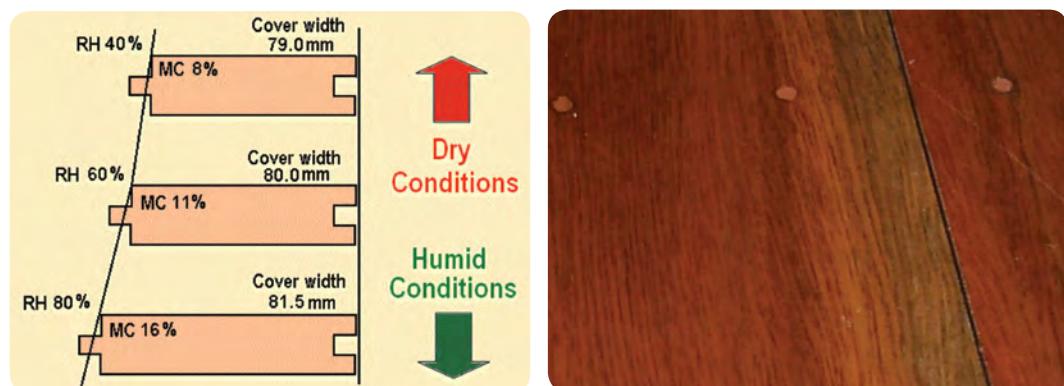
Left: The client's wishes need to be accommodated but not at the expense of floor performance.

Right: Showrooms provide an excellent environment, where clients not only see many types of floors and finishes but where valuable information can be conveyed regarding floor systems, performance and care of timber floors.

Timber Flooring and Floor Finishes

1.1 Movement in Timber Floors

Prior to discussing timber flooring products, it is important to understand the relationship between timber, humidity in the air surrounding it and the dimensional changes that occur as the result of changes in humidity. During consistently high humidity weather, timber will absorb moisture from the surrounding air causing it to swell or increase in size. Conversely, during drier times when humidities are low, timber will shrink, reducing in size. Unless tongue and groove (T&G) flooring is placed in a permanently controlled environment, it will always move in response to changing environmental conditions. Gaps between individual T&G boards will occur as the floor shrinks in dry weather. Similarly, during either persistent wet weather or at times of naturally high humidity, floors will tend to be tighter showing fewer and smaller gaps.



Left: Cover width variation with changing relative humidity.

Right: Small gaps at board edges may occur, particularly during dry weather.

A ‘continuous mirror finish’ cannot be expected from floor finishes. Localised shrinkage may also occur when areas of flooring are exposed to heat sources, such as fireplaces or sunlight through large doors or windows. The overall movement and rate of movement of timber varies depending on the timber species and cutting pattern of individual boards. Small moisture content variations in boards at the time of installation and differing conditions within the house (e.g. from sun exposure or fireplaces) will also cause variation in board movement.

Consequently, gapping across a floor can be expected and may be relatively even, depending on individual circumstances, but actual gap size between individual boards will vary. For the same changes in moisture content, wider boards will move more than narrower boards. Therefore, gaps in wide board floors are generally wider and more noticeable. An uneven distribution of gaps can detract from the appearance of the floor and may occur if a number of boards are bonded together by the finish penetrating into the joints. Floor finishes will not prevent timber movement, but may reduce the rate of response to climatic changes. Applying a finish to the underside of a floor may help reduce the impact of sudden changes in the weather.

1.2 Timber Species and Characteristics

Species, colour, grade and hardness

The species or species mix will generally determine the overall colour of the floor. Mixes may contain different species from one producer to another and may therefore appear different. Even when a single species is chosen there can be a wide variation in colour and a limited number of boards of a different species may be present due to similarity in appearance. As a guide, Table 1.1 (page 8) indicates the range of colours that may be expected. The sapwood of many hardwoods can be much lighter than adjacent heartwood and some boards may contain both light and dark colours. Even within a single species and within individual trees, large colour variations can occur.

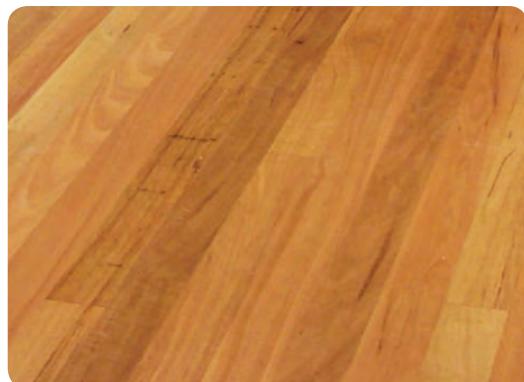
The age of the tree can have a significant influence on the colour, with younger timber often being lighter than more mature timber. The product supplied may differ in colour to showroom samples and this should be discussed with flooring suppliers and owners. It is also preferable that flooring is supplied from one manufacturing source and that the packs are of a similar age.

Some States, including Queensland and New South Wales, require the lyctid-susceptible sapwood of some hardwood species (e.g. Spotted Gum) to be preservative treated. Some treatments may impart a brown tinge to sapwood, while boron preservative is non-colouring. Light organic solvent preservative (LOSP) treatment is also used. In this instance H3 treatment may be used in lieu of H2 treatment to avoid the coloured dyes often used with H2 LOSP treatments.

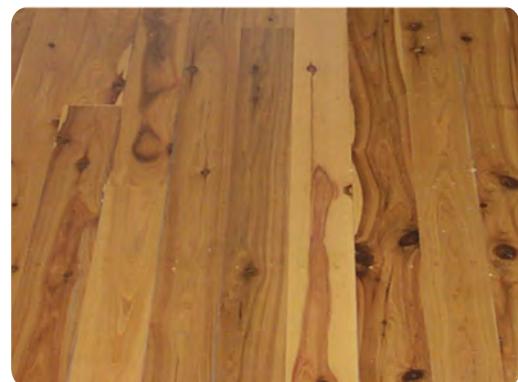
The character of the floor is influenced by the species characteristics and therefore the grade. Grading is a process that sorts boards according to the number and size of features present (e.g. gum veins and knots). The following table indicates the grades contained in relevant Australian Standards, but it should be noted that manufacturers often have their own grades. Often, flooring that contains more features is more moderately priced, however, irrespective of the features present, there is no difference between the grades in terms of machining tolerances, permitted machining imperfections and moisture content.

It is important to realise that the overall colour or blend of colour in a floor is dependent on the species or species mix chosen and the character of the floor, in terms of the features present, such as gum veins, is determined by the grade. If choosing an alternative species from the one originally considered, not only will the overall colour differ but the dominant type of feature may also change. It is important that suppliers, installers and clients work closely together to ensure that the desired look of the flooring is clearly understood by all.

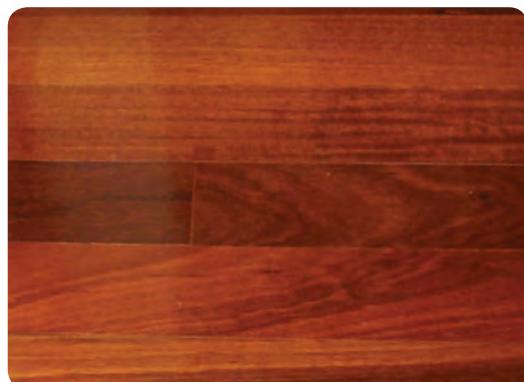
Hardness indicates the resistance of a species to indentation and abrasion. Damage to timber floors may occur due to continual movement of furniture, heavy foot traffic and in particular 'stiletto-heel' type loading. The selection of a hard timber species ensures improved resistance to indentation and abrasion. Soft timber species, if used in feature floors, can be expected to indent. Floor finishes will not significantly improve the hardness of timber flooring. In some species, the hardness of younger growth material can also be much lower than mature timber of the same species, but this varies from species to species.



Tasmanian Oak – Medium Feature Grade.



Cypress – Grade 1.



Jarrah – Select Grade.



Blackbutt – Select Grade.

Table 1.1: Australian Hardwoods to AS 2796 – Timber, Hardwood, Sawn and Milled Products.

Select Grade, Medium Feature/Standard Grade and in some species High Feature Grade

Species	Origin	Colour	Hardness	Common cover widths (mm)	Thickness (mm)
Hardwood flooring species grown in Queensland and Northern NSW					
(may also be supplied as a mix of similar colour)					
Spotted Gum (<i>Corymbia citriodora</i>) (<i>Corymbia maculata</i>)	Qld, NSW	brown, dark brown, light sapwood	very hard	60, 80, 85, 130, 180	19, 12, 13, 14
Blackbutt (<i>Eucalyptus pilularis</i>)	Qld, NSW	golden yellow to pale brown	very hard	60, 80, 85, 130, 180	19, 12, 13, 14
White Mahogany (<i>Eucalyptus acmenioides</i>)	Qld, NSW	pale yellow-brown	very hard	60, 80, 130	19, 12
Grey Ironbark (<i>Eucalyptus siderophloia</i>) (<i>Eucalyptus paniculata</i>)	Qld, NSW	dark brown or dark red-brown light sapwood	very hard	60, 80, 85, 130, 180	19, 12, 13, 14
Red Ironbark (<i>Eucalyptus crebra</i> and <i>fibrosa</i>) (<i>Eucalyptus sideroxylon</i>)	Qld, NSW	dark brown or dark red-brown	very hard	60, 80, 130	19, 12, 14
Rose Gum (<i>Eucalyptus grandis</i>)	Qld, NSW	straw pink to light red-brown	hard	60, 80, 85, 130	19, 12, 13, 14
Brushbox (<i>Lophostemon confertus</i>)	Qld, NSW	mid red-brown even colour	hard	60, 80, 85, 130	19, 12, 14
Tallowwood (<i>Eucalyptus microcories</i>)	Qld, NSW	greyish yellow, olive green	hard	60, 80, 85, 130	19, 12, 13
Turpentine (<i>Syncarpia glomulifera</i>)	Qld, NSW	pale reddish brown	very hard	60, 80, 85, 130	19, 12
Forest Red Gum (<i>Eucalyptus tereticornis</i>)	Qld	dark brown or dark red-brown	very hard	60, 80, 85, 130	19, 12, 14
Gympie Messmate (<i>Eucalyptus cloeziana</i>)	Qld	yellow brown	very hard	60, 80, 130	19
New England Blackbutt (<i>Eucalyptus andrewsii</i>)	NSW	straw to pale brown	very hard	60, 80, 85, 130	19, 12, 13, 14
Sydney Blue Gum (<i>Eucalyptus saligna</i>)	NSW	straw pink to light red-brown	hard	60, 80, 85, 130, 180	19, 12, 13, 14
Manna Gum (<i>Eucalyptus viminalis</i>)	NSW	pale straw pinks	mod. hard	60, 80, 130	19, 12
Hardwood flooring species grown in Victoria, Southern NSW and Tasmania					
Victorian Ash (<i>Eucalyptus regnans</i> , <i>E.delegatensis</i>)	Vic	pale pink to yellow-brown	mod. hard	63, 68, 80, 85, 108, 133, 160, 180	12, 14, 19, 20, 21
Tasmanian Oak (<i>Eucalyptus regnans</i> , <i>E. oblique</i> , <i>E. delegatensis</i>)	Tas	pale straw to light brown	mod. hard	60, 65, 85, 108, 133, 160, 180, 85, 112	10, 12, 13, 14, 19, 20, 21
Messmate (<i>Eucalyptus oblique</i>)	Tas	pale straw to light brown	mod. hard	60, 68, 85, 108, 112, 133	10, 12, 13, 14, 19
Mountain Ash (<i>Eucalyptus regnans</i>)	Vic, Tas	pale straw to light brown	mod. hard	60, 63, 68, 80, 85, 108, 112, 133	12, 13, 14, 19
Alpine Ash (<i>Eucalyptus delegatensis</i>)	Vic, Tas	pale straw to light brown	mod. hard	60, 63, 68, 80, 85, 108, 112, 133	12, 13, 14, 19
Southern Blue Gum (<i>Eucalyptus globulus</i>)	Vic, Tas	pale brown with some pink	very hard	60, 63, 80, 85, 108, 112, 133	12, 13, 19
River Red Gum (<i>Eucalyptus camaldulensis</i>)	Vic	rich deep reds	hard	63, 80, 85, 108, 133	12, 19
Yellow Stringybark (<i>Eucalyptus muelleriana</i>)	Vic	even, yellow-brown	hard	63, 80, 85, 108, 133	12, 19
Manna Gum (<i>Eucalyptus viminalis</i>)	Vic	pale straw pinks	mod. hard	63, 80, 85, 108, 133	12, 19
Shining Gum (<i>Eucalyptus nitens</i>)	Vic	pale brown some pinks	mod. hard	63, 80, 85, 108, 133	12, 19
Myrtle (<i>Nothofagus cunninghamii</i>)	Tas	straw & light pink, light sapwood	mod. hard	60, 65, 85, 108, 112, 133	13, 19
Blackwood (<i>Acacia melanoxylon</i>)	Tas	light golden to deep brown	mod. hard	60, 65, 85, 108, 112, 133	13, 19
Hardwood flooring species grown in Western Australia					
Jarrah (<i>Eucalyptus marginata</i>)	WA	rich reddish-browns to soft salmon pinks	hard	80, 85, 105, 125, 130	12, 13, 19
Karri (<i>Eucalyptus diversicolor</i>)	WA	rich reddish-browns to pale pinks	hard	80, 85, 125, 130	12, 13, 19

Species	Origin	Colour	Hardness	Common cover widths (mm)	Thickness (mm)
Cypress to AS 1810 – Timber, seasoned Cypress, milled products					
Grades No.1 and No. 2					
Cypress (White) (<i>Callitris glaucocephala</i>)	Qld , NSW	pale straw sapwood, dark brown heartwood	mod. hard	62, 85	20
Australian Softwoods to AS 4785 – Timber, softwood, sawn and milled products except Araucaria (Hoop Pine) for which industry grades apply					
Standard Grade for AS 4785					
Araucaria (Hoop) (<i>Araucaria cunninghamii</i>)	Qld , NSW	light straw	soft	87, 89, 102, 133, 152	19, 20, 21
Radiata (<i>Pinus radiata</i>)	Vic, NSW, SA, WA	straw	soft	104	19, 21

Australian Softwoods/Imported Hardwoods to AS 2796 – Timber, hardwood, sawn and milled products

Select Grade, Medium Feature / Standard Grade and in some species High Feature Grade

Kwila / Merbau (<i>Intsia bijuga</i>)	S.E. Asia	dark brown	hard	80, 130	19
Northern Box (<i>Tristania obovata</i>)	S.E. Asia	mid brown even colour	hard	80, 130	19
Maple (Rock or Sugar) (<i>Acer saccharum</i>)	Nth. America	light straw	mod. hard	50, 57, 83	19

Note: Not all species, width and thickness combinations are available. Check with suppliers before specifying.

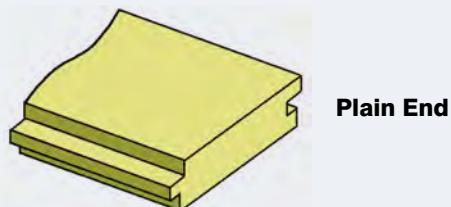
Cover widths, profiles, spans and end-matching

Typical cover widths and thicknesses for T&G strip flooring are as shown in the table above. Actual cover widths may vary from those shown and should be checked with individual suppliers. Typical T&G profiles are shown in the figure below. Some profiles are produced with grooves or rebates on the underside. Where the underside of a floor forms a ceiling, the board edges may be arrised to form a 'V' joint profile. Both profiles are used for top (face) nailing and secret fixing. The 'standard profile' is more commonly found on wider boards and some manufacturers indicate that such boards should be top (face) nailed. Some wider board flooring has the secret nail profile which allows temporary secret fixing prior to top (face) nailing.

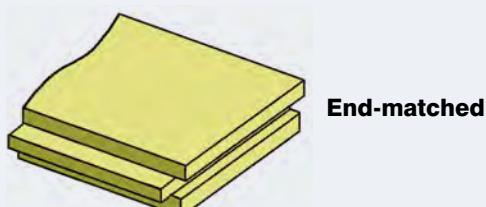


If the species or species mix contains a significant variation in colours the appearance of the floor will differ depending on the cover width. Narrower boards tend to blend the colour variations together. Gapping between individual boards during drier times is also less with narrower boards than it is with wide boards. A board width of 100 mm or less will limit potential gap size and other movement effects such as cupping (edges of the board higher or lower than the centre). If wider flooring is used then wider gapping can be expected and under certain conditions some cupping becomes more likely.

End-matching is a process where a T&G joint is provided at the ends of boards. The majority of flooring is now end-matched. For floors laid direct to joists or battens this allows joints to be placed between the joist or batten, resulting in less wastage than plain end flooring, which must have its ends fixed over the joist or batten.



Plain End



End-matched

Floor lengths

Flooring is generally supplied in random length packs up to 4.8 m in length. The average length is often between 1.8 m and 2.1 m. Packs of shorter overall length are also available from some suppliers to facilitate floors in high-rise buildings that require product to be taken to the appropriate floor by lift. The minimum length for timber being fixed to joists is 900 mm, based on a 450 mm joist spacing. In some instances, if it is known that the floor will be laid over a structural sub-floor, then lengths shorter than 900 mm may be provided.

Ordering flooring

When ordering timber flooring, the following details should be provided to the timber supplier:

- species (or species mix)
- grade
- profile and end-joint type
- cover width
- thickness
- quantity (in linear metres)

Flooring is generally supplied within the moisture content range from 9% to 14%. For larger jobs in specific environments a different range may be specified.

To calculate the linear metres of flooring required, the following method is recommended:

$$\text{Total length of flooring required} = \frac{\text{Area of floor (m}^2\text{)} \times 1000}{\text{Cover width (mm)}} + \text{Wastage}$$

Allowance for waste should be approximately 5% for end-matched flooring and 10% for plain end butt-jointed flooring.

1.3 Floors Over Different Sub-Floors

Depending on the T&G sub-floor supporting system (e.g. joists, plywood on slab etc), timber floors will both feel and sound differently when walked on. Generally T&G timber floors laid over joists or battens will have more spring under foot and there is likely to be some vertical movement at board edges and end-matched joints when walked on. Some squeaks can therefore be expected from most timber floors of this type. Squeaks can occur from movement of one board edge against another or from boards moving on nails. Squeaks are often more prevalent during drier weather due to loosening at the joints. Floors that are laid over plywood on a slab will have a firmer feel underfoot and some areas may sound drummy. Similarly, when floors are glued directly to concrete the feel is firmer, and again some boards may sound 'drummy' when walked on.

In cooler climates, slab heating may be present. Due to the direct heating effect on the timber and intermittent use throughout the year, substantial seasonal movement can be expected. Although strip flooring can be used, if care is taken with appropriate product selection and installation practices (refer to Appendix E – Underfloor Heating), it may be preferable to use engineered timber flooring products where less dimensional changes would be expected. Even with these products care is still necessary.

1.4 Floor Finish Types and Characteristics

Timber floor finishes can be grouped into four main categories: penetrating oils and waxes, curing oils and alkyds, oil modified urethanes, and polyurethanes. The latter three categories are available in solventborne and waterborne. The polyurethanes are also available in yellowing (aromatic) and non-yellowing (aliphatic) types. All four categories are available in low to high VOC – volatile organic (solvent) content. Gloss level options can range from very high gloss to matt.

Performance parameters such as durability can vary significantly within a category as well as between categories. All categories can be recoated with refurbishment coats. The degree of surface preparation required prior to recoating will vary with time and coating type.

Penetrating oils and waxes

These are blends of natural oils and waxes with added chemical salt 'driers'. They are dissolved into spirit type solvents, with some of the very low volatility ones meeting the Green Building Council of Australia guidelines of 140 g/L VOC emission. This coating type can have high maintenance requirements necessitating regular application of metalised acrylic polishes.

However, it is the natural look of the coated timber that is often the basis of selection. These types of coatings will darken significantly on ageing and are slow to cure in cold weather. Currently they do not form a large part of the floor finish market.

Oil-based finishes – curing oils and alkyds

Curing oils such as 'tung' or 'linseed', dissolved in mineral turpentine or white spirits, contain added chemical curing agents called metal driers. They are usually selected because they are low cost, have good edge bonding resistance and produce a rich timber colour. They can be very slow curing in cold weather and darken significantly with age. Some types can also yellow in the dark or when covered. Durability is low compared to the other coating types and they require frequent maintenance with use of metalised acrylic polishes. Gloss levels vary from high gloss to satin and they have good edge bonding resistance.

Alkyds are produced from reacting curing oils with synthetic resin and dissolving into spirit-based solvents. This results in durability being improved from a low to a moderate level. Maintenance requirements are considered to be of a medium level. Again, this is a lower-cost option when compared to the more durable options following, providing good edge bonding resistance and a rich timber colour. These more traditional types of finishes are not as commonly used as those outlined below.

Oil modified urethanes (OMUs)

These spirit-based solventborne coatings combine an oil with a smaller amount of a urethane. The higher the urethane proportion, the less the oil properties, such as higher flexibility and resistance to edge bonding. Conversely, the higher the urethane content, the higher the durability and the less the flexibility. Gloss levels vary from high gloss to satin. In recent times, waterborne OMUs have appeared on the market. Although of higher cost than the solventborne, the waterborne OMUs have the advantage of low VOC emissions.

All OMUs yellow significantly with age and their slow curing in cold weather must be considered. These coatings are often selected due to their intermediate cost, being isocyanate free, having good edge bonding resistance and being of intermediate durability.

Essentially they represent a coating that is reasonably durable and generally free from potential concerns such as edge bonding. They hold a moderate share of the market.

Polyurethane – solventborne

This coating type provides the highest durability and film build (% solids) of all coating types as well as the highest gloss levels for the gloss options. However, there is a strong solvent smell on application and they are also of highest toxicity (isocyanate content) until the coating has cured. This is more so with two pack than the one pack moisture cure (MC) variety. With the correct use of personal protective equipment this aspect is not considered an issue. There are yellowing (aromatic) and non-yellowing (aliphatic) varieties, with further options of high solids, and gloss levels from ultra high gloss to matt.

These coatings are often selected as they provide the best wear resistance or durability, resulting in lower maintenance. They can be used with fast dry sealers, provide the highest gloss and film build option, are of intermediate cost and generally provide trouble-free application. They do, however, have poorer edge bonding resistance. This type of finish is common in Australia.



Oil modified urethane.



Single pack solvent-based polyurethane.

Polyurethane – waterborne

This has the widest selection of sub-categories with acrylic – polyurethane blends, co-polymer urethane acrylates, 100% polyurethane resins, both yellowing and non-yellowing types, and blends of all the previous, with and without wax or silicone wear additives. As a result, there is a spread of properties including wear resistance from poor to arguably as good as solventborne polyurethane. Greater care is necessary in selection. Those without acrylic provide better wear resistance. They are available in one and two pack options, the latter utilising either a lower toxicity hardener or a more toxic crosslinker, which is a consideration at the time of mixing. Matt through to gloss finishes are available and these finishes generally darken less with time.

These coatings are often selected as a healthier option for both contractor and occupier due to the absence of any strong solvent smells on application.

They provide good edge bonding resistance. However, they have the highest product cost, can provide a lighter timber appearance depending on the sealer and products used, and have a higher chance of tannin stain application marks. Rapid shrinkage in the floor and the associated stretching of the finish at board joints has, on occasions, caused the appearance of light-coloured lines at board joints. These finishes have developed significantly over recent years and their market share is moderate and increasing.



Waterborne polyurethane applied.

The following table outlines the types of finish available and lists various properties of each.

Table 1.2: Timber Floor Coatings Selection Chart.

Property	Penetrating oil / wax	Oil based finishes	OMU	Polyurethane			
				Solventborne	Waterborne	1 pack	2 pack
Wear resistance	Low	Low-Med	Medium	Very High	Very High	Med-High	Med-VH
Ability of the floor to accept careful foot traffic 3 days after coating. (Av. temp. 20°C)	Low	Low	Medium	Medium	High	Medium	High
Timber colour 'richness'	Low-High	High	High	High	High	Low-Med	Low-Med
Resistance of the coating to yellowing with age	Low	Low	Low	Low-High	Low-High	Med-High	Med-High
Ability to cure in cold/dry weather	Low	Low	Medium	Medium	High	Medium	High
Ability to cure in cold and damp weather	Low	Low	Low	Medium	High	Low	Low
Edge bonding resistance	High	High	Med-High	Low-Med	Low	High	Med-High
Rejection resistance	High	Medium	Medium	Low-Med	Low-Med	Medium	Medium
VOC emission at application	Low-High	High	Med-High	High	High	Low	Low-Med
Inhalation hazard when coating is applied	Low	Medium	Medium	High	Very High	Low-Med	
Odour on application	Low-Med	Medium	Medium	High	Very High	Low	Low-Med
General product cost	Med-High	Low-Med	Medium	Medium	Medium	High	Very High

2

Pre-Installation Requirements

2.1 Storage and Handling Procedures

Flooring should be delivered by the supplier with plastic wrapping (top, sides and ends) in good condition in order to maintain the flooring at the appropriate moisture content. It is the floor installer's responsibility to check that the timber is at the appropriate moisture content at the time of installation, so flooring products must be protected from weather exposure and other sources of dampness.

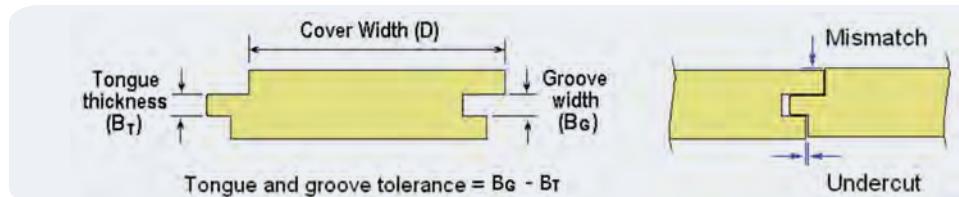
Ideally, delivery during rain should be avoided and flooring should not be delivered to the site until it can be immediately stored under permanent cover. If this is not achievable, other precautions that are equally effective to prevent moisture uptake and excessive sun exposure will be needed.

Plastic wrapping is easily damaged and should not be relied upon to keep the flooring dry. If moisture penetrates the plastic or timber is stored over a moist surface, subsequent moisture uptake can result in significant swelling of some boards. Flooring should not be laid in this condition, as wide gaps at board edges may result as boards re-dry. Wrapped packs should also be protected from excessive sun exposure as this too can have a detrimental effect.

2.2 Timber Flooring Standards and Specifications

When timber flooring is received on site it should generally meet the following requirements:

- Grade – flooring to be supplied to the specified grade, which may be a manufacturer's grade. Note that if a manufacturer has given a specific name to a grade, the product may be similar to one of the grades contained within an Australian Standard but it is likely to differ in some respects. This may or may not be important to customers and should be resolved prior to supply.
- Moisture content – should be in the range of 9% to 14% (10 to 15% for Cypress) with the average moisture content for all pieces approximately 11% (12% for Cypress).
- Timber moisture contents should be checked. (Resistance moisture meter readings must be corrected for species and temperature, and may be affected by other factors. Corrected readings are approximate only. If in doubt confirm results by oven-dry tests.) Water marks or a significant variation in cover width within a board may indicate that the timber has been moisture affected.
- Cover width – not more than 1 mm difference between one board and another. Cover widths should generally be within ± 0.5 mm of the nominal cover width. (If in excess of this, it can reflect changes to board dimensions that can occur after milling and prior to installation, and therefore be outside the limits of Australian Standards).
- Boards should not be visibly cupped – Australian Standards allow 1 mm per 100 mm of board width.
- Tongue and groove tolerance – not less than 0.3 mm nor greater than 0.6 mm. Boards should slot together to form a 'snug' fit. The fit should not be loose and sloppy or overly tight.
- Undercut or relief – the difference between the upper and lower cover width of the boards. Generally, an undercut of about 0.5 mm is appropriate for an 80 mm wide board and a little more as board width increases. If the undercut is large and there is significant expansion pressure after installation, 'peaking' (pressure-related cupping) can occur. The smaller the undercut, the less the effect.



Grading rules for solid T&G strip flooring are contained in the following Australian Standards:

AS 2796 – Timber – Hardwood – Sawn and milled products

AS 1810 – Timber – Seasoned Cypress pine – Milled products

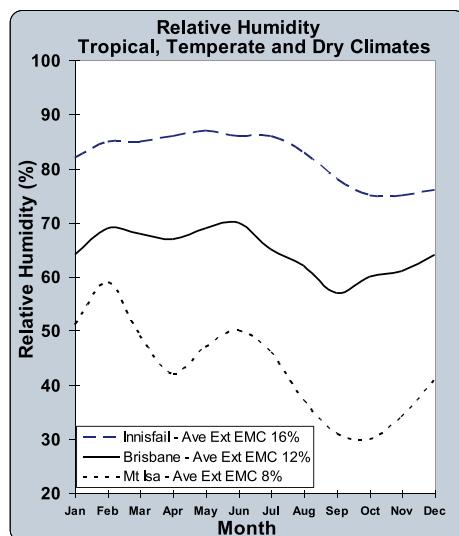
AS 4785 – Timber Softwood – Sawn and milled products

Any concerns relating to these specifications should be addressed prior to laying the floor.

2.3 Evaluating Site Conditions and the Installation Environment

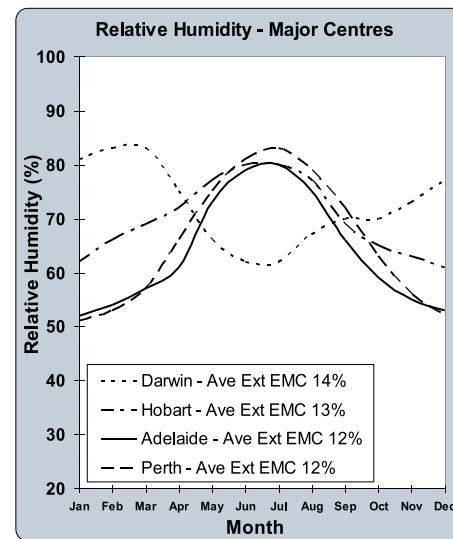
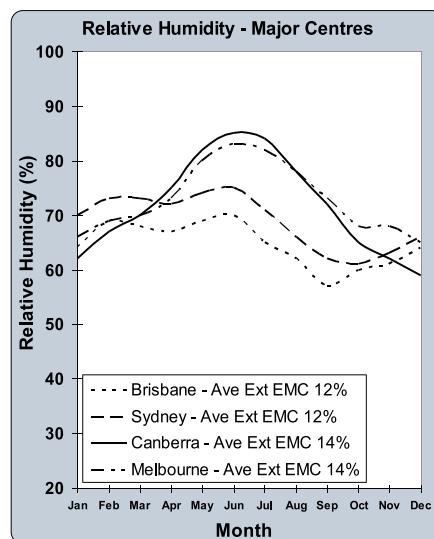
Evaluating site conditions

Every site requires assessment prior to the installation of a timber floor. It is important to know the climate in the area where a floor is being laid. Relative humidity is the major influence determining whether timber flooring will absorb moisture from the air and swell, or lose moisture to the air and shrink. If the moisture content of the timber flooring is close to the average in-service moisture content, subsequent seasonal changes in humidity will only result in small changes in moisture content. The climate can be assessed from 9 am relative humidity data available from the Australian Bureau of Meteorology website at www.bom.gov.au/climate/averages. The figure below shows annual relative humidity charts associated with a tropical climate, temperate climate and a dry inland climate. Approximate average external equilibrium moisture contents (EMC) are also provided on the graph for each climate. Equilibrium moisture content can be thought of as the moisture content that timber will approach under set conditions of relative humidity and temperature. It is evident from these graphs that the climate may result in moisture contents that can be either higher or lower than the average moisture content of the flooring that has been supplied.



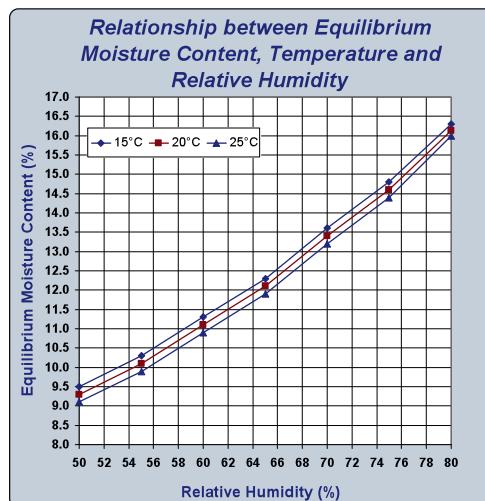
Climatic effects on timber floors – these must be considered when laying a floor.

Relative humidity graphs for the major capitals throughout Australia are provided in the figures below. Seasonal variation about the average can be seen to be greater in some locations than others. For example, the seasonal variation in Sydney is much lower than Melbourne. Where there are greater seasonal variations, greater seasonal movement (shrinkage and swelling) can also be expected.



Major centre climates and external EMCs.

Timber flooring is generally manufactured to suit temperate climates with average external EMCs of 12% to 14%. To provide assistance in assessing climatic influences the following figure outlines the general relationship between temperature, relative humidity and moisture content. Average internal EMCs are generally lower than external by 1% to 2% without heating or cooling systems operating and can be 4% to 5% lower for the periods when such systems are operating. Therefore, in climates that have cold winters, heating systems often lower the humidity within the dwelling and reduce the effect of high external humidity on the floor. Similarly, in tropical locations air-conditioning can reduce the effect of high external humidity on the floor. Installation and finishing practices need to accommodate climatic conditions associated with a locality and the seasonal movement that will occur in that climate.



Relationship between temperature, relative humidity and EMC.

Floors in moist environments

In areas of higher elevation than coastal areas, average moisture contents are often higher due to the associated local weather patterns. Similarly, houses built in bushy surroundings or gullies may experience higher average moisture contents. Moister conditions are also often experienced with houses on farmland or in rural settings particularly in coastal and hinterland areas experiencing higher or more consistent rainfall. In these areas, greater allowance for floor expansion is required at the time of installation.



Higher levels of expansion are experienced in moist localities and must be accommodated.

Building and installation considerations

Closed in sub-floor space

Many dwellings are 'bricked in' underneath and a lack of sufficient ventilation can result in high humidities in the sub-floor space. This may result in expansion and cupping of floorboards. Quoted figures for sub-floor ventilation are based on sub-floor spaces that are not subjected to seepage or where ventilation through the sub-floor space is inhibited. Where humidity remains constantly high beneath a floor, coatings to the underside of the boards will not reduce the moisture uptake into the flooring. Bushy surroundings and dense gardens may also cause higher moisture contents and reduced airflow through the sub-floor space.

Houses with open sub-floors

Special precautions must be taken when timber floors are laid on joists in a house that is open underneath, particularly when built on steeply sloping land or escarpments. In such locations, very dry winds or wind-blown rain or fog can directly affect the moisture condition of the lower surface of the floor. This can result in either extreme shrinkage or extreme swelling. In the latter case, the floor may lift off the joists and structural damage to the building may occur. Also, where there is little restriction to the prevailing wind, floors can react more rapidly to dry winds. The species used in the floor and board cover width affect the rate of movement and shrinkage. Depending on the severity of the exposure, options to protect the floor include providing an oil-based sealer to the underside of the floor, which may provide short duration protection to changes in weather, and installing a vapour-resistant lining to the underside of the joists or building-in the underfloor space.

Internal environment

Within a dwelling, a number of differing climates can develop, causing areas of flooring to respond differently within the same dwelling. The climate is influenced by large expanses of glass, fireplaces, refrigerators, air-conditioners, appliances that vent warm air, the aspect of the house and two-storey construction, all of which can affect the dimensional movement of floorboards. When floors are exposed to the sun through large glassed areas, protection should be considered before, during and after construction. Evaporative coolers add moisture to the air and raise the relative humidity, and can result in higher moisture contents in the flooring.



A dry sub-floor space and adequate ventilation is essential for good floor performance.



Greater localised shrinkage and possibly some cupping can be expected with high sun exposure.

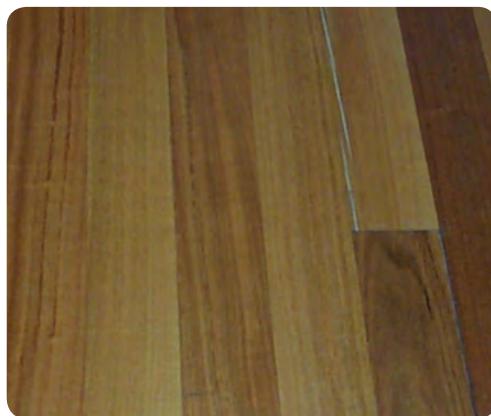
Araucaria (Hoop Pine) flooring and Araucaria floor framing

Where Araucaria floors and floor framing are not fully enclosed it is necessary to seal the framing members and lower surface of the floorboards to prevent attack from the Queensland Pine Beetle. Attack is specific to the Araucaria species (including Bunya) and generally restricted to the area from Bundaberg to Murwillumbah and east of the Great Dividing Range. In this region, exposed framing and floors (including ventilated sub-floor spaces) require sealing to meet BCA requirements. The sealer needs to have a film-forming finish, which may also reduce the effects of rapid weather changes.

2.4 Considering the Likely Movement After Installation

As discussed, timber is a natural product that responds to changes in weather conditions. Seasonal humidity and temperature changes in the air cause boards to shrink and swell at different times throughout the year.

The overall movement in individual boards and rate of movement will depend on the timber species and cutting pattern. Small differences in moisture content between boards at the time of manufacture (a 5% range is normally allowed by applicable standards) and variable conditions within the house (e.g. a west-facing room compared to south facing) will also cause further variation in board width. Consequently, small gaps can be expected at the edges of most boards, particularly during the drier months, and the actual gap sizes may differ across a floor. In cases where shrinkage occurs after installation, wider boards (e.g. 130 mm) will result in larger gaps at board edges than narrower boards. Air-conditioning installed after a floor has been laid may increase the size of shrinkage gaps at board edges.



Edge bonding can result in wide irregularly-spaced gaps at board edges and split boards within the floor.

Some movement usually occurs in timber floors after laying as the floor adjusts to the climate. Although floor finishes may retard moisture content changes, they will not prevent this movement. In applications where greater movement is expected after finishing (e.g. from seasonal changes, use of wide boards, air-conditioning installed after floor installation), particular care is necessary to ensure that the finish does not act as an adhesive and bond a number of adjacent boards together. With subsequent shrinkage, wide gaps between groups of four or five boards may occur or boards may split.

The way different timber species respond in a floor depends not only on their moisture content but also on the rate at which they take up and lose moisture, the associated movement and their density. High-density species are extremely strong and those that take up or lose moisture more quickly (such as Blackbutt) will also follow seasonal moisture changes more closely than slower responding species (such as Spotted Gum). Particular care is necessary to accommodate expansion of the higher-density species. In moist localities this may necessitate providing small expansion gaps every 6 to 10 boards during installation, in addition to normal expansion allowances. Lower-density hardwoods (e.g. Tasmanian Oak, Victorian Ash) and softwoods will, to some extent, compress at their edges when a floor expands. With these timbers, normal expansion allowance is generally able to accommodate the expansion in moist climates.

2.5 Installation Moisture Content and Acclimatisation

The moisture content of timber is the percentage weight of water in the timber compared to the weight of timber with all water removed. Moisture content varies with changes in the humidity and temperature in the surrounding air. To minimise the movement of a floor (swelling on moisture uptake, shrinkage on moisture loss) it is important to lay and fix timber floors close to the average moisture content of timber in the environment where it is to be laid. Along coastal areas, where higher humidities can be expected, moisture contents of flooring may vary from 9% to 14%. Timber flooring is usually supplied at an average moisture content between 10% and 12.5% and most boards can be expected to be within a few per cent of the average. Where conditions are drier, such as inland areas or in air-conditioned buildings, average moisture contents of flooring may vary from 7% to 12%. In these situations, flooring may need to be acclimatised on-site.

Where the average supplied moisture content of the flooring is near the expected average in-service moisture content, acclimatisation is not necessary.

In areas where higher average moisture conditions persist and where floors are expected to have higher moisture contents, additional allowance should be made for subsequent expansion. Such areas include tropical north Queensland and northern New South Wales and areas of dense bushland and rainforest, particularly at higher elevations and mountain areas.

Installation methods to be considered include either providing additional intermediate expansion joints or acclimatising the flooring.

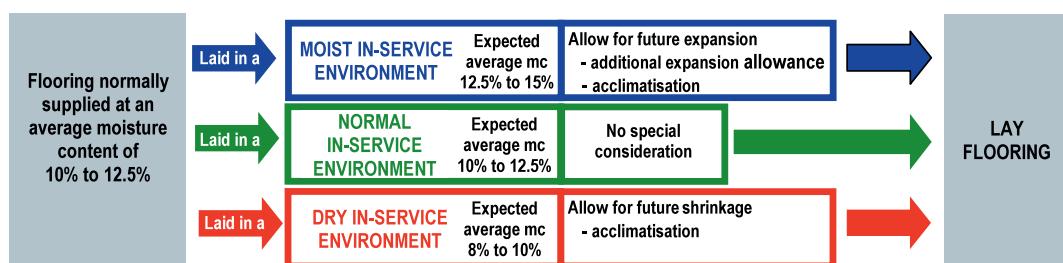
Acclimatising is the process of allowing partial equalisation of the moisture content of the timber as supplied to that of the surroundings in which the timber is to be installed. Increasing the average moisture content will only be effective if the humidity in the air is sufficient to cause moisture uptake. The rate of moisture uptake differs from species to species. Some higher-density species are very slow to take up moisture from the air (e.g. Spotted Gum) while others react more quickly (e.g. Blackbutt and Brush Box). If flooring is to be laid in a dry environment such as western New South Wales or a consistently air-conditioned building, then acclimatising can be effective in reducing the average moisture content of the flooring prior to laying and thereby reducing gap sizes at board edges from board shrinkage. In such climates, future expansion of the floor must be allowed for to accommodate periods of wet weather.



Acclimatisation can be effective if product moisture content and in-service conditions are known.

Acclimatising relies on each board being exposed to the in-service atmosphere so packs must at least be opened up and restacked in a way that allows airflow between each board. Acclimatising can only be effective in an air-conditioned building if the air-conditioning is operating at the time or in dry localities during drier periods. The species and period for which it is acclimatised will also influence effectiveness. For some higher-density species that are slow to lose or take up moisture, acclimatising may have little effect. Acclimatising in dry climates does not negate the need to provide for floor expansion during periods of wet weather and will not overcome poor drying practices.

A simple guide to pre-installation considerations is provided in the figure below which should be referred to in conjunction with the preceding text.



3

Installation to Timber and Sheet Sub-Floors

This section outlines the recommended practices for laying timber strip floors over timber and engineered timber joists (it does not include steel joists), structural sub-floors such as plywood, particleboard and over concrete, but does not include direct adhesive fix to slabs (refer to Section 4).

When laying a timber strip floor over joists, either directly on the joists or on sheet flooring fixed to joists, adequate sub-floor ventilation is essential for the satisfactory performance of the floor. Sub-floor ventilation recommendations are therefore included in this section.

3.1 Sub-Floor Ventilation

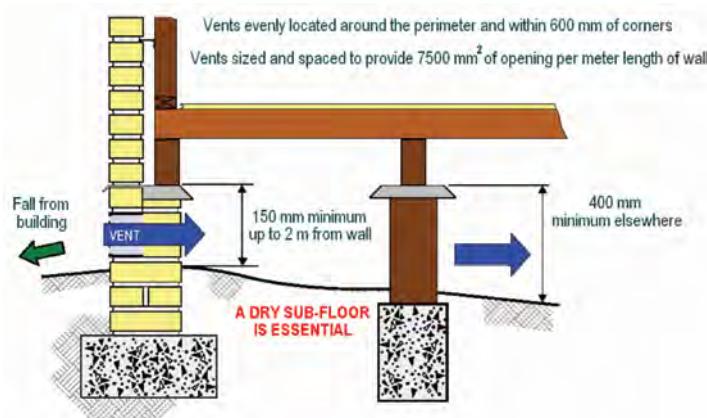
When the lower surface of timber floors or structural sub-floors (over which a timber floor is laid) are exposed to the ground and the space is enclosed (by brickwork etc), the sub-floor space must be adequately ventilated with permanent vents installed in the masonry during construction. The humidity in an enclosed sub-floor space can have a profound effect on the performance of a floor. If conditions are very moist, the lower surface of the boards may take up moisture, causing substantial swelling. Differential movement between the upper and lower surfaces of floorboards may also cause boards to cup. Similarly, caution needs to be exercised with timber floors laid in areas where the microclimate is often moist. In such locations the floor may reach higher moisture contents than in other nearby areas and additional allowance for expansion of the floor may be required (Refer Section 2 – Pre-installation Requirements). Timber floors should not be laid over moist sub-floor spaces, and structural sub-floors (e.g. plywood) cannot be relied upon to prevent moisture uptake in the T&G flooring if humidities in the sub-floor space remain high for extended periods.



Adequate sub-floor ventilation and a dry sub-floor space are a must for timber floor performance.

Ventilation requirements

T&G floors should be provided with sub-floor ventilation that exceeds minimum Building Code of Australia (BCA) requirements. The BCA levels (currently limited to 6000 mm² per metre length of wall for higher humidity areas) are primarily to limit the moisture content of sub-floor framing timbers, which can generally tolerate greater fluctuations in moisture content, than timber floors. The recommended minimum ventilation for T&G timber floors is 7500 mm² per metre length of wall, with vents evenly spaced to ensure that cross ventilation is provided to all sub-floor areas (see figure below).



In some localities, to meet constraints associated with energy efficiency, it may be decided to reduce ventilation levels to the values provided in the BCA. The BCA also outlines that a moisture barrier over the soil beneath the building reduces ventilation requirements and this approach is equally applicable to timber floors. If ventilation is below the recommended level, due consideration should be given to alternative measures as outlined above. Particular attention should be paid to ensuring that the sub-floor space remains dry throughout all seasons. The type of vent may also need to be considered as in bushfire areas the mesh size used in vents is limited. Some commercially available vents of various types, their dimensions, net ventilation area and required spacing for coastal Zone 3 is provided below. BCA relative humidity zones and associated BCA ventilation requirements are also provided below. The maximum vent spacing irrespective of net ventilation area is 2 m and any screens that may be necessary in bushfire areas or for vermin proofing may restrict airflow and this may need to be compensated for.

Vent Type and Specifications				Nett Ventilation Area Provided per Vent (mm ²)	Maximum Vent Spacing (mm)	
Material	Diagram	Vent size	Vent Pattern		ZONE 3 BCA Requirements (6000mm ² /m) No-membrane	T&G Flooring Requirements (7500mm ² /m)
Clay		160 x 230	8 slots each 75 mm x 8 mm	4800	800	640
Clay		160 x 230	15 holes each 16 mm x 16 mm	3840	640	512
Metal		200 x 400	8 slots 10 slots each 100 mm x 8 mm	5900 7400	983 1233	787 987
Metal		200 x 400	8 slots 10 slots each 175 mm x 8 mm	10700 13360	1783 2000	1427 1781
Besser Louvre Block 15.745		200 x 400	1 slot each 320 mm x 90 mm	28800	2000	2000
Gradwell Cast Aluminium Air Vent		9" x 6" (230 x 160)	4 slots each 195 mm x 10 mm	7800	1300	1040
Pryda Vent Pryda Vent		230 x 75 230 x 165	52 holes 117 holes each 11 mm x 11 mm	6292 14157	1049 2360	839 1888
Pryda Slim Vent (GVS90) Pryda Slim Vent (GVS90H)		250 x 90 130 x 90	12 slots 6 slots each 110 mm x 8 mm	10560 5280	1760 880	1408 704

Ventilation efficiency and site drainage

The sub-floor space must be free from all building debris and vegetation. Obstacles that prevent airflow to and from vents will reduce the efficiency of the sub-floor ventilation system. Landscaping around the external perimeter of the sub-floor space and structural elements should not limit airflow. Vents should be installed in the masonry course below floor bearers, and should not be obscured by engaged piers or piers/stumps/columns, or by any services. Where external structures (fences, etc) or landscape may reduce airflow, consideration should be given to the use of more than the minimum number of vents.

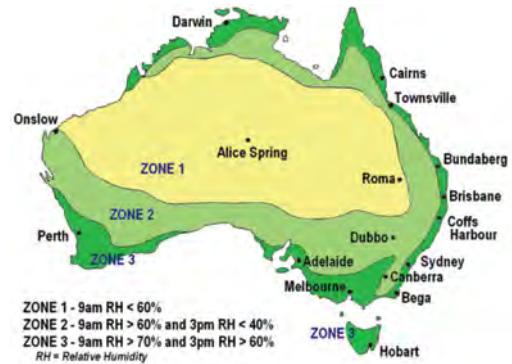
Where verandahs or decks are constructed outside the dwelling perimeter, care should be taken to ensure that the amount of ventilation provided around the verandah or deck perimeter is equivalent to or greater than the amount required for the adjacent external wall. Where ventilation is obstructed by patios, etc, additional ventilation should be provided to ensure that the overall level of ventilation is maintained and cross flow is achieved.

If adequate natural ventilation cannot be provided to sub-floor spaces, a mechanical ventilation system should be installed which replaces all the air in this space on a regular basis and prevents the formation of 'dead-air' pockets.

If there are doubts over the sub-floor humidity (areas of high water table, reduced airflow due to minimum clearances between the sub-floor framing and ground, external structures, etc) again a polyethylene membrane laid over the soil should be considered (taped at joints and fixed to stumps and walls). As discussed above, this can significantly reduce moisture uptake by the sub-floor air. Increased levels of ventilation should also be considered in such instances. With dwellings on sloping blocks that have enclosed sub-floor spaces, the possibility of seepage should be taken into consideration and appropriate control measures taken prior to the installation of the floor.

The drainage system provided to the dwelling site, should ensure that run-off water will drain away from the building perimeter (not towards it) and that run-off water is prevented from entering the sub-floor space. The ground beneath a suspended floor should also be graded so that no ponding is possible. Where springs or aquifers are present (e.g. exposed by earthworks on sloping sites) and cause water to enter the sub-floor space, a closed drainage system should be installed under the dwelling to remove this water. The ventilation system will not cope with this level of moisture in the sub-floor space.

BCA Sub-floor Ventilation Requirements		Min. Sub-Floor Ventilation mm ² /m of wall	
CLIMATE ZONE, CONDITIONS & SELECTED LOCATIONS		No membrane	Ground sealed with impervious membrane
1	Average 9am RH < 60%	2000	1000
2	Average 9am RH > 60% and 3pm RH < 40%	4000	2000
3	Average 9am RH > 70% and 3pm RH < 60%	6000	3000



3.2 Assessing Fixing Requirements

Due to climatic differences the fixing requirements of the floor need to be carefully assessed. Applicable fixing requirements differ to some degree between states and between locations within each state.

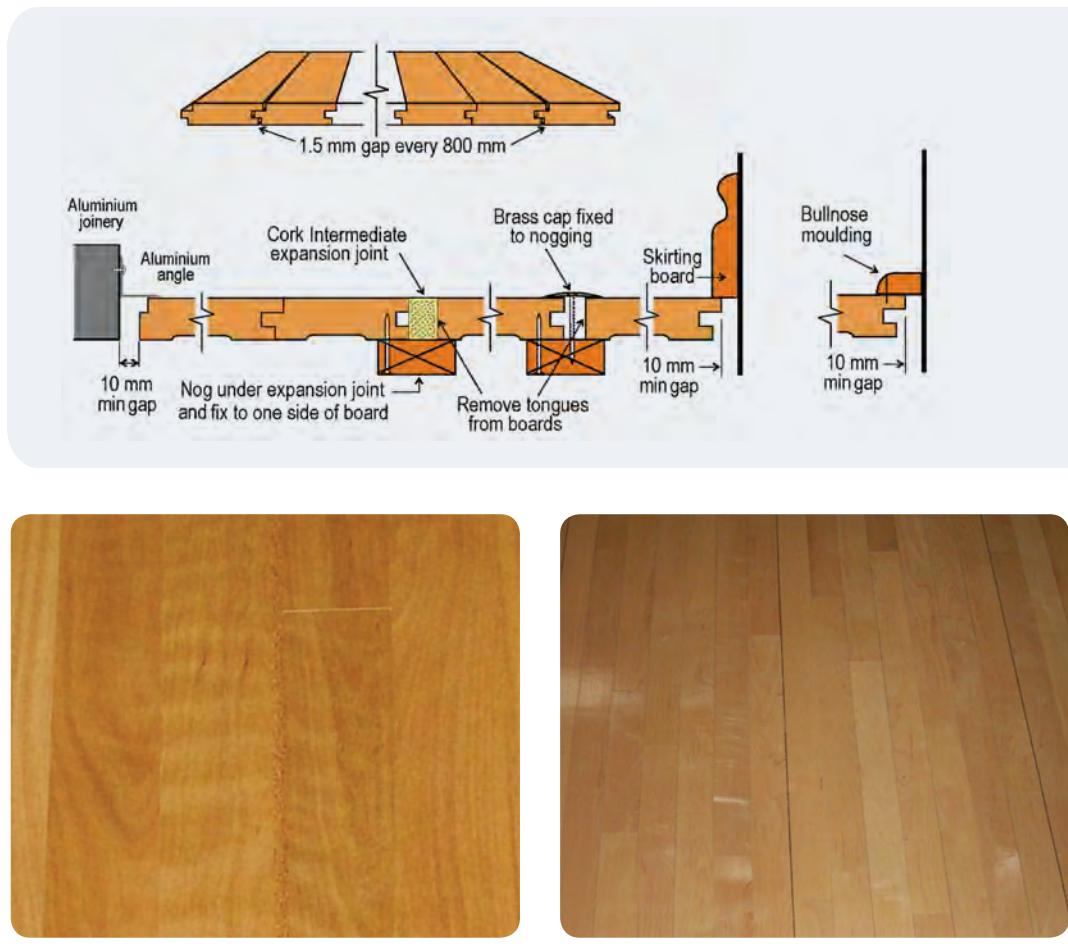
Top (face) nailing is a more robust fixing method than, say, floors secretly fixed with beads of adhesive. Top (face) nailed floors can accommodate greater movement and expansion pressure without buckling. Increasing the amount of adhesive used will also provide a more robust fixing and some installers elect to bond the floor with a full bed of adhesive. Where greater floor expansion is expected after installation, consider the method of fixing chosen and associated spacing of fixings or amount of adhesive. A full bed of adhesive in humid localities will limit floor expansion but can also contribute to higher pressure at board edges making the floor more prone to peaking, resulting in a cupped appearance and at times tenting of boards (refer to Appendix G – Troubleshooting Guide for explanation of terms).

It should also be noted that the specified recommendations in this manual are generic in nature and, although frequently used, installers with knowledge and experience in a particular locality may fix a floor in a manner that differs from that outlined here. There are also an increasing number of flooring manufacturers who are producing specific products with accompanying installation instructions and such instructions should be strictly followed. This includes wider thin overlay boards and standard profile flooring for secret fixing. Other manufacturers recommend that standard profile flooring should not be secretly fixed. It should be recognised that specific manufacturing methods may apply to certain products, similar looking products of different manufacture may not perform equivalently even with the same fixing method.

The installation methods covered by this manual are used extensively by many installers throughout Australia and form the basis for the industry's recommendations.

3.3 Allowance for Expansion in Floors

Fitted floors require a minimum 10 mm expansion gap between the floor boards and any internal or external wall structures. However, where board ends abut doorways, the gap may be reduced to a neat fit but with a small gap (approximately 1 mm) to prevent rubbing. Floors up to 6 m wide (measured at right angles to the run of boards) should not require intermediate expansion joints provided that it is a normal in-service environment (refer to figure below). For floor widths over 6 m or where extra allowance for expansion is required (e.g. moist locations) cramping pressure needs to be considered as well as providing an intermediate expansion joint or a series of smaller expansion gaps every 800 mm to 1000 mm to provide equivalent spacing. If cork expansion joints are used, the cork should be 2 mm or so proud of the floor surface when installed. This will be removed during the sanding process. Cork to the perimeter should be installed level with the timber surface. It should be noted that cork to aluminium door joinery can cause the joinery to bow under floor expansion and an aluminum angle as shown in the diagram below overcomes this. This angle may also be inverted and adhesive fixed to the aluminium joinery. Alternatively, a small timber bullnose moulding on flat fixed to the flooring can be used.



Cork intermediate expansion joints blend in well with timber floors.

Particularly for wide floors or in moist climates small regular gaps can be used to provide the additional expansion allowance needed. These often close during humid periods.

3.4 Floor Laying Practices

The moisture content, size and profile of the flooring should be checked (Section 2 – Pre-installation assessment) prior to laying. If the moisture content is not correct or the boards do not fit together properly, or are otherwise considered to not meet the specified grade, the installer should contact the supplier to resolve these issues before commencing laying. Similarly, any board found during laying that is considered outside the grade specification should not be laid.

Top (face) nailing is to be undertaken uniformly with respect to edge distances and alignment across the floor. Some variation due to batten and joist layout may occur.

When laying over a structural sub-floor such as plywood or particleboard it is important that the fixing is adequate. In moderately humid locations it has been found that nail and adhesive fixed sheet flooring has in some instances buckled off the joists, even when fixed in accordance with the relevant nailing requirements of Australian standards. Screw fixing to the joists as often used provides for a more robust fixing.

When laying over sheet flooring or an existing floor, boards should be staggered to provide the look of a floor similar to that laid over joists. It is good practice to ensure that end joints are at least 450 mm apart and that joints do not cluster together or align. For aesthetic reasons, close alignment of end joints in adjacent boards should generally be avoided.

Installers should consider how the boards will be distributed in the floor in terms of length, grade, feature and colour, irrespective of whether this is on joists or other sub-floor. As such it may be necessary to lay from more than one pack at a time so that the colour range and grade features can be blended through the floor.

3.5 Installation of Strip Flooring Direct to Joists

Construction method

Where the timber floor is to be sanded and polished (i.e. feature floor) fitted floor construction needs to be used. With this method, the timber flooring is installed after the roof cladding and external wall cladding are in place and the house is weather tight. This prevents initial degrading due to water and sunlight exposure, and reduces damage from trades during construction.

Sub-floor framing – bearer size, floor joist size and flooring spans

The size of timber members used to support the flooring boards can be determined from AS 1684 – Residential timber-framed construction. For end-matched flooring profiles, joists with a minimum thickness of 35 mm may be used. Where plain end flooring is butt joined at floor joists, 45 mm or 50 mm thick joists are recommended to reduce splitting problems at butt ends.



Adequate sub-floor ventilation and a dry sub-floor space are a must for timber floor performance.

If installing a secretly nailed floor over joists, the joists need to be seasoned timber or Cypress as secret nailing cannot be re-punched. If the joists shrink away from the floor, movement of boards on the fixings is likely to cause excessive squeaking.

Top (face) nailed floors may be fixed into either seasoned or unseasoned joists. If fixed into unseasoned joists, the joists need to be of a species not exhibiting high rates of shrinkage and be in single or similar species. Species exhibiting high tangential shrinkage rates or which are prone to collapse or distortion should not be used unless seasoned. The potential effects of floor frame shrinkage require assessment prior to specifying or ordering unseasoned floor framing, and due allowance made in the building design and detailing. Similarly, after installation, the effects of both shrinkage and possible nail popping need consideration.

The top plane of the joists must be sufficiently flat to accept the timber floor and to provide a finished floor appearance that also appears flat.

The allowable span of timber flooring is dependent on the timber species, density, grade, thickness and whether or not the flooring is end matched. The following table gives the acceptable joist spacing and maximum spans for various flooring products when fixed to timber joists. Maximum board span (the distance between where the timber is supported) needs to be considered in installations where flooring is at an angle to the joists, as this increases the board spans.

Allowable Joist Spacing and Maximum Span of Floorboards.

Species Group	Grade	Thickness (mm)	Acceptable Species, Grade and Joist Spacing			Maximum Span	
			450 mm End matched	450 mm Butt joined	600 mm Butt joined	End matched	Butt joined
Hardwood	AS 2796	19	✓	✓	✓	500 mm	630 mm
		19	✓	✓	✗	450 mm	570 mm
Cypress	AS 1810	19	✓	✓	✗	410 mm	510 mm
		20	✓	✓	✗	410 mm	510 mm
Softwood	AS 4785	19	✓	✓	✗	410 mm	510 mm
		19	✗	✓	✗	350 mm	470 mm
		20	✓	✓	✗	410 mm	510 mm

Installation direct to joists

In most instances, when laying over joists, boards are to be supported on at least three joists, however, there will be instances where some boards may not be (i.e. floor edges or the occasional shorter board within the floor), but this should be kept to a minimum. Flooring should be laid in straight and parallel lines. Butt joined boards must be cut to join over floor joists and joints in adjacent boards should be staggered. End-matched joints in adjacent boards should not occur within the same span between joists. It is essential that boards are in contact with the joists at the time of nailing, particularly when machine nailing is used, as this type of nailing cannot be relied on to pull the board down to the joist.

It is generally recommended that not more than 800 mm of flooring is cramped at any one time, however, this may be varied by the installer depending on the flooring used and conditions in which the floor is laid. The pressure used to cramp the boards together will differ from one floor to another, depending on the moisture content of the flooring at installation, the air humidity and the average moisture content conditions for the location. As a general rule, cramping should be sufficient to just bring the edges of adjoining boards together while maintaining a straight line.



Cramping should be sufficient to just bring the edges of adjoining boards together.

Top (face) nail and secret fixing direct to joists

Boards for top (face) nailing and cover widths of 65 mm or less should be top (face) nailed with one or two nails at each joist. Boards for top (face) nailing and a cover width over 65 mm and up to 135 mm wide should be top (face) nailed with two nails at each joist. Boards wider than 135 mm are often top (face) nailed with two or three nails.



Buckling of 80 mm wide Spotted Gum boards secretly fixed to pine joists in a humid locality.

Top (face) nailing is to be undertaken uniformly with respect to edge distances and alignment across the floor. Some variation due to joist layout may occur. Boards up to 85 mm wide can be secretly fixed with a staple or cleat at each joist and require a good coverage of flooring adhesive to the joist. In humid and moist localities, additional care is required to cater for possible greater expansion. Consideration should be given to board moisture contents, providing for expansion, the species, joist material and fixing method. In some locations, top (face) nailing will be the preferred option. Fixing sizes commonly used for 19 mm to 21 mm thick boards are provided in the following table.

TYPE OF FIXING	METHOD	JOIST TYPE	
		SOFTWOOD, LVL and I-BEAMS	HARDWOOD and CYPRESS
SECRET FIXING 19-21 mm thick boards	Machine driven	<ul style="list-style-type: none"> • 50 x 15 gauge staple or • 50 x 16 gauge cleat • and adhesive² to joist 	<ul style="list-style-type: none"> • 45 x 15 gauge staple or • 45 x 16 gauge cleat • and adhesive² to joist
TOP (face) FIXING 19-21 mm thick boards	Machine driven	<ul style="list-style-type: none"> • 50 x 2.2mm T – head or • 50 x 2.5 mm T – head • and adhesive² to joist 	<ul style="list-style-type: none"> • 50 x 2.2mm T – head or • 50 x 2.5 mm T – head • and adhesive² to joist
	Hand driven	<ul style="list-style-type: none"> • 50 x 2.8 mm bullet head and adhesive² to joist 	<ul style="list-style-type: none"> • 50 x 2.8 mm bullet head (adhesive² optional)

Notes:

1. Fixings may vary to some degree between locations due to installers' experience of local conditions.
2. A continuous bead (6 mm to 10 mm approx.) of flooring adhesive to be applied to the joist.

Recommended minimum edge distance for nailing at butt joints or board ends is 12 mm. All nails, including machine nails, should be punched at least 3 mm below the top surface. During fixing, the joint between floor boards and the top surface of floor joists should be checked to ensure that gaps are not present. If gaps are present, nails should be punched to draw boards tightly onto the joists.



It should be checked that boards are tight on the joists.



Secret fixing is recommended for boards up to 85 mm in cover width.

3.6 Installation of Strip Flooring over Existing Timber and Sheet Floors on Joists

Assessing the existing floor

Timber T&G flooring may be laid over an existing T&G floor or sheet floor (plywood or particleboard). Where the existing floor is structurally sound, either overlay flooring (generally 11 mm to 14 mm thick) or structural flooring (generally 19 to 21 mm thick) can be laid. Floors may be fixed through the sub-floor into the joists or into the existing floor only. Where there is doubt over the structural adequacy of the existing floor:

- remove the existing floor and use structural flooring laid at 90° to the joists, and fix into the joists;
- replace the defective boards or sheets to make the existing floor structurally sound (structural or overlay flooring may then be used); or
- if the existing floor is not made structurally sound, use structural flooring at 90° to the joists and fix through the existing floor and into the joists.

The new boards may be fixed at an angle (other than 90°) to the joists in the first two options above, provided that the thickness of the new boards is appropriate to the increased span between the joists (as a consequence of the angle).

Top (face) nails in existing flooring should be re-punched where necessary. The existing floor may need rough sanding to provide an appropriate surface over which the new floor is to be fixed.

Adhesives require a clean, structurally-sound floor that is free from surface moisture, loose particles and contaminants. In some instances sheet sub-floors (substrates) can sag between joists and if not levelled the sagging will show through to the new floor.

It is necessary to check that the existing floor moisture content is appropriate to accept the new floor. The cause of any excess moisture (wetting during construction, leaks, inadequate sub-floor ventilation, etc) needs to be addressed prior to installation of the new floor. Moisture meters are unpredictable in sheet flooring and this may necessitate oven dry testing. Prior to laying, the new floor should be of similar moisture content (within a few per cent) to the existing floor.

Squeaking present in an existing T&G floor may be reduced by providing a bead of flooring adhesive to fill any gaps between the underside of flooring and tops of joists (caused by cupping, shrinkage, etc). Further reductions may be achieved by fixing a seasoned batten (approximate dimensions 35 x 45 mm or 19 x 60 mm), to the underside of flooring (mid-span between joists) and parallel to the joists fixed with a full-length bead of flooring adhesive and screwed at approximately 450 to 600 mm centres to hold the batten in place until the adhesive is set.

Installation

The methods below are generally suitable for board widths up to 135 mm, both overlay and structural flooring.

The secret fixing of boards requires one staple or cleat at the appropriate spacing. For (top) face nailing of boards through the sub-floor and into the joists, two nails per board are required at each fixing for boards exceeding 65 mm cover width.

In humid and moist localities, additional care is required to cater for possible greater expansion. Consideration should be given to board moisture contents, providing for expansion, board size, the species and fixing method. In some locations top (face) nailing may be the preferred option or a full bed of adhesive used. Overlay flooring can be more reactive to changes in environmental conditions induced not only by conditions beneath the floor but also by sun exposure through large windows above the floor. Some manufacturers do not recommend that their 130 x 19 mm or wider boards be secretly fixed and other manufacturers have specific fixing recommendations providing for the secret fixing of wider flooring that should be strictly adhered to.

Installation of flooring should not proceed until other construction activities (particularly wet trades) are complete and until after the building is roofed and enclosed, with the temperature and humidity as close as possible to the expected in-service conditions. As detailed above, expansion gaps of 10 mm minimum should be provided at all walls and other fixed obstructions, which are parallel to the run of floorboards. Intermediate expansion joints should also be provided in larger floors (width at right angles to boards exceeding 6 metres), to give an equivalent gap of 10 mm every 6 metres (approx. 1.5 mm every 800 mm) or alternatively the boards should be loosely cramped.

Secret fixing into sub-floor (substrate) only

When relying on the sub-floor or substrate for fixing, boards should be secretly fixed with the first and last few boards that do not allow secret fixing, top (face) nailed. When laying over an existing T&G sub-floor the new flooring may be laid either parallel with the existing boards or at 90° to or at any other angle to the existing boards, providing the sub-floor (substrate) is within the required flatness tolerances. The fixing of the floor may be undertaken relying on a combination of mechanical and adhesive fixing.

When fixing boards with a maximum width of 85 mm at close centres up to 225 mm, beads of adhesive to provide a cushion between the two floors should be used to minimise possible squeaks. This is achieved by using a continuous bead of adhesive at 90° to board length, midway between fixing points. Where flooring adhesive is used to provide more of the fixing, staples or cleats may be spaced up to 450 mm apart with beads of adhesive at the fixing points and midway between.

With wider flooring up to 135 mm, a full bed of adhesive with fixings up to 300 mm apart is applicable. Due to the reliance on the adhesive to provide much of the fixing in this instance, it is important that the adhesive manufacturer's recommendations for using the adhesive are followed. Surface cleanliness, flatness provisions and spread rate are all important. Further information on adhesives is provided in Section 4.

For 19 mm thick flooring staples for boards up to 85 mm wide should be a minimum of 32 x 15 gauge and cleats should be a minimum of 32 x 18 gauge. For wider boards to 135 mm x 19 mm, 38 mm x 15 gauge staples or 38 mm x 16 gauge cleats are recommended. For overlay flooring which is generally up to 15 mm thick, 25 mm long fixings are commonly used for all widths. Fixing is also required within 50 mm of board ends, however if too close splitting at ends may occur.

Recommended Fixing of T&G Flooring to Sub-floors of Plywood, Particleboard and T&G on Joists⁽¹⁾

TYPE OF FIXING	BOARD SIZE	SUB-FLOOR on JOISTS
		PLYWOOD, PARTICLEBOARD or T&G
SECRET FIXING	T&G boards up to 85 mm in width and 19-21 mm thick	<ul style="list-style-type: none"> • 32 x 15 gauge staples or 32 x 18 gauge cleats at 225 mm centres and • Adhesive beads² to be provided midway between fixing points.
	T&G boards greater than 85 mm and up to 135mm wide and 19-21 mm thick	<ul style="list-style-type: none"> • 32 x 15 gauge staples or 32 x 18 gauge cleats at 450 mm centres and • Adhesive beads² to be provided at the fixing points and midway between fixing points.
		<ul style="list-style-type: none"> • 38 x 15 gauge staples or 38 mm x 16 gauge cleats at 300 mm centres with a full adhesive bed³. • Suitability of flooring for secret fixing to be checked with manufacturer.

Notes:

1. Fixings may vary to some degree between locations due to installers' experience of local conditions.
2. Adhesive beads of 6 mm to 10 mm are often applied in a zigzag pattern.
3. Full bed adhesive to be applied to the adhesive manufacturer's instructions.
4. For overlay flooring up to 15 mm thick a fixing length of 25 mm is commonly used.

Top (face) nailing into joists through the sub-floor (substrate)

When structural 19 mm flooring is used, the floor should be top (face) nailed with 65 x 2.5 mm machine nails or 65 x 2.8 mm hand-driven nails through the existing floor and into the joists. For thinner overlay flooring, 50 x 2.5 mm machine nails or 50 x 2.8 mm hand-driven nails should be used. In all cases, continuous beads (6–10 mm approx.) of flooring adhesive should be provided at the joists and midway between them to provide a cushioning effect between the two floors. Board ends adjacent to walls should be fixed with flooring adhesive and nailed to the sub-floor.

3.7 Installation of Strip Flooring over Plywood and Battens on Concrete Slabs

The methods below are generally suitable for board widths up to 135 mm wide. Use structural flooring on battens and either structural or overlay flooring on plywood. The secret fixing of boards requires one staple or cleat at the appropriate spacing. For top (face) nailing of boards to the batten, two nails per board are required at each fixing for boards exceeding 65 mm cover width. Fix boards wider than 135 mm to battens with two or three nails.

In humid and moist localities, more care is required to cater for possible greater expansion. Consideration should be given to board moisture content, providing for expansion, board size, the species and fixing method. In some locations, top (face) nailing to the battens may be the preferred option or a full bed of adhesive used on plywood sub-floors. Overlay flooring can be more reactive to changes in environmental conditions induced not only by conditions beneath the floor but also by sun exposure through large windows above the floor. Some manufacturers do not recommend that their 130 x 19 mm or wider boards be secretly fixed and other manufacturers have specific fixing recommendations providing for the secret fixing of wider flooring that should be strictly adhered to.

Assessing the concrete slab

Timber floors may be laid on battens or plywood over a concrete slab, or by direct fix. Direct fix to the slab (as outlined in Section 4) is a more specialist field and appropriate professionals in this field should be consulted if considering this method. The following covers installation of T&G flooring on plywood over concrete or on battens over concrete. Prior to installation, ensure that the concrete is sufficiently level to accept the system. Where there is a deviation of more than 3 mm below two high points in a slab within a 1.5 m length, a concrete topping (levelling compound), grinding or packing should be used. Slabs on ground should be constructed with a continuous under-slab vapour barrier (in accordance with AS 2780).

Timber floors should not be installed until the concrete slab has been assessed in accordance with Appendix A3. Generally, the slab will need to have cured for at least 4 months, however, if due to moisture assessments or age of a slab it is considered to be near ready to accept a floor, applied moisture vapour barriers can provide the necessary protection from slab moisture.



Methods to lay timber floors over concrete slabs include battens, direct adhesive fix and over plywood.
Direct adhesive fix should be undertaken by professional floor installers.

Installation

When floors are to be fixed over a plywood sub-floor, overlay or structural flooring may be used. When floors are to be fixed to battens at 450 mm centres, structural flooring (19 mm or thicker) is to be used. The plywood sub-floor or battens need to be at a moisture content within a few per cent of the flooring to be installed at the time of installation.

Installation of flooring should not occur until other construction activities, particularly wet trades, are complete. The building should be roofed and enclosed with the temperature and humidity as close as possible to the expected in-service conditions. For secret fixing, one staple or cleat per board at each fixing is required. For top (face) nailing to battens, boards exceeding 65 mm cover width require two nails per board at each fixing. As detailed above expansion gaps of 10 mm minimum should be provided at all walls and other fixed obstructions, which are parallel to the run of floorboards. Intermediate expansion joints should also be provided in larger floors (width at right angles to boards exceeding 6 metres), to give an equivalent gap of 10 mm every 6 metres (approx. 1.5 mm every 800 mm) or the use of loose cramping.



Secret fixing to a plywood sub-floor. A polyethylene moisture barrier has been placed over the slab and both the plywood and flooring are clear of the wall.

As an added protection against moisture from the slab (from slab edge effects, beam thickening, etc) or minor building leaks a 0.2 mm thick polyethylene membrane is recommended. The polyethylene should be lapped by 200 mm, taped at the joints and brought up the walls (or fixed columns, etc) to or above the intended top surface of the flooring. The polyethylene is then covered by the skirting. Note that fixings of plywood sub-floors or battens through the polyethylene are not considered to reduce the overall effectiveness of the membrane. An applied moisture vapour barrier over the slab may also be used to protect against possible slab moisture (see Appendix C – Slab Moisture Assessment).

Fixing recommendations – plywood sub-floors to concrete slabs and flooring to plywood

Plywood sub-floors should be structural grade, a minimum 15 mm thick and with a type A bond. Plywood 12 mm thick is also used by floor installers but with this thickness greater consideration needs to be given to slab evenness and the possible perforation of moisture barriers beneath the plywood. Sheets may be installed in a 'brick' pattern or at 45° to the direction of the strip flooring with a minimum 6 mm gap between sheets and a minimum 10 mm gap to internal and external walls.

In most cases the plywood is fixed to the concrete. Where for technical or acoustic reasons, the plywood cannot be fixed to the concrete, the plywood sheets are laid at 45° to the direction of the floorboards and the end joints of the plywood sheets are staggered. Various methods of fixing the plywood sheets to the concrete are used, including adhesives and mechanical fixing.



Plywood mechanically fixed to concrete.



Adhesive spread prior to fixing.

The option detailed below is for hand-driven spikes, which provides solid fixing to the slab:

- Slabs should be flat. There should not be more than 3 mm below a straight edge spanning between two high points in 1.5 m. If not, the effect needs to be assessed and a topping compound prescribed for the purpose or other measures to provide a satisfactory floor installation should be used.
- Install 0.2 mm polyethylene vapour barrier.
- Fix plywood sheets through the membrane to the slab with hand-driven 50 mm long by 6.5 mm spikes ('Powers SPIKE' or equivalent). A minimum of 20 spikes to be used per 2400 mm x 1200 mm sheet, equally spaced (4 rows of 5 spikes down the length of the sheet) and with the outer spikes 75 mm to 100 mm from the sheet edge. If a brick pattern is used, it is preferable that sheets be staggered by 900 mm so that fixings do not line up from sheet to sheet.

The fixing of the floor may be undertaken relying on a combination of mechanical and adhesive fixing.

When fixing boards with a maximum width of 85 mm at close centres up to 225 mm, beads of adhesive to provide a cushion between the two floors should be used to minimise possible squeaks. This is achieved by using a continuous bead of adhesive at 90° to board length, midway between fixing points. Where flooring adhesive is used to provide more of the fixing, staples or cleats may be spaced up to 450 mm apart with beads of adhesive at the fixing points and midway between.

With wider flooring up to 135 mm, a full bed of adhesive with fixings up to 300 mm apart is applicable. Due to the reliance on the adhesive to provide much of the fixing in this instance, it is important that the adhesive manufacturer's recommendations for using the adhesive are followed. Surface cleanliness, flatness provisions and spread rate are all important. Further information on adhesives is provided in Section 4.

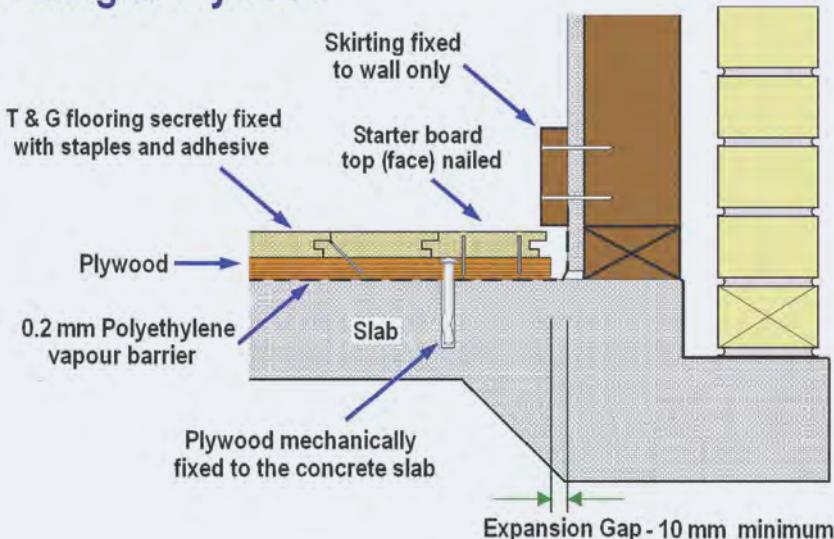
For 19 mm thick flooring staples for boards up to 85 mm wide should be a minimum of 32 x 15 gauge and cleats should be a minimum of 32 x 18 gauge. For wider boards to 135 mm x 19 mm, 38 mm x 15 gauge staples or 38 mm x 16 gauge cleats are recommended. For overlay flooring which is generally up to 15 mm thick, 25 mm long fixings are commonly used for all widths. Fixing is also required within 50 mm of board ends, however if too close splitting at ends may occur.

TYPE OF FIXING	BOARD WIDTH	SUB-FLOOR on CONCRETE SLAB
		PLYWOOD (15 mm thick)
SECRET FIXING	T&G boards up to 85 mm in width and 19-21 mm thick	<ul style="list-style-type: none"> • 32 x 15 gauge staples or 32 x 18 gauge cleats at 225 mm centres and • Adhesive beads² to be provided midway between fixing points.
	T&G boards greater than 85 mm and up to 135mm wide and 19-21 mm thick	<ul style="list-style-type: none"> • 32 x 15 gauge staples or 32 x 18 gauge cleats at 450 mm centres and • Adhesive beads² to be provided at the fixing points and midway between fixing points.
		<ul style="list-style-type: none"> • 38 x 15 gauge staples or 38 x 16 gauge cleats at 300 mm centres with a full adhesive bed³. • Suitability of flooring for secret fixing to be checked with the manufacturer.

Notes:

1. Fixings may vary to some degree between locations due to installers' experience of local conditions.
2. Adhesive beads of 6 mm to 10 mm are often applied in a zigzag pattern.
3. Full bed adhesive to be applied to the adhesive manufacturer's instructions.
4. For overlay flooring up to 15 mm thick the fixing length of 25 mm is commonly used.

Fixing to Plywood



Fixing recommendations – battens to concrete slabs and flooring to battens

Battens are to be seasoned and may be either hardwood or softwood. Battens may be fixed to the slab using 75 x 6.5 mm gun nails at 600 mm maximum spacing. 'Powers Spike Fasteners' with a minimum embedment of 32 mm or equivalent fastener at 900 maximum spacing or M6 masonry anchors at 900 mm maximum spacing. Batten spacing is dependent on the species and grade of timber flooring used and the spacing shall be up to that for flooring being supported by joists provided above in the section on the 'Installation of Strip Flooring Over Joists'. Where higher expansion forces are expected after installation (e.g. warm humid, rural and coastal environments) batten spacing is often reduced to provide more robust fixing and floor secretly fixed. If battens are a minimum of 35 mm in thickness, the spacing between fastenings may be increased up to a maximum of 1200 mm provided minimal floor expansion force is expected after installation. Again where higher expansion forces are expected after installation a maximum fixing spacing of 600 mm is more frequently used with fixing in each adjacent row offset by 300 mm. This is to reduce the risk of the battens lifting off the slab surface under floor expansion resulting in small surface undulations in the floor and more frequent drummy sounds.

Boards for secret fixing up to 135 mm wide can be secretly fixed with one staple or cleat at each batten. Adhesive is recommended for board widths greater than 85 mm and often used with boards up to 85 mm wide. Boards for top (face) nailing and cover widths of 65 mm or less should be top (face) nailed with one or two nails at each batten. Boards for top (face) nailing and a cover width of 80 mm and up to 135 mm wide should be top (face) nailed with two nails at each batten. Boards wider than 135 mm are generally top (face) nailed with two or three nails into thicker battens. Top (face) nailing is to be undertaken uniformly with respect to edge distances and alignment across the floor. Some variation due to batten layout may occur.

In warmer humid or moist localities, additional care is required to cater for possible greater expansion. Particular consideration should be given to board moisture contents, providing for expansion, board size, the species and fixing method. The following table and figure outline the minimum batten size and recommended fixing recommendations for structural 19-21 mm thick flooring to battens. The notes to the table outline that some fixing options are more suitable for some locations and installation environments than others.

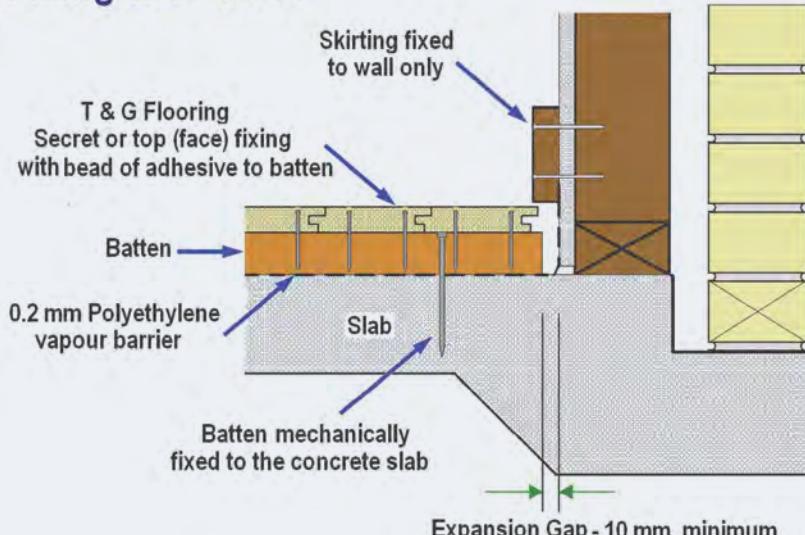
TYPE OF FIXING	METHOD	BATTEN TYPE	
		SOFTWOOD, CYPRESS, HARDWOOD (min size 35 x 70 mm)	High density ² HARDWOOD (min size 19 x 60 mm)
SECRET FIXING 19-21 mm thick boards	Machine driven	<ul style="list-style-type: none"> ▪ 45 or 50 x 15 gauge staple^{3,4} and adhesive⁵ to batten 	<ul style="list-style-type: none"> ▪ 32 or 38 x 15 gauge staple^{3,4} and adhesive⁵ to batten for boards wider than 85 mm and up to 135 mm
TOP (face) FIXING 19-21 mm thick boards	Machine driven Hand driven	<ul style="list-style-type: none"> ▪ 45 x 2.2mm T – head⁴ or 50 x 2.5mm T – head and adhesive⁵ to batten ▪ 45 x 2.5mm bullet head⁴ or 50 X 2.8 mm bullet head and adhesive⁵ to batten 	<ul style="list-style-type: none"> ▪ 32 x 2.2mm T – head⁶ and adhesive⁵ to batten or ▪ 38 x 2.2mm T – head and adhesive to batten optional

Notes:

1. Fixings may vary to some degree between locations due to installers' experience of local conditions.
2. High density refers to species with published densities above 750 kg/m³.
3. Cleats of an equivalent length (50 x 16 g, 45 x 16 g, 38 x 16 g) may be used in place of the staples.
4. In localities where the internal environment is heated during colder winters (e.g. Sydney and Melbourne) the smaller fixing size is more commonly used. In seaside locations, moist rural locations or where humid weather frequently enters the dwelling (Queensland) larger fixings, adhesive and battens at reduced centres are often used.
5. A continuous bead (6 mm to 10 mm approx.) of adhesive to be applied to the batten.
6. The practice of top nailing into 19 mm battens constitutes a recommended practice in Sydney and surrounding areas. In warmer, more humid locations more robust fixing is needed due to greater floor expansion forces.

Recommended fixing of T&G Flooring to Battens over a Slab

Fixing to Battens



4

Installation by Direct Adhesive Fix to Slabs

This section outlines the recommended practices for laying timber strip floors by direct adhesive fix to concrete slabs. This is one of three methods of laying a timber floor over a concrete slab and practices within this category differ between states. Timber floors are also regularly laid on plywood or battens over a concrete slab and procedures for these two methods are covered in Section 3.

When laying a floor by this method, which may include additional pinning (either temporary or permanent) there are issues to consider in addition to those when laying over plywood or battens. Greater knowledge and understanding of concrete properties, levelling compounds, moisture vapour barriers and adhesive performance are all necessary. Installation should not be attempted without this knowledge and sound experience of general timber floor installation practices.

Spotted Gum direct stick overlay floor.



One of the advantages of direct adhesive fix is that it can overcome possible height restrictions and the method is necessary with pre-finished flooring. However, it is not uncommon for such floors to have some 'drummy' areas and this needs to be accepted to some degree.

Western Australia, with its sandy soils and predominance of slab-on-ground double brick house construction, has developed a particular method of installation and the vast majority of all timber floors in that state are laid by that method. In other states, methods differ and there is a much greater mix of floors being laid by direct stick, over battens and over plywood. It is not uncommon for some individual installers in the eastern states to lay floors over slabs by each of these three methods depending on client preferences and site conditions. Floors will have a different feel and sound when walked on depending on what they are laid over. In Western Australia ATFA-WA has a specific 'Best Practice' guide which provides information on practices and floor acceptability in that state and some provisions in it may differ from those provided below.

4.1 Assessing and Preparing the Slab

Slab assessment requirements are defined by most moisture vapour barrier and adhesive manufacturers. These differ between product manufacturers both in content and specific details. Practices used in slab assessment should meet the requirements of the respective product manufacturer and the assessment may need to go beyond what they require.

Aspects that commonly need to be assessed and what is required to prepare a slab are outlined below:

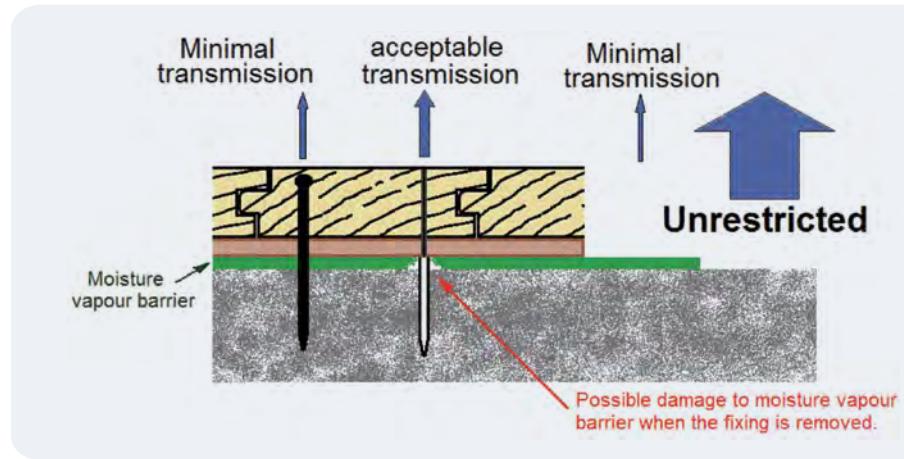
- **Slab Moisture** – Details regarding the moisture assessment of slabs is provided in Appendix C and this needs to be referred to. It is imperative that slabs are sufficiently dry to accept a timber floor to avoid cupping, inadequate adhesion and expansion related issues that may arise from the redistribution of moisture in a slab after the floor is laid. Moisture vapour barriers are often used as an added precaution.

- **Surface Contaminants** – It is expected that the surface will be clean, dry and free of paint, oil, grease, concrete curing sealers, previous adhesives and loose material, etc. There have been a number of instances where incompatible slab curing coatings that are not visible at the time of floor installation have prevented adhesion. Water droplets on a slab should freely soak into the surface; if not, the presence of a sealer or similar should be suspected. Mechanical removal is considered the most effective means of contaminant removal (grinding and shot blasting, etc).
- **Slab Construction and Soundness** – It is generally accepted that the new slabs will have been constructed to meet AS 2870 for residential slabs and footings with a steel-trowelled finish and will be free of floating ridges. Adhesive-fixed timber floors can fail if the slab is not suitably strong and the possibility of weak surface layers or patches of lower strength needs to be determined. Where suspected, the surface should be tested for weakness and hollow sounds. Any weak material needs to be removed and repaired.
- **Flatness and levelling** – Flatness provisions differ between adhesive manufacturers with many indicating a required flatness of 3 mm in 3 m. The method of measurement is not generally outlined but it would be reasonable that any deviation is not more than 3 mm below two high points within a 3 m length. Self-levelling compounds with high tensile strength and rapid drying times may be required to level the slab or alternatively high spots may be ground off. If a moisture vapour barrier is to be applied it is usually applied beneath the levelling compound and primed prior to the levelling compound being applied. The primer enhances bond strength but may not be compatible with the adhesive. In such instances, care is needed to ensure that all primer is covered.
- In some situations, particularly when there is some uncertainty over slab integrity, it has been beneficial to undertake bond testing. This is where half the length of 300 mm long pieces of flooring are glued to the slab and after 24 hours levered up to ensure sufficient strength and appropriate failure. The flooring should not be easy to lift and failure through the adhesive and the timber would be expected with minimal failure from the slab.

4.2 Moisture Vapour Barriers

Many of the adhesive companies manufacture a compatible moisture vapour barrier or will state what moisture barrier is recommended with their product. Moisture vapour barriers are not mandatory but may be required by adhesive manufacturers as part of their warranted system. Many installers assess slab moisture and will determine the need to apply one or not. The purpose of the moisture vapour barrier is to reduce to a sufficiently low level any residual moisture migration from the slab so that the timber flooring above is not affected. A moisture vapour barrier is not a waterproof membrane. Requirements differ between products and usually the application of one or two coats is required with application by brush or roller. As with all coating systems, temperature and humidity constraints apply as well as recoating intervals. A curing period applies prior to the application of adhesives or levelling compound and there is often a time window for application for the adhesive, outside of which further preparation is necessary. Aspects relating to surface preparation as applicable, such as soundness and surface contaminants, are outlined above.

In timber flooring applications, it is often necessary to temporarily or permanently pin the floor to the slab. Following clarification on the effect of this from a number of moisture vapour barrier manufacturers and after testing undertaken by these companies, they considered a limited number of nail penetrations as acceptable with their products.



Effect of fixings through moisture vapour barriers.

When a fixing is put into a slab and the moisture vapour barrier is perforated, you would expect some leakage of moisture vapour around the fixing. If the fixing was removed, there would be even greater moisture vapour transmission. The indicative diagram above shows the effects of moisture vapour transmission through moisture vapour barriers that have perforations from fixings. As indicated, the effects are small.

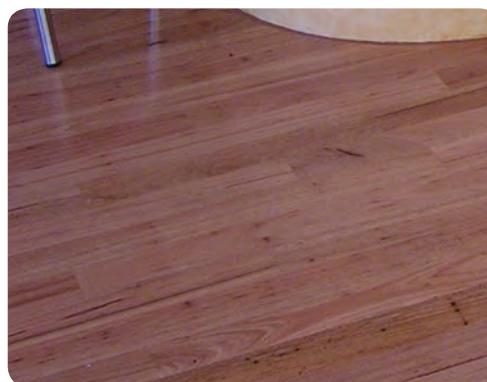
When a fixing is removed, there will generally be some damage to the moisture vapour barrier. Consideration must be given to this. Damage can expose a much larger area than the hole size of the fixing. For this reason, it is best to leave fixings in place. If temporary fixing is used with clamps or similar for cramping the floor, this may mean grinding the fixing off flush with the sub-floor surface. It is necessary that nails are vertical. Angle fixing, as would occur with secret fixing, invariably chips the concrete surface and moisture vapour barrier.

Companies that have undertaken testing consider that up to 10 fixings per square metre of a diameter of 3 to 4 mm would not significantly affect the performance of the moisture vapour barrier or the timber flooring above. Provided the manufacturers' recommendations are complied with in all respects, this number of penetrations should not affect the manufacturer's warranties. To ensure that warranties are maintained, confirmation should be sought from the specific moisture vapour barrier supplier that this applies to the product being used.

Slabs that are drier present less risk from moisture vapour transmission and it is recommended that all slabs be at or near the recommended levels for timber floors over concrete slabs, prior to the use of moisture vapour barriers (refer to slab moisture assessment in Appendix C).

4.3 Adhesives

Most of the adhesives on the market for direct stick flooring are one part moisture curing polyurethane products. Recommendations for the use of these products differ between manufacturers, both in content and specific details. It should not be assumed that each product is the same in its properties. Some differences such as cured flexibility and foaming characteristics are easily observed, however, other characteristics such as initial hold, curing rate and final strength are not easy to discern.



Direct stick 80x19 mm Standard Grade Blackbutt.

All major manufacturers have data sheets for the use of their products and these need to be adhered to, specifically noting that the requirements in particular aspects of use may differ between products.

Aspects to be aware of or emphasised include:

- Adhesives are not designed to be moisture barriers and will not perform this task.
- The adhesive may not be compatible with primers used with levelling compounds.
- The curing rate for moisture curing adhesives will be slower in very dry conditions and can differ markedly between products.
- The working time will differ between products and needs to be adhered to.
- Full curing can range up to about 7 days.
- Cleanup is easier with some products than others.
- Trowel size and angle at which the trowel is held are both important in order to obtain the correct spread rate.
- It is necessary that some means of holding boards in place (weighting or pinning) while the adhesive cures is undertaken.
- Floor sanding is often not recommended to be undertaken for about 3 days.

Adhesives provide significant restraint to board movement (shrinkage and swelling), however, many of Australia's hardwoods are very dense and the swelling forces generated can exceed that of the adhesives. Irrespective of how flexible an adhesive is, a similar amount of movement often occurs with higher density species. In locations where atmospheric moisture uptake causes significant expansion pressure, 'peaking' can also occur. This is a pressure-induced cupped appearance across a floor. Some flooring profiles are more prone to this than others. Profiles with higher levels of undercut or relief (difference between upper and lower cover widths) are generally more prone to peaking. To reduce in-service expansion pressure, it is also necessary that the average moisture content of the flooring at the time of installation is aligned as closely as possible to that which the installed floor will attain in-service during humid periods.

4.4 Direct Stick Installation Practices

Practices in the eastern states of Australia

Installers may use a variety of practices to lay floors by this method and the following outlines the more common.

General cleanliness is important and the floor area must be kept clean and free from debris such as stones that could prevent adequate contact between the board and the slab. Similarly, it must be ensured that partially-cured adhesive on the trowel does not lessen the required spread rate or height of the adhesive. Adhesive height is particularly important to ensure bonding with variations in slab flatness. The adhesive to be used may be in either sausage form or pail. If in a pail, any skin formed should be carefully removed to the point where the adhesive is soft below. The adhesive can then be squeezed from the sausage or distributed from the pail onto the slab surface. With pails, the lid should be loosely placed on a pail between applications to reduce the risk of curing in the pail. Care is also necessary to keep edges of lid and pail clean if overnight storage of a part-used pail is necessary. In such instances the pail with lid firmly attached is placed upside down.

Generally, for visual and expansion reasons, boards are laid parallel to the longest wall in the room or where boards will run lengthwise down hallways.

From the wall where the floor is being started, a chalk line parallel to the wall is 'flicked' on the floor approximately 800 mm out from the wall. The distance needs to take into consideration the actual board width and an allowance of at least 10 mm for expansion beneath the skirting.

Temporarily fix the 'starting board' with adhesive and concrete nails, often called 'mickey pins', to this line with the tongue facing the 'starting wall'. Ensure that the 'starter board' remains in firm contact with the adhesive until the adhesive has cured. The temporary pins may be removed after the adhesive has sufficiently cured which is generally at least 24 hours.

At both ends of the floor, the required minimum 10 mm expansion allowance is also to be provided. A piece of timber of the required expansion width, placed along the wall and later removed, can be used to assist in providing an even gap.

Only use sufficient adhesive for the area that can be covered in about 20 minutes. This may be only 3 to 4 boards at a time. Adhesive manufacturers recommend that the adhesive should generally be spread at right angles to the edge of the board. The recommended notched trowel should be used, taking care to ensure the appropriate spread rate and height of adhesive is maintained.

Working from the area between the 'starter wall' and 'starter board' (now fixed in place), begin installing the floor left to right from the end wall, maintaining the required expansion gap. Lay the first row of boards away from the 'starter wall' by slotting the tongue of each board into the groove of a 'starter board' and then press the board firmly down into the adhesive.

When laying the boards it is necessary to position the tongue and groove together and press the board into the adhesive as significant sliding action will spread the adhesive more thinly, lowering its height. This, in turn, can result in poor bonding between the board and slab.

In the first row each board is laid until the wall is reached where the final board will need to be cut to fit, ensuring the required expansion gap is also provided at this wall. A board should be chosen so that the off-cut is long enough to be used at the start of the next row. With each new row the boards should be gently tapped together, using an appropriate block so as not to damage board edges and to ensure a tight fit.

Continue to lay the floor left to right. For any direct adhesive-fixed floor to perform, the boards must be held down with the adhesive contacting both board and slab while the adhesive cures. Systems generally use the temporary concrete nails (as above) or weights (filled bags, filled pails or railway irons etc). During the installation, temporary pinning will be required every 800 mm or so or the floor will need to be weighted to ensure a relatively even weight distribution.

It is good practice to ensure that end joints are at least 450 mm apart and that joints do not cluster together or align. This practice provides a floor that is more visually appealing. If there are many short board lengths in the flooring, this may not be easy or possible to achieve.

When the wall opposite the 'starting wall' is reached the final board should be scribed and cut, again ensuring that the required expansion allowance is provided along the full length of the wall. Note that the walls in the room may not be parallel.

Once the main floor area has been laid, the area near the starting wall can be completed. At an appropriate time, all temporary fixings or spacers can be removed.

A number of adhesive manufacturers indicate that floors should not be sanded for at least three days. With some flooring products longer periods can be beneficial.

Practices in Western Australia

In Western Australia, concrete nails approximately 3 mm in diameter provide mechanical fixing through the top surface of the boards in addition to a full bed of adhesive beneath the floor. The nailing is done randomly throughout the floor, particularly in areas where dummy spots were observed during installation. Careful colour matching of the filler results in the nail penetrations blending in with the floor. The following outlines performance-based considerations for acceptable practice by West Australian installers. Individual practices will vary to some degree between installers.



The nail penetration is to the bottom right of the photo.

Sub-floors and underlay

Surfaces must be clean and free from substances which may compromise the adhesive bond. The surface is to be in a sound condition and suitable for the purpose, that is cohesive in structure and able to withstand the forces resulting from possible floor expansion above.

Cementitious screeds or concrete screeding may be required to patch or level sub-floors which are outside the flatness tolerances or to rectify surfaces unsuitable for glue fixed installations. A sub-floor is generally considered sufficiently flat when no part of the sub-floor is more than 5 mm below a 3 m long straight edge placed at any location on the sub-floor. Screed application should be in accordance with manufacturers' instructions. Primers or bonding additives are recommended to enhance the bond strength of the screed. It is essential that all contaminations such as paint, plaster, old adhesive or PVA sealers be removed completely prior to screeding.

Underlay may be used as a base for glue-fixed timber flooring and common products are wood fibreboard, cement fibreboard and plywood. Underlays should be glue-fixed and nailed to achieve a sound base. Underlay thickness can vary and the installed product must be well bonded and solid.

Removal of old floor coverings such as carpet, vinyls, etc, is often required prior to placing glue-fixed timber flooring and the slab may need further work to provide a suitable substrate.

If there is doubt about the suitability or otherwise of a sub-floor for glue-fixed timber flooring, a trial lamination should be carried out.

Moisture testing

Moisture testing is required prior to the installation of glue-fixed timber flooring. The moisture testing survey should include the proposed timber flooring and the slab. Where practical, the average relative humidity associated with the installation site should be established which will assist in confirming the suitability of materials and site conditions.

When moisture vapour barriers are applied to the slab, it is not considered necessary to conduct moisture assessment of the concrete slab, providing the slab is at least 4 months old.

Slab vapour barriers

Slab moisture vapour barriers are used to protect timber flooring from contamination via slab moisture present at the time of installation and as insurance against moisture that may enter the slab during the in-service life of the flooring. Moisture vapour barriers need to be compatible with the proposed adhesive system and installed in accordance with the manufacturers' recommendations.

Adhesives

Adhesive, generally polyurethane based, should be applied using a notched trowel as recommended by the manufacturer of the relevant product and the timber flooring should be well adhered to the sub-floor or underlay/sub-floor system, achieving a solid bond with no underfoot movement detectable after adhesive curing. When a board is placed into a bed of adhesive applied to recommended practices, the transfer of adhesive to the underside of the board with contact being maintained between the surfaces should achieve a minimum of 75% coverage. Some 'drummy' boards can be expected.

Clamping

Clamping/cramping of glue-fixed T&G timber flooring is applied to reduce the gaps between boards. The degree of clamping/cramping required will vary with each product and consideration should be given to site conditions and the installer's evaluation of the product. Not all installations are gap-free and some gaps are considered normal and acceptable in glue-fixed timber flooring. The filling or gaps in such floors resulting in an ongoing coherent surface is an acceptable practice.

Supplementary fixing

Supplementary fixing is carried out primarily to hold the timber boards or timber sections in place while the adhesive sets. These fixings can be permanent or temporary and can be applied mechanically or manually. The amount of fixings can vary significantly and are often randomly applied across the floor depending on the flatness of the sub-floor. The amount and type of fixings are determined by the installer and based on site and material conditions. All holes or puncture marks resulting from supplementary fixing require filling.

5

Sanding and Finishing Timber Floors

The sanding and finishing process is particularly important to the overall performance and appearance of the timber floor, and offers a wide array of methodologies and coating systems. The practices outlined are those employed broadly throughout the industry, however variations on sandpaper grades and procedures are common.

The aim in all cases is to provide a smooth surface with the desired surface coating suitably applied to give an even level of sheen across the body of the floor. It is important that when the floor is being sanded and finished the floor is not walked on by anyone unless under the supervision of the sander and finisher. Simple things such as fly spray, silicone sealer, boots and bare feet can detrimentally affect the floor finish. Generally floors are out of bounds to everyone until the finisher indicates that they can be walked on.

5.1 Assessing the Floor Prior to Sanding

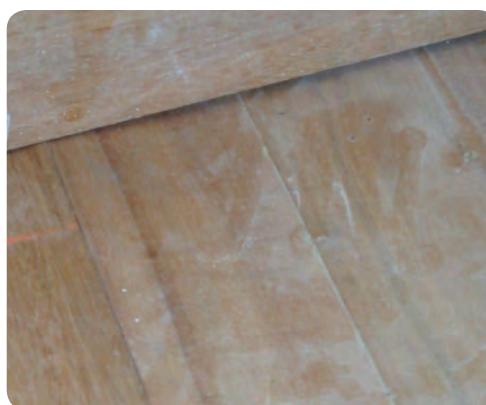
Prior to sanding, the condition of the floor should be assessed to ensure that it is suitable for sanding. This may include assessing vertical movement at board or end-matched joints, an appraisal of the overall condition of the floor (e.g. degree of cupping in boards, gapping at board edges, signs of moisture) and if there are signs of abnormal moisture content. It should also include taking and recording moisture contents of the installed floor. This ensures a complete history of the floor, should issues arise in the future. Any issues should be provided in writing to the applicable person (e.g. principal contractor, owner) and an appropriate course of action taken. It is good practice to let the floor 'settle' for a period, which may be 3 to 14 days before the sanding process takes place. This period is also beneficial for curing of adhesives where utilised.

5.2 Preparation for Sanding

Punching nails and filling nail holes

Before the sanding process can begin, ensure that all nails are punched a minimum of 3 mm below the surface of the boards. Any nail that is not suitably punched will potentially damage the sanding equipment and affect the sanding process. It is important to note that secret nailed floors may have been top (face) nailed adjacent to a wall or other areas where access is limited.

The punched nail holes can then be filled with either oil or non-oil based filler. Oil-based fillers may bleed oil into the timber and affect the colour of the wood surrounding the nail hole or may not be compatible with various coating products. The colour of the filler should be carefully selected in order to minimise any visual impact of the filler. Many of these products are sold in colours pre-matched to specific species. In mixed species floors, or where significant colour variations are present, it is usual to mix or select a neutral colour that is slightly darker than mid-range between the extremes of colour. Generally, all fillers are slightly darker and this allows for the boards to deepen in colour following finishing and UV exposure.



Prior to sanding, the floor should be assessed to ensure that it is in a condition suitable for sanding.



Nails to be punched and holes filled.

Filling can be done at this stage or after the first coat of finish is applied. By filling after the first coat any potential for the filler to impact on the surrounding timber through bleed or moisture is minimised. In all cases, the filler must completely fill the hole so as not to affect the finish quality.

Cleaning

The floor requires thorough cleaning to make it free from dirt, grit and debris. These particles can cause deep, uneven scratching in the timber surface requiring substantial additional sanding to remove. The floor should initially be swept followed by vacuuming, paying particular attention to areas which are not effectively cleaned by sweeping, such as gaps underneath the skirting, corners, window sills and the like. The vacuum should have sufficient capacity in terms of both suction and filtration to satisfactorily clean the floor.

It is important to remove any materials that may potentially impact on either the sanding or coating process. Additional care should be taken with silicone-based sealants that may have been dropped onto the floor. These products can potentially be widely spread through the sanding process, affecting the bond between the coating and the timber.

Protection

During the sanding and finishing process it is imperative that access to the area of the work be restricted. Any trades working in or around the area can potentially generate dust, wet the floor, introduce silicone-based mastics and sealants, walk over the area or generally contaminate it. Clear instructions should also be given to the owner or occupants regarding access, opening windows which may blow dust over the area, and the time required for coating systems to adequately cure.

5.3 Sanding

The sanding operation will vary based on the condition of the floor and the hardness of the flooring species. Where the floor is being sanded for the first time, the sanding process is made up of a number of separate sanding stages, which generally start with a coarse paper and progress to a relatively fine grade of paper. It should be noted that the sanding process is effectively scratching off the surface of the boards, and the reduction in grades of paper means that you start with a severe scratching action and finish with a more subtle action.

Level/basic sanding

The level/basic sand, as the name suggests, is to cut the boards level, taking out any ridges or high points in the floor. It typically involves three passes with the sanding machine. The level or basic sanding is to provide a level, completely sanded floor – each of the sanding procedures that follow this step are designed to remove the sanding scratches generated by this initial step.

Pass 1 is done from a small angle up to 45° to the direction of the grain (diagonally). This angle is dependent upon the layout and size of the area to be sanded. A coarser grade of paper is used depending upon the species and the condition of the boards. A lower grade of paper may be used to enhance the effectiveness of the sanding process in a floor that is very uneven or with hard species such as Turpentine or Ironbark.

Each room is sanded starting at a point that will allow the longest path of travel at approximately 45° (or as is deemed appropriate given the room parameters) to the grain direction (run of boards). The machine is started ensuring that the drum is not touching the boards. Walking slowly forward, the drum is eased onto the boards. A slow walking pace and consistent pressure is maintained. At the end of the pass, the drum is raised smoothly off the floor. Then by walking backwards, pulling the machine, it is eased back onto the floor for the return pass. The power lead must be kept well clear of the drum.

When the original starting point is reached, the drum is again gradually raised off the floor. The machine is moved to the right or left hand side of the first path, ensuring an overlap to the first cut path. Sanding continues in that direction, sanding strips and maintaining a similar overlap in each forward and backward pass. When the limit of accessibility has been reached in the corner of the room, the machine is brought back to the starting point and the remainder of the floor is sanded in the same direction and manner but to the opposing side of the first cut. That is, if sanded to the left of the first cut, sanding then takes place to the right of that first cut, ensuring that there is an overlap of around 200 mm between the two sides of the floor.

The second pass is carried out on the opposite diagonal to Pass 1 using a similar grade paper.



During the sanding process progressively finer papers are used.



First pass of sanding at 45° to board direction.



Second pass of sanding at 45° to board direction.



Third pass of sanding in the board direction.

The third pass continues in the direction of the boards using a similar grade paper to remove the sanding lines from the action of passes 1 and 2. Typically, the operator should start at a point that is a few metres off the side wall. The process of walking speed and easing the drum onto the floor is as previously described.

Once a forward and reverse path is sanded, the machine is moved, ensuring an overlap to the previous cut and sanding recommences in the same manner. This process is carried out across the room. When the full width of the room is sanded, the operator should turn 180° and sand the unsanded band of floor.

At the completion of the level or basic sanding, the boards should be generally smooth and free from cupping and mismatching of surface levels between adjacent boards. If this has not been achieved the floor will require additional passes to achieve this state.

The sanding drum should never contact the floor unless moving forward or backward. Doing so will cut a groove into the floor (drum mark), which may not be recoverable. Specialist equipment and manufacturers' recommendations and user instructions should be followed.

Edging

The sanding machine will not be able to sand the boards along the edges of the room, in corners or areas of reduced access such as wardrobes, etc. In these areas the boards need to be sanded level and generally blended into the body of the floor using an edge sander. The machine may be a disc, orbital or belt sander. In all cases, care is necessary to ensure the operation does not dig grooves into the boards and the finished edge is level with the body of the boards.

The most commonly used machine for the edging process is the disc sander. When using this machine, the operator should move the machine in a smooth, even pattern at board ends and across the grain. The pattern of sanding should overlap and blend into the body of the sanded floor. It is important that the machine is held level as the boards are easily grooved with any uneven pressure. On each movement, the machine should sand an approximately 50 mm section of unsanded floor. Along walls parallel with the boards, the edge sanding machine should be smoothly moved, back and forth, in the direction of the grain overlapping some 100 mm into the body of the sanded floor.



Edge sanding requires a smooth action to blend into the floor.

On new and old floors, in good clean condition, finer grit papers are usually sufficient for edging.

It may be necessary in areas of very limited access or at the corners of the room to hand scrape the floor. The scraping action should always be in the direction of the grain with the surface being hand sanded or machine sanded with a smaller machine, i.e. orbital sander. With orbital sanders, too much pressure or use of an overly aggressive grade of paper can result in deep swirl marks, which will show up in the finish. Once again, care needs to be taken to blend in these hand-scraped areas with the body of the floor.

This process is repeated following the second sanding process.

Finish sanding

The finish sanding operation involves two separate stages of operation.

Stage 1 – Initial cuts

The initial cuts utilise a finer grade of paper than that used in the level or basic sanding operation. Typically, an F60-100 grade paper is used and the floor is sanded in the direction of the grain (board run). The purpose of the initial cuts is to smooth off the coarse sanding marks left by the level or basic sanding. Once a suitable level of smoothness is achieved, the final stage of sanding may be carried out.



Initial cut.

Stage 2 – Final sand

The final sand utilises an even finer grade of paper – again reducing the depth of scratching and preparing the floor for the coating system. The floor must be fully cleaned of dust, grit and debris. Any matter left on the floor will invariably affect the quality of the finish.

Typically, the final sand is carried out using a rotary sander, plate orbital sander or similar machine with a 100-150 grade paper or screenback. The sanding should be carried out in the direction of the grain ensuring a smooth action and applying a balanced control of the machine.

If a water-based coating system is specified, the final sand may need to be carried out using a new or worn 150 mesh screenback (see manufacturer's recommendations). The floor is then vacuumed thoroughly and, if required, tack rag cleaned. Special attention should be paid to any potential dust traps in the floor (dig out any dirt or dust and vacuum away). These can contaminate the floor coating system if not cleaned adequately, as the applicator will most certainly pull the dirt onto the body of the floor. It should also be noted that heavy sanding equipment may have the potential to create wheel marks on low-density floor boards. Additional care should be taken in these applications.

Final sand.



5.4 Coating System Application

The following information is a typical application methodology, which might be utilised for the various finish types with minor product-specific variations.

Cleaning

The floor finish will be easily contaminated with any dirt, dust or other extraneous matter left on the floor. It is essential that the area be thoroughly cleaned/vacuumed, paying particular attention to any areas which may have caught dust during the sanding process such as window sills, picture rails, skirtings, power and light switches, light fittings, handrails, etc. The floor needs to be well lit with adequate ventilation. It is important not to have draughts blowing across the floor during the process as they may well introduce contaminates from outside of the actual working area.

Mixing the coating

The coating material should be thoroughly mixed so that all the solids are blended through the body of the liquid. Care should be taken not to stir too quickly or roughly as this may introduce air bubbles to the material which affects the coating quality. If there are any additives to be used, ensure they are mixed thoroughly into the coating liquid. In all cases follow the manufacturers' instructions.

Cutting in

Using a clean, good-quality brush, cut in the finish around the perimeter walls and any other obstructions or areas which may not be accessible to the main applicator. The cutting in should extend out approximately 150 mm into the body of the floor so that the applicator is not required to venture too close to the skirtings and other limited access areas. If any bristles fall out of the brush into the finish, remove immediately.

Cutting in the finish around perimeter walls.



Applying coating

The initial coat applied to the raw sanded timber may be either a recognised sealer coat as prescribed by the coating manufacturer or the same material to be used as a finish, except when outside the manufacturer's recommendations. Sealers are available in both water-based and solvent-based products. The use of a sealer can enhance the development of colour in the timber floor and can reduce the risk of 'edge bonding'. Penetrating and low-rupture sealers are available. In all cases it is imperative to closely follow manufacturers' instructions.



Application of the initial coat.

There are many approaches and methods used in the application of floor finishes and coating systems. The following approach is one such application method, that has generally been accepted by the industry.

The applicator as specified by the coating system manufacturer (often a 6 mm Mohair roller or equivalent) is immersed in the coating contained in a large painter's tray or applicator bucket. These allow the applicator to be lightly squeezed on the shallow portion of the tray to avoid drips. The product should be applied to the boards in a smooth action starting at one end of the boards and working the product in line with the grain of the timber boards. The finish should be feathered off at the outer edge to minimise any build up of coating at that point. This process should leave a 'wet edge' so that each successive section of application blends into the previous section without any ridging, which can occur if the material skins or dries off before the next application strip. The application process should continue in the same manner working from one end of the area to completion. An even, wet look should result, without any dry patches.

Filling/stopping

It is not a recommended practice to fill tongue and groove timber floors.

Any nail holes not previously filled and any cracks or other open faults should be filled with a suitable filling compound that is compatible with the finish type. (Note: ensure the coating system is dry.) Generally, a non-oil-based filler that is suitably colour-matched to the timber is best.

The filler should be installed with a clean bladed applicator. Ensure the filler slightly overfills the hole and has been fully pushed into the void. If the material is not completely filling the void, it may potentially come loose in service. Clean off any filler that is spread over the floor surrounding the hole. Any excess will be sanded away in the light sanding between coats.

Sanding between coats

The floor will typically have a slightly rough feel to it after the first coat of finish, depending on the system used and the degree of grain raise created. It is normal for more open grain timbers to exhibit a higher degree of initial grain raise than denser close grain species. The floor requires a light sand after the first coat to remove this roughness and to also key the surface for the next coat of finish. A 150 or finer grit paper or screenback is used at this stage with a rotary sander or similar. It is imperative that the sanding does not expose the timber as this will create further raised grain. The sanding process is required to smooth off the roughness in the coating, not the timber. Edges must be hand or orbital sanded to a similar smoothness.

Cleaning between coats

All dust should be thoroughly removed from the floor, along with any potential dust traps as previously described. Ensure that there are no draughts blowing through the area that could contaminate the final coat(s). In addition, it may be prudent to use a tack rag over the floor to remove any dust missed by the vacuum. This will ensure that the floor is as clean as possible for the final coat(s).

Second coat

The floor should again be edged with a clean brush coming out some 150 mm or more into the body of the floor. The application process is as per the first coat with the applicator being worked along the full lengths of the boards and lightly feathered at the outer edge of each strip of application.



Application of the second coat.

Additional coats

Any additional coats should follow the same processes of a light sand of the previous coat, thorough cleaning and application of the coating. Typically, a three-coat system is utilised, however all manufacturers' recommendations should be followed in regards to number of coats and sand paper grades, in addition to any requirements of the specifier. Various water- and oil-based coating systems require a finer grit of paper between coats as compared to the solvent-based products.

6

Overall Appearance to be Expected

There are no standards that outline what an acceptable appearance of a timber floor should be. There are standards that relate to the manufacture of timber flooring and when recommended sanding and finishing practices are undertaken, and there is a general level of acceptance of the finished product in the marketplace.

Floors of the same species can differ markedly in their appearance depending on timber source, age of the tree, board cover width, the finish system used and the lighting in which the floor is viewed. Timber is a natural product that will shrink and swell in response to changes in atmospheric humidity, differences in the building environment, or if the sanding and finishing is not undertaken in a dust-free factory environment. Finishes may also darken with time. Even with these variables, a high standard in the finished floor is achievable.



A high standard of appearance is achievable.

6.1 Acceptable Appearance

Colour, species and grade

The overall colour or blend of colours in a floor is dependent on the species or species mix and the character of the floor. The features present in a floor, such as gum veins, are determined by those features permitted by the grade. Even when a single species is chosen there can be a wide variation in colour and it is also possible that a limited number of boards of a different species may be present due to similarity in appearance. It is also important to realise that grading rules do not cover either colour or colour variation. Grade names that do not align with the Australian Standards are likely to be similar to those in these standards but clarification should be sought regarding differences.

The grading process is rapid and relies on quick visual assessment where graders must assess the size and extent of a feature without relying on measurement. Due to this, some inaccuracy in grading can occur that may result in a limited number of boards that are outside grade limits. The sanding of a floor can also increase the size of some features or cause features to appear that were not present prior to sanding. Consequently, some boards in a finished floor may not meet the specified grade description. The presence and development of such features needs to be acknowledged by those purchasing timber floors. When viewing a floor, there is generally a clear difference between a floor that is of the incorrect grade and a floor where grade limits have been exceeded in some boards.

Where the number of boards in a floor that has features that exceed grade limits, in terms of size and number, are relatively few (less than 5%) and the overall appearance of the floor is in line with the chosen grade, no remedial work is considered necessary.



A select grade Blackbutt floor where the backsawn gum vein toward the top right exceeds grade limits but is acceptable within the floor.

Grading also does not account for the distribution of features in boards, between boards within a pack of flooring or within a finished floor. It is a reasonable expectation that the installer, when laying the floor, will provide a relatively even distribution of colour and feature throughout the floor. With regard to colour however, it must also be recognised that coating a floor highlights colour differences and the extent of the change is at times not easy to discern. Similarly, it can be expected that board lengths will be relatively evenly distributed in the floor and that groups of short boards or board ends will not be frequently clustered together.

Even timber surface

The following outlines some problems that affect the surface of the boards and these should not generally occur in timber floors. However, specific heat sources from appliances or sun exposure through large uncovered windows may induce some cupping of boards in the affected area. Similarly, wide boards or thinner overlay boards may also show some slight cupping or peaking in certain house environments. It should also be recognised that the actions or inaction of owners can contribute or even cause these to occur.

- **Cupping** – boards with their edges either higher or lower than the centre of the board. Heat in a specific location or a very dry environment above the floor may result in cupping. Moist sub-floor spaces can also cause boards to cup. Cupping is more likely to be observed in overlay flooring and standard thickness boards that are wider than 100 mm. To some degree a small amount of observable cupping may occur in some locations within a dwelling (e.g. sun exposed floor).



Boards ends should be spaced out and preferably 450 mm or more apart.



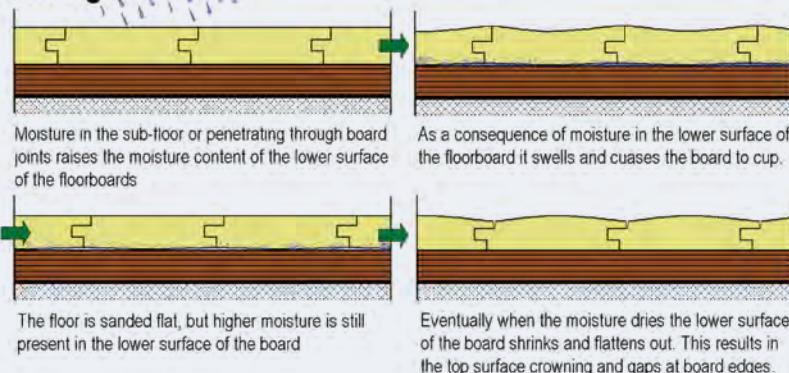
Cupping – Board edges higher than the centre of the board, but which is barely visible in the floor.

- **Peaking** – this has the appearance of cupping but is the result of expansion pressure in the floor.
- **Tenting** – two adjacent boards, where the adjoining edge has lifted above the level of the adjacent flooring. This is often associated with high moisture beneath the floor and can be from many causes.
- **Buckling** – a section of flooring containing a number of boards that is raised above an adjacent section.

- **Crowning** – floor boards that are flat on their lower surfaces but where the upper surface has its edges lower than the centre of the board. This may occur if a floor is cupped (board edges up) at the time of sanding. Crowning does not become apparent until some months after finishing.

Note: Floors exposed to heat sources after occupancy (e.g. no curtains, fireplaces, vents from appliances, houses closed up for extended periods) may cause boards to cup. Cupping and shrinkage from such sources may be the owner's responsibility.)

Crowning



Relatively even gapping between boards in areas not exposed to specific heat sources

During drier times of the year, shrinkage gaps between boards may average 0.75 mm for boards of a cover width of 80 mm. For wider boards, proportionally wider average gapping can be expected. Some gaps will be larger than the average gap size and others smaller, however the appearance generally indicates gapping between most boards. An appearance can be expected that is free from split boards and wide gaps between boards that may be irregularly spaced across the floor. Irregularly spaced wide gapping may occur from either the edges of boards being bonded together or from a proportion of boards being high in moisture content at the time of laying. The provision of expansion gaps as part of the installation process and evident throughout the life of the floor is acceptable.

Limited vertical movement at T&G joints

Flooring is manufactured with the board tongue narrower than the groove. This is necessary so that boards will fit together during installation. When floor boards are laid over joists in particular, some differential vertical movement may occur between adjacent boards when a load is applied to an individual board. This is due to the clearance between the tongue and the groove. The clearance should not exceed 0.6 mm.

Minimal squeaking

A small amount of noise can be expected from most timber floors when walked on. Noises can occur from movement of one board edge against another or from boards moving on nails. A floor is often more noisy during drier weather due to loosening at the joints.

Indentations

Timber strip floors can be expected to show some indentations depending on the hardness of the species used, volume of traffic and footwear worn.

A finish with minimal contamination and sanding marks

A finish similar to that of fine furniture should not be expected. Sanded and polished timber strip floors are not finished in a factory environment and different pieces of flooring will sand differently. The home environment is also not dust free. However, the finished floor can be expected to have an even appearance free from heavy sanding marks, blooming or frequent air bubbles in the surface. A minimal level of contaminants, minor sanding marks and small depressions of the finish at board edges and in nail holes, etc, may be visible. The perimeter and other hard-to-get-at places are more likely to contain these irregularities. Due to this, a mirror finish is an unachievable expectation. Some finishes will also yellow with time and if rugs are moved, a contrast in the depth of colour can be expected.

Inspect floors for imperfections during daylight hours with lighting on. The overall assessment of the floor is from a standing position with the floor viewed from positions that are usually occupied by people. Internal and external reflections in areas not usually covered by furniture should be assessed. Acceptability relies on judgment that takes into consideration the effect of lighting on noticeable surface imperfections as well as initial wear of the floor, which can cause some imperfections to significantly lessen or disappear. A floor is subject to much heavier wear than furniture and although a good quality finish can be expected, the same finish quality to furniture should not be expected.

Some imperfections that could be expected to some degree in a floor but which should also be assessed include: sanding quality; gloss variation; dust, insects and debris; bubbles and gel particles and coat levelling.



The same area of flooring but with downlights on in the right hand photo. Downlights highlight sanding imperfections and dust, some of which can be acceptable.

7

Care and Maintenance

Timber floors vary in ease of maintenance depending on the type of coating used and the severity of use. They always greatly benefit from regular care. In doing so, the life of the floor finish and floor are greatly enhanced. However, at some stage the floor will need to be rejuvenated and this usually requires buffing back and re-coating.

Some of the softer floor finishes can also benefit from application of metalised polish which provides an additional wear surface. It is important that maintenance aspects are passed on to home owners as it assists in ensuring ongoing customer satisfaction.

7.1 A Newly Finished Floor

Although a floor may be walked on after initial curing, some precautions are necessary with a newly finished floor until the coating system has fully hardened and this may take in the order of two weeks. Use of the floor before the full cure has been realised can result in increased tendency for scuffing and scratching. It is recommended that rugs are not laid until after the floor finish has fully hardened. Additionally, rugs with rubber backings should never be used as these may tend to stain the applied coatings. While light furniture can be replaced and used during this period, it should be ensured that furniture protection felt pads are attached to the feet of tables and chairs, etc, and furniture such as chairs should be lifted. Similarly, it should also be ensured that heavy items such as fridges are moved carefully into position and at no time should they be dragged over either newly finished or fully cured floors. Consideration should also be given to chairs with castors as they can indent softer timbers and also cause premature wear of the coatings they are in contact with. Again, these should not be used until the finish has hardened and barrel type castors are less likely to damage a floor than ball castors.



Timber floors are easy to maintain and greatly benefit from regular care.

7.2 Ongoing Care and Maintenance

Ingress of grit and direct sunlight

The are some things that are enemies to timber floor finishes and one of these is sand or grit that can be brought into the house with footwear. These small particles act like sandpaper, resulting in scratches in the floor. Mats placed both outside and inside external doors provide a simple and effective means of significantly reducing the grit entering the house. Similarly, in high-wear areas, runners and rugs can be effective and can also add to the décor of the house. The kitchen floor generally experiences high wear and a floor rug in this area can be particularly beneficial.

Another aspect that should be considered is the amount of direct sunlight that is reaching the floors. Direct intense sunlight can contribute to gapping and possible cupping of boards. It will also cause the colour of both boards and finish to change with time. Some floor finishes are more prone to darken with age and direct sunlight accelerates this process. Filtered sunlight through sheer curtains or blinds provides an effective means of slowing the colour-change processes and is also effective in controlling gap size and possible cupping. If the sunlight has not been controlled by window coverings, patio roofs or awnings, floor rugs can be used.



Floor mats at doorways provide a simple means of limiting the amount of grit from entering the home.

Maintenance plan

Establishing a regular cleaning program will greatly assist in keeping floors in pristine condition. There are many aspects that affect how often the floor requires cleaning and these include the degree of grit present (particularly from children and pets), type of exterior and interior matting used, the level of traffic, type of footwear and general conditions of the area outside the house. Spills should be mopped up when they occur and any leaks must be attended to immediately. Failure to attend to leaking pipework can result in severe damage to timber flooring, particularly when laid over sheet flooring or directly adhered to a slab. Scuff marks or stubborn stains may be removed with light rubbing using a timber floor cleaner. As some cleaners can attack certain types of coating, where possible use the cleaning regime specified by the coatings manufacturer. Alternatively, always test rub an isolated area of floor to verify compatibility of the cleaner used with the coating.

For regular cleaning of domestic floors an antistatic mop provides an effective means to collect dust and grit. Continual walking on a dirty floor will quickly damage the finish. If a vacuum cleaner is used, the condition of the brushes should be regularly checked. If they have worn thin, contact of the metal head on the floor can result in scratching. Also, do not use hard head vacuum cleaners as they will invariably cause fine scratches on the floor.

Steam mops are not recommended on polished floors as they can damage certain types of coatings.

Floors can also benefit from monthly damp mopping. Providing the mop is only damp and the finish is in good condition, mopping carried out correctly will not affect either the finish or the timber. Damp mopping provides an effective deep clean and should be undertaken with a neutral pH wood floor cleaner or product recommended by the finish manufacturer. Harsh detergents or abrasive cleaners are to be avoided as is use of methylated spirits and vinegar as they can chemically attack some types of coatings, e.g. waterborne polyurethanes and penetrating oils. After wetting, the mop should be wrung out until it is moist. Using clean water, a final mopping with a mop wrung out till it is 'dry' may be used to further remove excess moisture on the boards. Periodically, the protective pads on furniture legs should be checked to ensure they are clean of grit or to see if they need replacing.

Re-coating

Timber floors are subject to different wear patterns and it is in areas of higher wear that there will initially be signs that the floor requires re-coating. It is important to ensure that excessive wear has not occurred if a total re-sand and re-finish is to be avoided. The finish should be inspected in the high-wear areas and if a few drops of water bead on the surface then the finish is still intact and may require cleaning rather than re-coating. If, however, after a few minutes the water begins to soak in and the timber colour darkens, then the finish is partially worn and re-coating should be undertaken.

A

Appendix A – Moisture Content and Timber Movement

Water In Wood

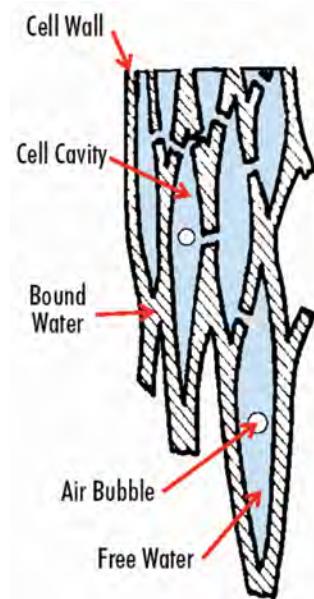
In all common applications, timber contains moisture. Even timber that has been in service for 100 years will contain similar amounts of moisture to seasoned timber that has just been put into service. The reason for this is that the moisture in the air (humidity) maintains a certain level of moisture in the wood. The moisture present in freshly sawn (i.e. green) timber, straight from the log, is much higher and as a consequence of this, the air absorbs moisture from green timber until a balance is achieved.

Moisture content

For timber products such as flooring, the amount of moisture present or its moisture content is defined as the mass of water present in the timber divided by the mass of the timber with all water removed, expressed as a percentage. The mass (measured in grams or kilograms) of water present can be determined from the difference in the mass of the timber with water (initial mass) to the mass of timber with the water removed (oven dry mass). The following equation is used to determine the moisture content of timber:

$$\begin{aligned}\% \text{ mc} &= \frac{\text{mass of water present}}{\text{"oven dry mass"}} \times 100\% \\ &= \frac{\text{"initial mass" - "oven dry mass}}{\text{"oven dry mass}} \times 100\%\end{aligned}$$

The structure of the cells in timber can be likened to a number of drinking straws glued together. If the straws were full of water it could be expected that the mass of water contained in the straws would be greater than the mass of the drinking straws alone. In such a case the moisture content as calculated above would exceed 100%. In a tree the moisture content may be as low as 40% but can be as high as 180%. Green off-saw timber could have moisture contents of 180%, which means the timber contains 1.8 kg of water for every 1.0 kg of dry timber that was present. In softwoods such as Radiata Pine and Araucaria the average moisture contents of 180% or more often occur. In many of our common hardwoods the moisture content may be no greater than 70%. Cypress, a softwood that grows in drier areas, may only have average moisture contents of 45%. There can also be sizeable variations in moisture content between the outer sapwood of a tree to the inner heartwood.



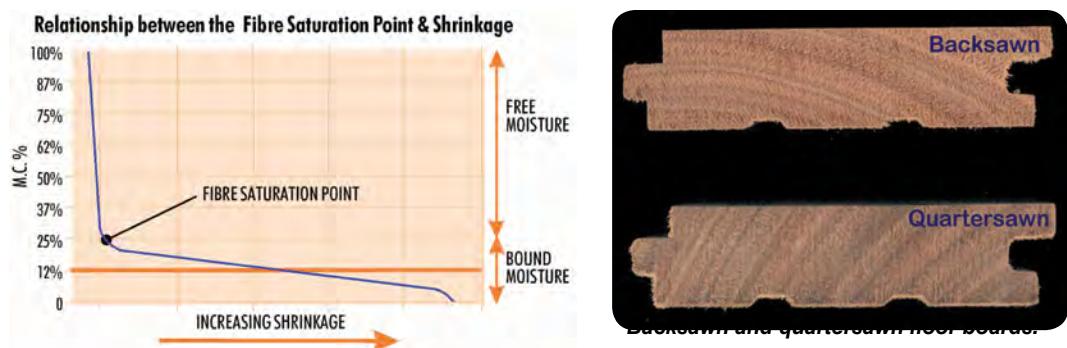
The Drying of Timber for Flooring

Seasoning or drying is the process by which moisture is removed from timber and green (i.e. freshly cut boards) may be either air dried or kiln dried or a combination of both. The drying process for flooring often includes more than one stage. Timber is initially stacked to allow air movement between each layer of timber and in this state it can be either air dried by leaving it out in the open for some months or placed in a low temperature pre-dryer to gently reduce its moisture content under controlled conditions, prior to drying being completed at higher temperatures in a kiln. Some hardwoods are kiln-dried from green but many operations use initial air drying or a pre-dryer followed by kiln drying. Softwoods are generally air- or kiln-dried from green.

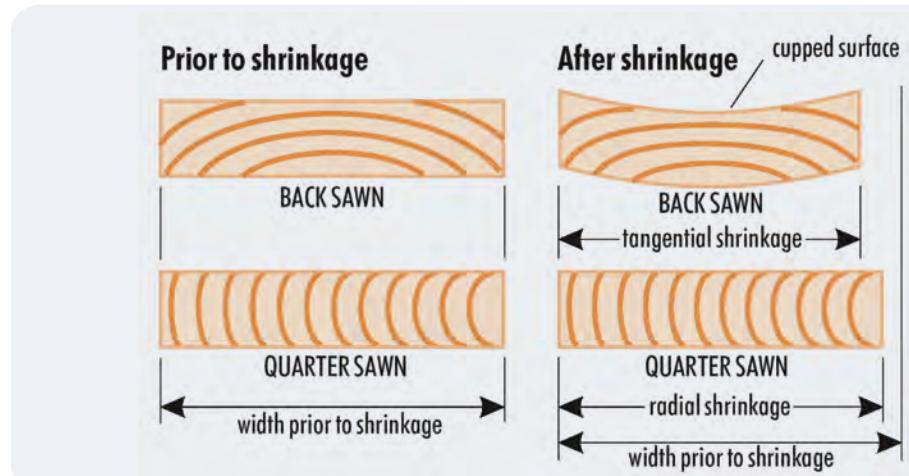
When we refer to seasoned timber, we are usually referring to timber that has moisture contents from 9% to 14%. This range has been chosen because timber in coastal Australia will usually remain within this moisture content range, when used internally. Whether timber is dried by the air or in a kiln there is always a small variation in the moisture contents of individual boards (usually about 5%). Due to these variations, some boards will take up moisture from the air after being put into service, while others may lose moisture. When timber takes up moisture it expands and when it loses moisture it shrinks. The small moisture variations present at the time of flooring manufacture therefore translate into small differences in board widths as board moisture contents adjust to be in balance with the humidity in the air.

Movement in Timber with a Change in Moisture Content

Water in wood resides both within the 'straws' (called free water) and in the walls of the 'straws' (bound water). As indicated above, the moisture content in living trees will vary greatly depending on the species, age of the tree and location in which it is grown. However, no matter what the initial moisture content is of the wood in the trees, shrinkage in timber is minimal until the moisture content reaches approximately 25%. At this level much of the free water has been removed and it is from this point (called the fibre saturation point) that there becomes a significant reduction in the bound water tied up in the cell walls. Associated with this, the cell walls begin to shrink and we observe shrinkage in timber. This relationship is shown diagrammatically in the graph.



Within the sawmilling industry, boards are referred to as being either backsawn or quartersawn (see image above) and the movement characteristics of each is quite different. In a backsawn board the angle of the growth rings on the end section to the widest face is less than 45°. In quartersawn boards this angle is greater than 45°. Backsawn boards are often valued for the 'figure' that appears on the surface of the timber flooring and with backsawing the amount of usable timber recovered from the tree is also usually greater. However, backsawn boards can be expected to shrink in width more than a quartersawn board and due to the angle of the growth rings, backsawn boards will have an inherent tendency to cup when they dry.



The amount of shrinkage that occurs radially (i.e. in a direction that radiates out from the centre of the log) differs from that occurring tangentially (at right angles to the radial direction). Therefore, in a backsawn floorboard the cover width will vary as a result of tangential movement and in a quartersawn floorboard the cover width will vary from radial movement. Flooring manufactured from species grown in Tasmania and Victoria are often quartersawn, whereas species from Queensland, New South Wales and Western Australia are predominantly backsawn.

A useful measure of movement is what is termed the ‘unit tangential movement’ (UTM). This is the percentage dimensional change for each 1% change in moisture content between 3% and the fibre saturation point for the particular species. For example, Brush Box has a UTM of 0.38. A 3% increase in moisture content could on average be expected to cause an 80 mm wide backsawn floorboard to increase in size by:

$$0.38 \times 3\% \times 80/100 = 0.9 \text{ mm}$$

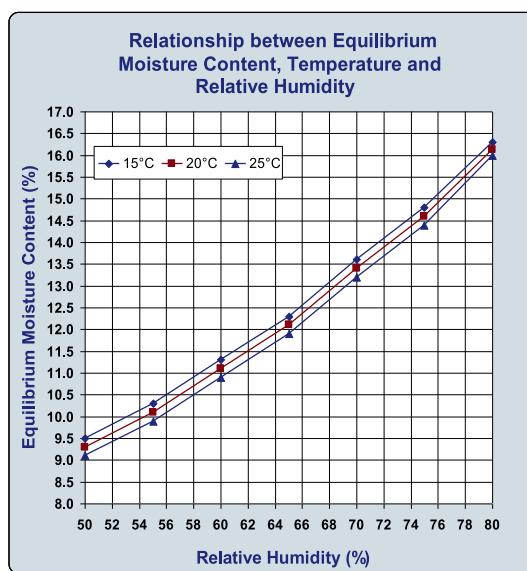
When dealing with seasoned timber, the UTM can be used to estimate anticipated movement, however actual movement is often less than the estimate, due to the presence of quartersawn material and with regard to applications such as flooring, some compression of the timber often occurs. Care is necessary when applying these figures. Tables of UTM are available from state timber organisations.

Flooring response to changes in humidity

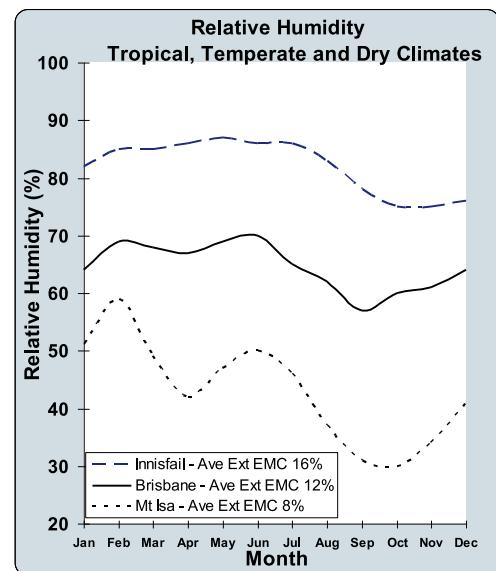
A relationship exists between the air temperature, relative humidity of the air and the moisture content that timber will try to attain. This relationship is shown in the following chart and it can be seen that humidity has the predominant influence over moisture content. As an example, if timber is in a room at 25°C and the relative humidity is 65% then the timber will, in time, try to reach approximately 12% moisture content.

Obviously, humidity and temperature will change on a daily basis as well as on a seasonal basis. Because of timber’s relatively slow response rate, we are usually more concerned with seasonal changes. The effects of seasonal changes may be observed in a polished timber floor by the opening and closing of gaps between adjoining boards at different times of the year.

Weather data provides information on the changes in relative humidity that can be expected in a particular locality and this is particularly important if installing a floor in a location that differs from the one that you are used to. There can be significant changes over short distances, for example, between a coastal city and hilly rural environment, a half hour’s drive away. Examples of different climates, seasonal humidity fluctuations and average moisture contents are given in the graphs below.

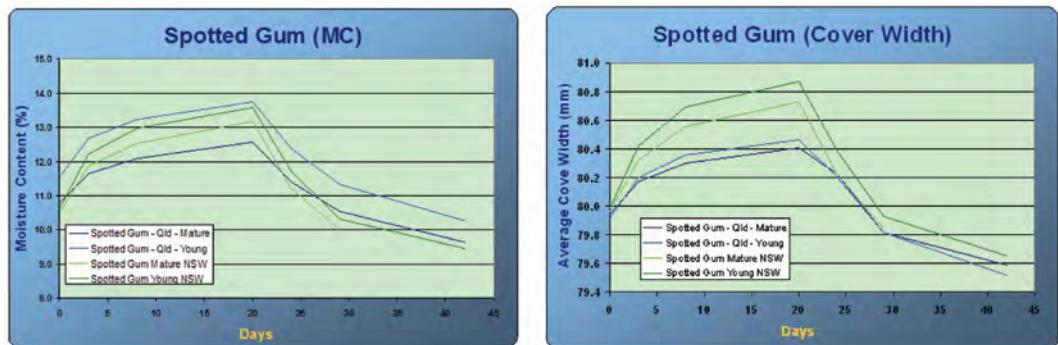


Temperature, relative humidity (RH) and equilibrium moisture content (EMC).



Climatic effects on timber floors.

Although these graphs link timber moisture content to surrounding environmental conditions they do not show the response rate of different species to these changing conditions. The response rate of softwoods such as Hoop Pine or Radiata Pine is more rapid than that of the denser hardwoods such as Spotted Gum. However, even within the hardwood or softwood groups, response rates can also vary quite markedly. Indicative response curves from one trial for Spotted Gum when placed in a very humid environment (18% EMC) followed by a dry environment (8% EMC) is shown in the graphs below. The first graph shows moisture content changes and the second graph the change in cover width. Clearly this illustrates the variability that can be present. Blackbutt, although a dense hardwood, takes up and loses moisture quite rapidly.



Results from the FWPRDC Research on Timber Flooring undertaken by Timber Queensland Ltd.
The graphs show averages of ten pieces of Spotted Gum flooring from different sources placed in a conditioning chamber at 18% EMC for 21 days followed by 8% EMC for 21 days.

The species that more quickly take up or lose moisture will generally follow seasonal changes more closely. The graphs also indicate that the rate of moisture uptake, which may result from a relatively quick and sustained change in weather conditions, can initially be quite rapid but the rate of increase then slows over time. This aspect is also reflected in timber floors. Floor installers sometimes comment that a floor may have shrunk a lot in the first week or so after laying but that it hadn't moved much since then.

As a guide, the table below outlines the density of the species, whether the flooring is predominantly backsawn or quartersawn and an indicative measure of the species response rate to moisture uptake and loss. In locations where floors are likely to expand after installation particular care is necessary to adequately accommodate the expansion that will occur (i.e. intermediate expansion joints, loose lay and acclimatisation). This is particularly so with higher density timbers and particularly those that respond quickly to seasonal humidity changes.

Species classification	Density classification	Cutting pattern	Movement in response to humidity changes
Radiata Pine	Low	Backsawn	Low
Tasmanian Oak	Medium	Quartersawn	Medium to high
Victorian Ash	Medium	Quartersawn	Medium to high
White Cypress	Medium	Backsawn	Low
Jarrah	Medium to high	Backsawn	Medium to high
Rosegum	Medium to high	Backsawn	Medium
Blackbutt	High	Backsawn	High
Spotted Gum	Very High	Backsawn	Low to medium
Grey Ironbark	Very high	Backsawn	Medium

B

Appendix B – Measuring Moisture Content of Timber and Sheet Products

Checking the moisture content of timber flooring prior to installation is important to provide a check on the product supplied, evaluate the need for additional expansion allowance and to ensure that subsequent movement (shrinkage and swelling) remains within accepted bounds. This appendix outlines the various methods used to test the moisture content of timber. Also included in the appendix is a method to evaluate the moisture content compliance of packs of flooring.

Moisture Content Measurement

Moisture content

Moisture content is simply the mass of moisture present in wood divided by the mass of the wood with no moisture in it, expressed as a percentage. What's important about the moisture content in timber is that the board width will increase with increasing moisture content and will decrease with decreasing moisture content. At the time of machining, cover width variations are usually minimal and subsequent variations in board widths are usually due to changes in moisture content. It is often the current and future variations in board width that are of primary importance and one important purpose of moisture content testing is to indicate what future movement can be expected.

By simply looking at the end of a pack of flooring that may be a month or so old it is often possible to obtain information about the moisture content of the timber within the pack even without using a moisture meter.



For example, in a three-month-old pack of flooring, some moisture changes are likely to have occurred. If the nominal cover width is 80 mm and:

- if board widths are between, say, 79.6 mm and 80.4 mm, then the material is likely to have been dried to within narrow moisture content bounds and should perform well in service.
- if board widths range from, say, 78 mm to 81 mm and some boards are cupped, then the material is likely to have been dried to quite wide moisture content bounds and the floor is likely to show some wide gaps at board edges along the length of the board and near end matched joints.
- if board widths range from, say, 80 mm to 84 mm, then some of the material may have become wet after manufacture.

It is important when considering moisture content to also take the board widths into consideration. Australian Standards that cover the moisture content of flooring vary in their limits as this depends on the species.

The table below provides some information on species types, the number of the applicable Standard and the moisture content ranges applicable to flooring.

Species Group	Moisture Content Bounds (moisture content anywhere within a board)	Number of the applicable Standard
Hardwood	9% to 14%	AS 2796
Softwood	9% to 14%	AS 4785
Cypress	10% to 15%	AS 1810

Methods of Measuring the Moisture Content of Timber

How moisture content is measured

Moisture content is generally measured by either a meter or through oven dry testing. The two common types of meters in use are the resistance meter and the capacitance meter. Meters use changes in electrical properties caused by the wood and water within it to provide an estimate of the moisture content. Oven dry testing requires a set of scales and an oven. The moisture content is determined from the change of mass as the sample dries.



Capacitance moisture meter measures average moisture content. Need to set species density.



Resistance moisture meter – measures moisture content between the pins. Need to correct reading for temperature and species.

Measurements by different methods

In any piece of flooring the moisture content is likely to vary to some extent down the length of the piece and from the outer surfaces (case) to the centre (core). With regard to case-to-core differences some methods of measurement are able to measure this while others can only measure the average moisture content of the board. This can be an important consideration when choosing a measuring method as case-to-core variations or the difference between upper and lower case may need to be determined. At other times it may be important to gain many measurements quickly in order to gain an appreciation of the average moisture content. In cases of dispute, accuracy may be of prime importance.

Resistance meters measure the highest moisture across the exposed ends of the pins whereas capacitance meters measure an average through the piece. Oven dry testing measures the average moisture content of the sample placed in the oven but by cutting the sample up into applicable smaller pieces, case and core moisture contents can also be determined.

The three common methods of measurement, including their application, benefits, limitations and accuracy are outlined on the next page.



Oven dry testing provides the most accurate moisture content test.

Oven Dry Method

When is it used?

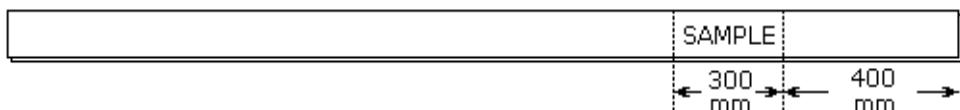
- Oven dry testing is often carried out where variations in moisture content in the final product can have a significant effect on the performance of the product.
- It is used where accurate results are required or meter readings are known to be inaccurate which can include some timber species but also particleboard and plywood sub-floors.
- In case of disputes Australian Standards generally refer to this method as it provides measurements that are more accurate and reliable.
- Manufacturers of board products often undertake oven dry testing in the manufacture of their products.
- Some timber organisations also have the appropriate testing equipment and contract out these services.

Testing equipment and facilities

- The equipment required is an accurate balance or set of scales and a laboratory oven that is able to maintain a temperature of $103^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

Sampling from a pack

- The samples need to be representative of the timber in the pack being tested and capture the variation present. This may include some outside boards as well as some from within the pack.
- If cupping is present or there is variation in the cover width by more than 1 mm, samples should be provided which include two boards that are cupped, two with wider cover widths and two with narrower cover widths. (Packing pieces are not to be provided as samples.)
- If boards are not cupped and there is little variation in cover width throughout the pack, five boards should be chosen. (Packing pieces are not to be provided as samples.)
- The samples from which test pieces will be cut should be taken not less than 400 mm from the end of a board and should be approximately 300 mm long.



Note: If the sample is from a board on the top, bottom or edge of the pack, it should be marked as being an outside board.

- The samples should be individually wrapped in 'Glad Wrap' or similar to reduce moisture content changes during transport.
- The samples should be stored in a cool place and delivered to the testing facility within 24 hours.

Testing Procedure

- From the 300 mm long pack samples, test pieces are cut with a length between 15 mm and 30 mm so that the required mass is achieved to suit the accuracy of the mass-measuring equipment. If the equipment measures to 0.1 g then a test sample of at least 50 g is required. The sample may be less than 50 g if the equipment measures to 0.01 g.
- The initial masses of the test pieces (and usually the cover widths) are recorded. The test pieces are placed in the oven for at least 24 hours and then reassessed at four-hour intervals until there is minimal change in mass. For longer samples in denser species times of 48 hours or so may be required. The mass after drying in the oven (i.e. oven dry weight) is recorded.
- The moisture content is then calculated for each test piece by applying the following equation:

$$\text{Moisture content (\%)} = ((\text{Initial mass} - \text{oven dry mass}) / \text{oven dry mass}) \times 100\%$$

For example, if the initial mass is 57.6 g and the oven dry mass is 43.3 g then the moisture content is: $\text{Moisture content (\%)} = ((57.6 \text{ g} - 49.3 \text{ g}) / 49.3 \text{ g}) \times 100 \% = 16.8\%$

- This method provides the average moisture content for the test pieces. Case and core measurements can be obtained by cutting the appropriate sections out of larger test pieces prior to testing.

Interpreting results

- The sampling method outlined above aims to capture the variation present in a pack of timber and from this it can be assumed that most of the timber within the pack will fall within the upper and lower moisture content measurements.
- In applications where cover width is important, both the cover width and the moisture content should be considered. Often boards of lower cover width are also those of higher moisture content and further shrinkage of this material can be expected.

Benefits and limitations

- The main advantage of this method is its accuracy.
- The method is time consuming, not portable and more expensive.
- The most common error results from insufficient drying, which underestimates the moisture content. If sample masses are small then measuring errors can significantly affect the moisture content calculation.
- Microwave ovens can produce good results and speed up testing, however there are no formal procedures and there is the risk of evaporating volatile compounds in addition to the water which affects accuracy.

Resistance Meter

Principle of operation

The electrical resistance of timber reduces as the moisture in timber increases. These meters measure the flow of electricity between two pins where the timber acts as an electrical resistor between the pins. The scale on the moisture meter is graduated to read moisture content. Wood temperature affects the readings and for this reason wood temperature above or below 20°C requires correction to the reading. Temperature correction, if not already taken care of by the meter, is applied before species correction. Species correction is necessary as two different timber species at the same moisture content may not have the same electrical resistance. Meters are generally set up relative to one species and that is Douglas Fir (Oregon) and species corrections are then applied for other species. There comes a point where the water in timber is so low that the resistance is difficult to measure accurately, or on the other hand is sufficiently high that the resistance does not change greatly and is prone to greater errors. These meters generally provide reliable results between 6% and 25% moisture content.

Types of meters

A wide variety of meters is available. All have two pins that are used to penetrate the timber but the pins may vary in length from about 6 mm up to 50 mm. The longer pins are often insulated up to the pointed ends to prevent surface moisture effects from interfering with core measurements. Those with longer pins are also usually of the 'sliding hammer' type, which provides a means of driving the pins into the timber. The sophistication of the meters varies greatly in terms of features such as in-built temperature correction, preprogrammed species calibration and depth indication. Many of the meters now come with a calibration block.

Using resistance meters

- The calibration of the meter should be checked prior to use and this is usually done with a test block that contains electrical resistors that correspond to the moisture contents specified on the test block.
- Measurements are then taken in clear timber at least 400 mm from the ends of boards.
- Some meters require measurements to be taken with the pins running down the length of the board, while with others the pins are to run across the width of the board (check with the manufacturer's manual).
- The pins are driven to the desired depth to which the moisture content reading is required. As case and core measurements can be significantly different, use of meters with short pins may require boards to be cut and the pins inserted in the end grain to provide a better estimate. In high density timbers, holes may need to be drilled for the pins.
- The pins need to be in firm contact with the timber, otherwise low readings may occur.
- Readings should be recorded to the nearest 0.5% and read shortly after penetration.
- Each reading is to be corrected for wood temperature first (provided this is not done automatically) and then for species (providing the species has not been set on the meter).

- Refer to Table B.1 for temperature correction factors and species correction factors for some common commercial species. Additional temperature and species correction factors are available in AS 1080.1.

Limitations, accuracy and precautions when using resistance moisture meters

When using meters, a common sense approach is necessary and each reading should be evaluated and if not as expected, then the reasons for this should be investigated. The meters generally provide a reasonable estimate of the moisture content to $\pm 2\%$ in the measuring range from 8% to 25% and as stated above readings should be recorded to the nearest 0.5%. There are a number of factors that are known to affect meter readings and these are:

- Measurement necessitates damaging the surface of the timber.
- The method is conducive to only taking a relatively small number of sample readings.
- Readings near the board surface can be significantly different from the core.
- Low battery can cause low readings in high moisture content material.
- Uncertainty over species they are being used in can make species corrections difficult.
- Species such as Brush Box have very high species correction factors and are prone to greater error.
- Use for extended periods in high humidity environments can raise meter readings.
- Meters only read the wettest part that the exposed surfaces of the pins are in contact with.
- Surface moisture can provide artificially high readings not reflecting wood moisture content.
- Salt water or any preservative treatment salts can affect meter readings and will usually raise them.
- Electrical wiring in walls can affect the readings.
- If meter readings are not in line with what is expected, this may necessitate oven dry testing to more accurately estimate the moisture content.

Capacitance Meter

Principle of operation

These meters measure an electrical property called the 'dielectric constant' and in so doing an electric field produced by the meter and the presence of the timber on which the meter is positioned, form a 'capacitor' type of arrangement. The electric field can penetrate deep into the timber but meter readings are biased toward moisture in the surface layers. Both the moisture content and the density of the timber affect this electrical property. The effective range of capacitance meters is from approximately 0% to 30% moisture content. The more sophisticated meters can be adjusted for timbers of different densities. Less expensive meters do not have density compensation and for these meters corrections to meter readings must be applied based on the density of the species being tested. Such meters are usually preset to be more suited to softwoods and lower density hardwoods and this can cause limitations with higher density species (i.e. large correction factors are necessary).

Types of meters

Meters are imported from overseas and range from those with few features to those with a wider range. Features may include settings for timber density (or specific gravity) and timber thickness as well as the ability to store readings and apply some statistics to the results. It is necessary to ensure that the meter is going to meet your specific needs and if being used with higher density hardwoods then timber density (or specific gravity) adjustment must be seriously considered.

Using capacitance meters

- The appropriate meter settings for density and board thickness, etc, should be applied and the meter checked for calibration.
- The density (specific gravity) is often calculated differently for different reasons (i.e. green density, density at 12% moisture content or basic density). Specific gravity is the density of a material divided by the density of water (about 1000 kg/m³). It is necessary to obtain from the meter supplier the relevant figures applicable to the meter being used. Table B.2 provides densities at 12% moisture content.
- Measurements are then taken in clear timber away from knots, etc.
- Some meters require measurements to be taken with the meter in a particular orientation on the board (check with the manufacturer's manual).
- The plate of the meter must be in firm contact with the board before a reading is taken.
- Readings should be recorded to the nearest 0.5%. If no density (specific gravity) settings are available then these meter readings need correcting.

Limitations, accuracy and precautions when using capacitance moisture meters

Similar to resistance meters, common sense must prevail when using these meters with readings evaluated and investigated if not as expected. Providing the density is accurately assessed then these meters also provide a reasonable estimate of the average moisture content in a board up to about 25% moisture content. Again there are a number of aspects that need to be considered when using these meters:

- Readings can be taken very quickly both within a board or in a number of boards.
- The meters do not damage the surface of the timber that is being measured.
- Within species density variations can be quite high, particularly between mature and young growth material.
- Estimating the correct density adjustment can be difficult, particularly if the meter is being used on a wide range of different timbers.
- Density (specific gravity) information for Australian species relating to specific meters is not well documented.
- Difficulties with setting density (specific gravity) adjustment often reduces field measurement accuracy.
- If no timber thickness adjustment is provided then thicker pieces at the same moisture content are likely to read high.
- Any gap between the meter and the board (e.g. a cupped surface) will cause lower readings.
- Framing raises meter readings where exposed timbers cross (e.g. softwood floor over hardwood joists).
- The presence of salts (either from salt water or preservation treatment) will cause readings to be higher.
- Readings also considered to be less reliable with Brush Box.
- Again, if meter readings are not in line with what is expected, this may necessitate oven dry testing to more accurately estimate the moisture content.

Assessing timber moisture content for conformity

Australian Standard 1080.1 – Timber – Methods of Test – Method 1: Moisture content outlines a procedure for moisture content acceptance testing of timber using a resistance moisture meter. For full details the standard should be referred to. Provided below is a summary of the procedure:

- Sample at least one pack out of every ten or one pack out of every five for higher value products (e.g. flooring).
- For each pack assessed (of up to 200 boards per pack) 15 boards are randomly selected and tested.
- The pack is deemed to comply if not more than one test result (after applying temperature and species correction factors) is outside the allowable range. This is providing the result outside allowable limits is not too different from other results.
- This sampling procedure is based on at least 90% of the samples falling within the allowable range.

Measuring the moisture content of plywood and particleboard

Meters do not provide an accurate and reliable measure of moisture content in these materials. To determine the moisture content of these materials, the oven dry method should be used.

Table B.1: Temperature correction factors for resistance moisture meters.

(Note: This is wood temperature not air temperature.)

Meter reading %	8 %	10%	12%	14%	16%	18%	20%	22%	24%
Wood Temperature	Temperature correction to be added to or subtracted from meter reading before applying the species correction factor								
15 °C	Nil	Nil	+1	+1	+1	+1	+2	-	-
20 °C	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	-
25 °C	-1	-1	-1	-1	-1	-1	-1	-1	-
30 °C	-1	-1	-1	-2	-2	-2	-2	-2	-2

Table B.2: Species correction factors for resistance moisture meters.

Meter reading %	8 %	10%	12%	14%	16%	18%	20%	22%	24%	Density
Species	Resistance meters are generally calibrated to Oregon (Douglas Fir). Apply the following species corrections after temperature correction.									At 12% MC
Oregon (Douglas Fir)	0	0	0	0	0	0	0	0	0	550
Australian Hardwoods										
Yellow Stringybark (NSW)	+4	+4	+3	+3	+2	+2	+1	+1	0	900
Red Ironbark Broad Leaved & Red (NSW)	+4	+3	+3	+3	+2	+2	+2	+1	+1	1100
Grey Ironbark (Qld)	+3	+2	+2	+2	+2	+2	+2	+2	+1	1105
Forest Red Gum – Blue Gum (Qld)	+3	+2	+2	+2	+2	+1	+1	+1	0	1000
White Mahogany – Honey Mahog. (Qld)	+2	+2	+2	+2	+2	+2	+2	+2	+2	1000
River Red Gum (Vic regrowth)	+2	+2	+2	+2	+2	+2	+2	No data	No data	900
Rose Gum – Flooded Gum (Qld & NSW)	+2	+2	+2	+1	+1	0	0	0	0	750
Sydney Blue Gum (NSW)	+2	+2	+1	+1	0	0	-1	-1	-1	850
Blackbutt (Qld & NSW)	+1	+1	+1	+1	+1	+1	+1	+1	+1	900
Turpentine (Qld & NSW)	+1	+1	+1	+1	+1	+1	+1	+1	0	950
Blackbutt (NSW regrowth)	+1	+1	+1	+1	+1	0	0	0	No data	900
Grey Ironbark (NSW)	+1	+1	+1	+1	0	0	0	0	0	1100
Red Ironbark Narrow Leaved (Qld)	+1	+1	+1	0	0	0	0	0	0	1090
Blackwood (Tas)	+1	+1	0	0	0	-1	-1	-2	-2	640
Myrtle (Tas)	+1	+1	0	0	-1	-1	-2	-2	-2	700
Spotted Gum (Qld Citridora)	+1	0	-1	-1	-2	-3	-3	-4	-5	1100
Shining Gum (Vic)	+1	0	0	0	0	0	0	-1	-1	700
Jarrah (WA regrowth)	0	0	+1	+1	+1	+1	+1	+1	No data	780
Grey Gum (Qld & NSW)	0	0	0	0	0	0	0	0	0	1050
Tallowwood (Qld & NSW)	0	0	0	0	0	0	0	0	0	1000
Alpine Ash (Vic & Tas regrowth)	0	0	0	0	0	0	-1	-1	No data	650
Mountain Ash (Vic & Tas regrowth)	0	0	0	0	0	0	-1	-1	No data	650
Messmate (Vic & Tas regrowth)	0	0	0	0	-1	-1	-1	-1	-2	750
Southern Blue Gum (SA plantation)	0	0	-1	-1	-1	-2	-2	-3	-3	700
Spotted Gum (NSW Regrowth Maculata)	0	-1	-1	-2	-3	-4	-4	-5	-5	1100
Brush Box (Qld & NSW)	0	-1	-2	-3	-4	-5	-6	-8	-9	900
Manna Gum – Satin Ash (NSW)	-1	-1	-1	-1	-2	-2	-2	-2	-3	800
Imported Hardwoods										
European Beech	+3	+3	+3	No data	690					
Kwila / Merbau (Malaysia)	+2	+2	+2	+2	+1	+1	+1	+1	+1	850
Sugar Maple (Nth America)	-1	0	+1	+1	+1	+1	+1	+1	No data	740
Softwoods										
Araucaria – Hoop Pine (Qld & NSW)	+3	+2	+2	+2	+1	+1	+1	0	0	550
Radiata Pine (Vic)	+2	+2	+2	+2	+2	+2	+2	+2	+2	550
Cypress (Qld & NSW)	+2	+1	+1	+1	+1	+1	+1	0	0	700

Notes: No correction factors are published for Gympie Messmate, New England Blackbutt or Northern Box. Oven dry testing is the preferred method for Brush Box. Table only contains some common species – refer to AS 1080.1 and FWPRDC report PN01.1306 for a more complete list. The tabled figures are based on the Deltron Moisture Meter. Figures may differ for other meters – refer FWPRDC report PN01.1306).

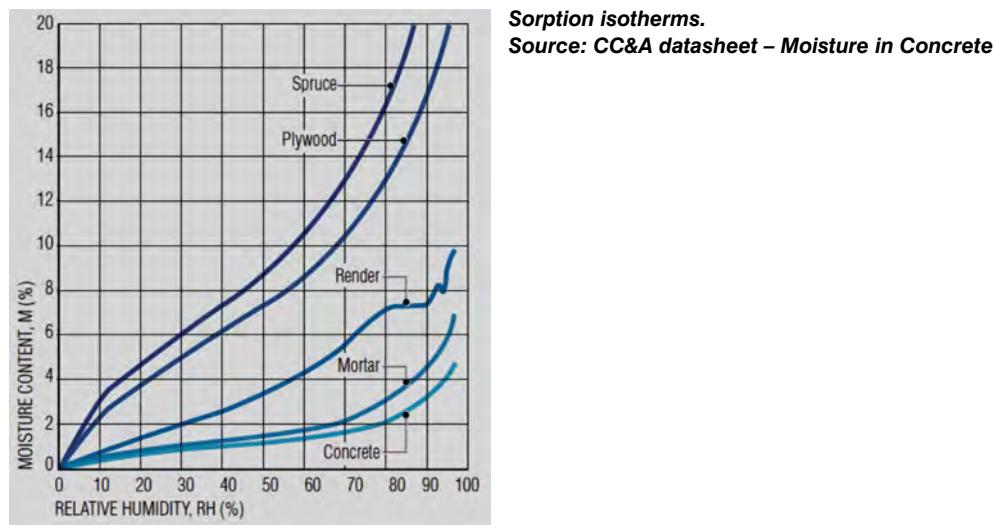
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Appendix C – Slab Moisture Assessment

Properties of Moisture in Concrete

Concrete is a porous material that is able to hold water and water vapour in small voids or pores within its structure. Similar to the cells in timber, the pores can be saturated and full of water or moisture can also exist inside the pores as a vapour.

It is possible to determine the moisture content of concrete by the oven dry method, similar to timber, but with concrete it is also possible to determine the quantity of moisture vapour held within the pores by measuring relative humidity within a slab.



Another similarity to timber is that water vapour will move in and out of concrete depending on atmospheric conditions and the relative humidity within a slab will remain quite high until the water in the pores has evaporated. At this point the moisture content of the concrete is near 2%. However, when concrete is near saturation the moisture content is only about 5% or so.

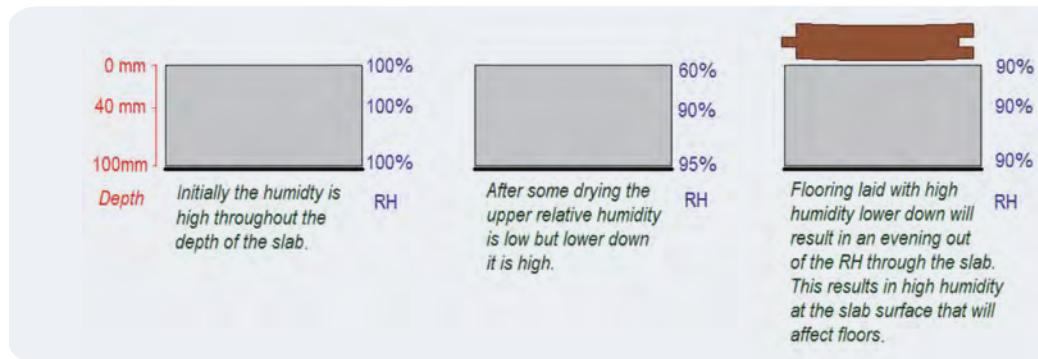
Referring to the graph above it is apparent that once both timber and concrete have lost their 'free water' from inside their cells and pores then under conditions of 75% relative humidity timber attains a moisture content of approximately 14% and concrete about 2%.

When concrete cures, a hydration reaction occurs that uses up much of the added water, however, even after curing the pores will contain a significant amount of water, similar to the water within the cells of a board that has been freshly cut from a tree. In both cases, it is from here that drying begins with the lower relative humidity air of the surroundings causing evaporation from the surfaces and this continues until the 'equilibrium moisture content' is achieved. Similarly, with both materials the thicker either the board or slab is, the longer it takes to dry.

With timber, we know that density affects the drying rate. With concrete, the water-cement ratio can and does vary and the lower that this ratio is, the shorter the drying time. Lower water-cement ratio concrete also results in less permeable higher strength concrete. With a water-cement ratio of 0.5, drying will generally be achieved within three months. Concrete will be slower drying in higher humidity lower temperature conditions or with higher water-cement ratios.

When measuring the moisture content of an unseasoned timber post, the moisture content soon becomes much lower near the exposed surface than in the core. The same principle applies to a concrete slab. If we were to measure the relative humidity throughout the depth of a slab as it dried it may initially be close to 100%. Over time, the relative humidity may reduce to, for example, 50% near the surface, but toward the lower surface of the slab it may still be well over 90%. In either case, a surface moisture content reading is not going to provide an indication of the moisture held deeper within the post or toward the bottom of the slab.

If a timber floor is laid directly over a concrete slab prior to it drying from lower down, then moisture will migrate to the slab surface and affect the timber floor. This is illustrated in the diagram below for a 100 mm thick slab over a ground vapour barrier.



Relative humidity redistribution in a concrete slab as it dries.

From the diagram above it is evident that surface moisture measurements cannot be relied on to ensure performance of a timber floor above and for this reason in-slab relative humidity measurement is gaining in popularity around the world. You will also note in this example that with flooring laid over the slab the relative humidity at 40 mm or 40% of the depth of the slab is the same at 90% relative humidity prior to and after the flooring was laid. It has been found in slabs that dry from one side only, measurements taken at 40% of the slab depth provide a close approximation to the relative humidity that will occur beneath the floor covering at some later date. If able to dry from both sides then measurements at 20% of the slab depth are applicable.

Timber Floors and Concrete Slabs

Whenever a timber floor is laid over a concrete slab it is important that the slab is sufficiently dry irrespective of the method of installation of the timber floor. As an added precaution a polyethylene vapour barrier or slab moisture vapour barrier can be used directly over the top of the slab. Note that it is NOT recommended that such barriers be used to compensate for slabs where slab age is young and other testing indicates that slab moisture levels are high. A moisture vapour barrier will still permit the transfer of some moisture and the rate is to some degree dependent on the moisture within the slab. In such instances the flooring could still be affected. Note that not all moisture vapour barriers used on concrete are recommended for use with timber floors. Appropriate measures must also be taken when there are construction joints or where a new slab is added to an existing slab.

It is important to ensure that slabs have ground moisture barriers beneath them that comply with AS 2870. These barriers separate the concrete from possible sources of moisture that may delay or could prevent the concrete from drying adequately. Provided they are installed correctly, water vapour transmission through them is minimal. It has been shown that such barriers form close contact with the slab, preventing lateral moisture movement between the two. Puncturing or gaps can result in localised areas of higher moisture and slab edge dampness also needs to be considered.

With a water-cement ratio up to 0.5 (although likely to be a little higher in house slabs) three months drying should be sufficient in a 100 mm thick slab drying from one surface only, for a 150 mm thick slab six months and for a 200 mm thick slab 12 months. If drying from both sides of the slab then these times are halved. However, relying only on slab age is not sufficient as experience has indicated that in some instances moisture-related problems have still occurred. At the time of floor installation you will generally not be aware of what the actual water-cement ratio was (or if water had been added on site), how well the ground moisture vapour barrier was installed or how well the concrete was placed. The presence of beams also needs to be considered. As indicated above aspects such as weather, including temperature and humidity, also influence drying. Therefore, regardless of the age of the slab, its moisture levels require further assessment prior to laying a timber floor.

Measuring Slab Moisture

There are various methods of measuring the moisture content of slabs and similar to timber, these include both types of electronic moisture meters. However, there are also other means that measure the vapour emission from the slab. These tests include a simple polyethylene film test, use of a hygrometer to measure the humidity above or within a slab and use of various chemicals.

Preferences of test method vary considerably and each has its limitations. Meters or use of a hygrometer are often preferred as they are relative quick and easy to use and results may be recorded. However, as with any electrical instrument, the accuracy of the instrument needs to be taken into consideration and periodic calibration checks are necessary. As with all testing, the results need correct interpretation.

It is evident from the above that what is important is the potential amount of moisture that can be released from the slab as well as the rate at which it is released. Test methods and equipment have been developed for each but each has its pros and cons.

A qualitative test was developed where clear polyethylene film or glass is fixed over the slab and condensation or darkening of the concrete after 24 hours can indicate a high release rate of moisture from the slab. However, this simple method has been found unreliable as it is temperature dependent and results at times have indicated that slabs were dry when they were not. In the USA the moisture vapour emission rate (MVER) has been the standard test for many years. Calcium chloride readily absorbs moisture from the air and this method uses its increase in weight when encased above a slab to determine the moisture release from the slab. For timber floors 15g/m²/24 hr was deemed to be the upper limit. This method takes a number of days to complete and over the years has been found deficient under certain conditions. It also does not account for moisture deep in the slab. In New Zealand and some other parts of the world a relative humidity box above the slab has been used. In Australia moisture meters, either resistance or capacitance, have recently been used. As in other parts of the world, in-slab relative humidity measurements are being taken and this method is becoming increasingly accepted as providing more useful information about slab moisture.

Test methods and considerations relating to moisture meters and in-slab relative humidity are outlined below. However, with either method it must be remembered that the test provides no indication about how slab moisture may change seasonally or that outside moisture sources can affect the flooring system. Although the flooring contractor may not be responsible for such external influences, it is expected that the contractor would assess the moisture condition of the slab prior to floor installation.

With regard to this it would be appropriate to determine quite precisely when the slab was laid and assess moisture contents or relative humidities along with the age of the slab. It should also be assessed when an older slab may not have a moisture barrier beneath the slab. These details need to be recorded for each job and for the installer to be satisfied with the results prior to proceeding.

Moisture Meters

Both resistance moisture meters and capacitance meters have been available for some years. Australian standards such as the pre-2007 version of AS 2455 (Textile floor coverings – Installation practice) specified that moisture contents below 5.5% were acceptable for resilient flooring and it appears that this figure was taken up by the timber flooring industry. In view of the information provided in the graph on page 62 on sorption isotherms, it would appear that this limit is consistent with a saturated slab. There have been many floors laid with readings of, for example, 4.5 to 5% where no problems were experienced. In other instances, however, readings of this level have been associated with floor moisture issues. Due to this quandary and the fact that meters (particularly capacitance meters) only measure within 25 mm of the concrete surface, their use can provide guidance and be useful for comparative purposes but should only be used as part of the assessment. With one brand of capacitance meter, readings of 6% to 7% have been recorded on a slab that was a few days old and on a 5-year-old slab with no moisture concerns, readings of 1.7% to 2.0%. This is in line with data in the graph on sorption isotherms.



The availability of resistance moisture meters has reduced and the use of capacitance moisture meters has increased. The capacitance meter has the advantage of being able to perform many tests very quickly over the slab and therefore for the purpose of doing a quick survey and comparing different areas it has significant benefits. Finally, it should be noted that additives as used in some parts of the country may have an effect on meter readings.

In-Slab Relative Humidity

In the USA the test method is covered by ASTM F2170 'Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs using in-situ Probes'. Simply, the method involves drilling a hole in the slab, inserting a capped sleeve, waiting a period of time and then inserting a probe to measure the relative humidity of the air in the hole in the slab. Various specifics of the testing requirements are:

- The in-service conditions of relative humidity and temperature are to be maintained for 48 hours prior to testing (21°C to 29°C and 40% to 60% RH).
- The depth of the hole is 40% of the slab thickness if drying is from one surface or 20% if drying from two surfaces.
- The hole is sealed for 3 days to allow the internal relative humidity of the air in the holes to become the same as that of the concrete. The probe must be given time to equilibrate before taking a reading.
- Three tests are required for approximately 100 m² of floor area.

There has been much discussion about acceptable in-slab RH levels and no clear guidance is available at this stage. In some literature a maximum value of 75% is suggested, in other literature specific to parquetry floors a figure of 60% is quoted. However, in humid climates it may be difficult to achieve 60%. Literature is also not clear whether there is a difference between above-slab relative humidity limits and in-slab relative humidity limits. Similarly, companies producing measuring equipment do not provide guidance in this area.

Considerations for house slab assessment

When considering house slabs a check list, such as the one below, can be used to assess the risk. Note that there can be differences between the readings of capacitance meters and the limits in the table provided may differ and need to be determined, depending on the meter and locality.

If the answer to any of the following questions is 'no' then risks are greater and need to be considered.

1. Is the slab height/floor >150 mm above ground level (including above external patios)?
2. With slab surface testing, was the slab found to be sound, flat and with no hollow sounds under any patches?
3. Do water droplets readily absorb into the slab?
4. Is the slab known to be of an age where an under-slab moisture barrier was a building requirement?
5. Moisture testing (refer to table) – If using a capacitance meter, record at least 20 readings including all internal and external corners and where possible slab thickenings or beams may be present. Are all readings in the moderate to low range of the table? If using an in-slab Hygrometer are the readings below 75%?

SLAB AGE	MOISTURE CONTENT	RISK
< 3 Months	-	Very High
3 Months	Up to 5%	High
3 to 6 Months	Up to 4%	Moderate
6 Months - 3 yrs	Below 2.75%	Low
6 Months - 3 yrs	2.75% to 3.5%	Moderate
6 Months - 3 yrs	Over 3.5%	High
> 3 years	Over 3.5%	High

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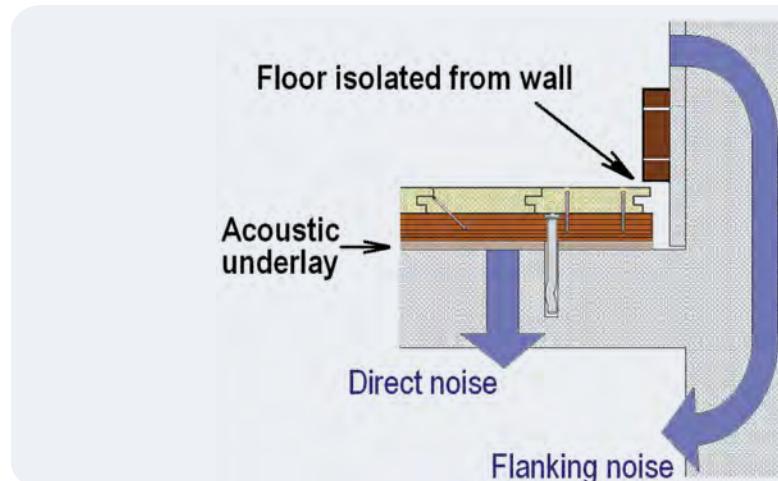
Appendix D – Acoustic Performance

Timber floors are used in many multi-storey apartments, both in new construction and renovation work. With new projects, building regulations often apply restrictions to sound transmission between units and in renovation work the noise associated with any replacement floor can often be no greater than the original floor. With regard to sound transmission, timber flooring is similar to other hard flooring surfaces and, in particular, it will freely transfer impact sounds. For this reason, it is necessary to ensure correct detailing and installation measures in order to provide a floor system with the required sound performance.

Noise Transmission Through Timber Floors

Whenever the acoustic performance of a material is being tested great care is taken to ensure the material is isolated so that only the sound transmission through that material is being tested. When materials are not isolated, as occurs in building, that is floors connected to walls and walls being common to upper and lower storey units, additional non-direct sound transmission paths or ‘flanking’ paths are introduced. Sound from a floor above can then radiate from the wall surfaces in the unit beneath and this can contribute considerably to sound transmission between units.

This indicates that great care is necessary in building design and detailing to provide effective solutions and the system needs to consider providing isolation, absorptive materials and increased mass (i.e. slab thickness). Each of these is important in order to reduce sound transmission. Timber floors, as with other hard floor surfaces, are particularly affected by impact noise resulting from foot traffic.



Acoustic underlay and floor isolation significantly reduces direct and flanking noise transmission.

Approaches to Improve Acoustic Performance

Timber floors on battens

Timber floors over concrete slabs are often fixed to battens which are, in turn, directly fixed to the concrete slab. To provide a degree of isolation between the slab and the batten, resilient pads may be used between the batten and the slab. Fixing of the batten to the slab is still necessary and this will result in some sound transmission. Generally, thicker battens require less frequent fixing and thereby reduce the frequency of direct fixing. With battens at 450 mm centres, 19 mm strip flooring may be used for domestic loading. The flooring may be secretly fixed to 19 mm thick hardwoods batten or top (face) nailed. If top (face) nailing is used the hardwood battens need to be at least 35 mm thick. For more specific details of floor fixing refer to Section 3 of this manual.

Timber floors over sheet floors

This system utilises a complete sheet of acoustic underlay over an existing timber floor or slab. A plywood sub-floor is then laid over the acoustic underlay and fixed to the slab or timber floor beneath. Again, the fixing of the sub-floor will result in some sound transmission. Both 19 mm thick and overlay flooring may be used in this instance as the boards are fully supported. Secret fixing with the addition of a polyurethane flooring adhesive is generally used to fix the boards. More specific floor fixing details are provided in Section 3 of this manual.

Other Important Considerations

Selecting the underlay and isolation pads

The purpose of the underlay or pads is to provide isolation of the timber floor from the building elements beneath. Many products are available and each should have test data relating to performance.

- Pads need to be sufficiently thick to ensure separation is maintained when the floor is being walked on.
- The product needs to be rigid to prevent compression when the floor is walked on.
- It needs to provide long-term performance without flattening, particularly under heavy appliances and furniture.

Isolation at floor edges

It was outlined above that isolation is a key aspect to prevent flanking sound transmission. Gaps need to be maintained between the flooring and all walls, steps, window joinery, etc, and a small gap is also necessary between the skirting and the floorboards.

Further improvements

Improvements in sounds transmission from a floor to a unit below can also be achieved at the design stage by ensuring that the slab is of adequate thickness. An extra 25 mm in slab thickness can make a significant difference to sound transmission. In addition to this, ceiling systems can also be used which isolate the sound source (i.e. timber floor) from the unit beneath. These systems generally consist of a grid of isolation mounts with furring channels attached. Insulation and plasterboard complete the system. With multi-residential timber framed construction (MRTFC) two layers of fire-rated plasterboard are used. Such systems are effective and are considered to be relatively economical. Finally, rugs, hall runners and mats used in conjunction with timber flooring can not only complement the timber floor but, with their sound absorbing properties, can also reduce noise levels both within and between units.

Appendix E – Underfloor Heating

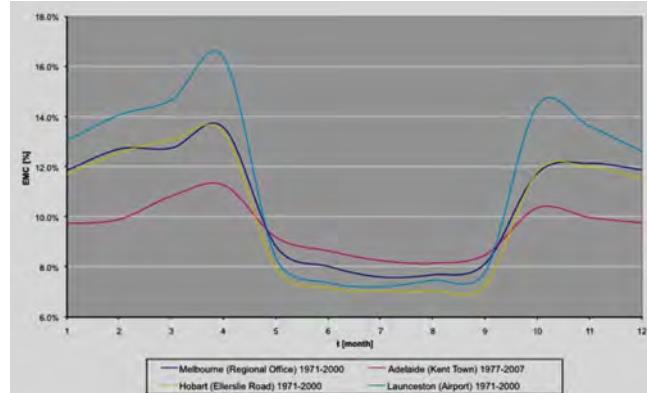
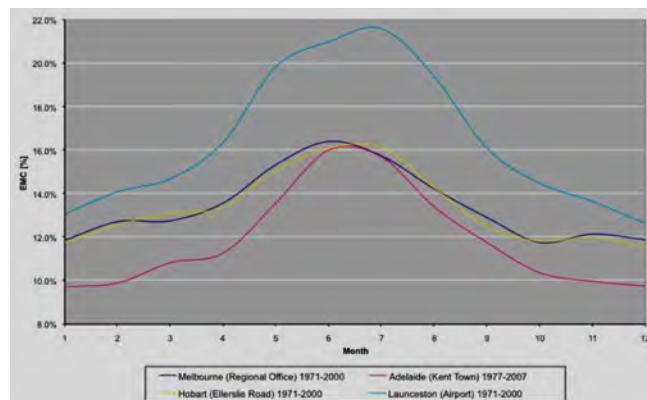
Timber Floors and Underfloor Heating

Timber floors with underfloor heating systems (UFH) are common in Europe and North America. In the cooler southern states of Australia they are not common, yet public interest is increasing. Due to the limited number of installations, experience in Australia is limited, particularly with the medium and higher density hardwoods that are available. Research by the Centre for Sustainable Architecture with Wood (University of Tasmania) has recently evaluated the use of overseas practices with the performance of Messmate and Blackbutt. Floors with an underfloor heating system in place were monitored in Tasmania over a period of time, through winter and summer. This appendix provides guidance regarding the installation of timber floors over underfloor heating systems and is relevant to the southern states of Australia.

The Climate Experienced with Heating Systems

Temperature and relative humidity are the two key factors that influence the internal climate or environment within a dwelling. An increase in the temperature inside the dwelling will cause a lowering of the relative humidity and with this the drying capacity of the air increases. Low relative humidity will result in timber flooring releasing some of its moisture to the air, and thereby reduce in moisture content and shrink. The moisture content of a floor is affected by changes in the heated environment. The term equilibrium moisture content (EMC) is often used. EMC can be thought of as the moisture content that timber will attain under set conditions of relative humidity and temperature. If the conditions inside a dwelling are maintained at 20°C and 60% RH then the flooring, depending on its current moisture content, will either take up or lose moisture to try to attain a moisture content of about 11%.

The external EMC can be calculated from weather data and the graph below illustrates how this varies seasonally for the southern states. The external RH during winter is high and in summer it is much lower. When cooler external air is then heated, as in an internal environment, the RH and therefore the EMC drops significantly. The Tasmanian study calculated the effect of EMC values resulting from heating to 20°C for the period from May to September and this is shown in the lower graph.



Source: FWPA Project PN07.104 – Advanced Research into Floor Performance Issues – University of Tasmania – 2008.

As can be seen from the preceding graphs the effect is dramatic and suggests that the conditions associated with a heated internal environment will result in EMCs between 8% and 9% during the heating period. Note that both graphs are based on external relative humidity values and a less extreme variation would be expected inside a dwelling. Even so, the flooring needs to be able to cope with very dry conditions during the heating period over winter and moderate rises in moisture content over summer. While this can be catered for, there is an obvious concern if the UFH system was not to operate for a significant period over winter as this could create expansion that was greater than would occur over the summer months.

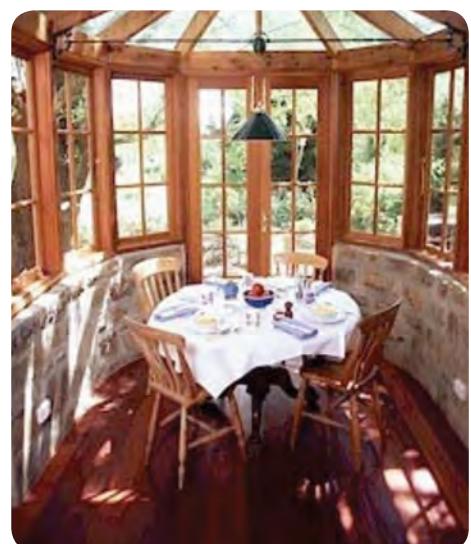
Choice of Timber Flooring

In the Tasmanian research undertaken two species were chosen, Messmate, a medium density hardwood, and Blackbutt, a higher density hardwood. Both species are known to be relatively responsive to moisture uptake and loss from the air, however, under floor expansion the Blackbutt would tend to crush less at board edges and result in greater expansion forces. Blackbutt is also usually backsawn whereas Messmate is usually quartersawn. For the same increase in moisture content a backsawn board will swell more than a quartersawn board. The cover width of the 19 mm thick flooring used in the research was 85 mm for Tasmanian Oak and 80 mm for Blackbutt.

In the United Kingdom recommendations are to limit board width to 75 mm with underfloor heated applications, however, with American Oak, a cover width up to 130 mm has been found to give good results. It is not recommended that board widths in Australia exceed 130 mm and the preference is for 80 mm or 85 mm boards in these applications to minimise gapping and the potential for a cupped or crowned appearance.

The Tasmanian research indicated that 19 mm thick flooring was considerably more robust to effects of cupping than 12 mm thick overlay material. It must be considered that in times when heating may not be on and floor expansion occurs, then the thinner boards will be more reactive and the risk of cupping is very high. For this reason a board thickness of 19 mm is recommended.

Concerning the moisture content of the flooring, AS 2796 indicates a normal manufacturing range of 9% to 14%. However, research has indicated that 8% to 9%, which is near the middle of the expected internal seasonal range in Australia's southern states, is more appropriate. Overseas, an average of 8% is often recommended. In Australia it is unlikely that manufacturers will produce specific batches of flooring at these low moisture contents. Much of the flooring is produced to the lower end of the 9% to 14% range of AS 2796 and flooring packs with boards averaging 10% are likely to be available. To obtain this, close liaison between manufacturer or supplier and the installer would be necessary. To determine suitability, the proposed flooring would need to be sampled and oven dry testing undertaken to determine exact moisture contents. This can be expected to add some cost but is considered important. Also, great care of the lower moisture content flooring needs to be taken to ensure minimal change in moisture content prior to laying. Irrespective, some gapping at board edges after installation can be expected as a result of the underfloor heating.



Sydney Blue Gum floor with underfloor hydronic heating.

Heating System Considerations

Heating systems used with solid timber floors range from hydronic heating, where warm water is piped through a concrete slab beneath the floor, to electric heating systems beneath the floor. It is necessary that the client makes available to the floor installer full installation and operating instructions of the system that is in place, and that the system or proposed system is considered compatible with solid timber floors by the heating system manufacturer.

Even heat distribution is vitally important as hot spots can cause greater board movement (shrinkage or cupping) in some areas of the floor compared to others. Pipes within a slab set at different heights can be the cause of this and the installer should make the client aware of this possibility.

The client should also recognise that with seasonal operation of the system some gapping and change in board shape (slight cupped or crowned appearance) is likely and particularly so if the client has chosen wider boards.

The client also needs to be made aware of the constraints to the system with regard to operating temperature and the need to avoid abrupt changes when adjusting floor temperature. Small increments of 2°C per day are appropriate and underfloor temperatures should not exceed 27°C.



**Blackbutt flooring (130 mm wide)
with electric underfloor heating in Adelaide.**

Typical Installation Procedures

Installation procedures in countries that more regularly lay floors over underfloor heating are relatively consistent but can vary in certain details.

A typical procedure, provided for guidance only as Australian experience is limited, involves the following steps:

1. Site conditions

The site should be free from all wet trades, be in a state where the dwelling can be lived in and with the heating system fully commissioned. The sub-floor should also have been levelled if necessary to accept the timber floor.

2. Pre-heat the sub-floor prior to laying to remove excess sub-floor moisture

The heating system needs to be operated for 2 weeks prior to floor installation to lower the moisture content of the sub-floor and particularly so if it is a slab to remove further moisture. The possibility of higher levels of humidity in the room during this process should be checked for and ventilation provided as required. When conditions are sufficiently dry, the flooring should be stored in the installation location in a manner that does not interfere with the drying of the sub-floor. During and particularly toward the end of this period the room conditions regarding temperature and humidity should be checked and the relative humidity should be in the range from 45% to 60% at a temperature of about 20°C. This equates to an EMC of 8.5% to 11%. The moisture content of the flooring to be laid should have already been thoroughly checked prior to supply to ensure that boards are generally 9% to 10% moisture content and this should again be checked prior to laying. Similarly, the sub-floor should also be checked to ensure it is suitable for accepting a timber floor. The sub-floor temperature should not exceed 27°C with in-slab heating. (With hydronic heating water temperatures may be 45°C or so to attain an underfloor temperature up to 27°C.)

3. Turn off the heating and follow this by a non-heating period

The period of time that the heating remains off is generally about two days.

4. Lay and fix the floor

If the floor is laid direct to a slab then an elastomeric polyurethane adhesive is used, and as this may differ from those used with normal floor installation, advice should be obtained from the adhesive supplier. For other types of sub-floor, normal fixing practices apply. Following installation the heating is to remain off for a further two days.

5. Gradually increase the UFH to normal expected temperature

The heating should be increased in stages from a low level to the desired room temperature over a period of about 10 days, incrementing by no more than 2°C each day, and then maintained for a further two weeks.

6. Sanding and finishing

Recommendations vary with some indicating that it should be carried out about 3 days after the heating was turned back on, while others indicate that the heating should be turned off and the floor sanded two days after the floor has cooled.

7. Turn the heating system on

The system with installed and finished floor can then be operated but again the temperature should be raised gradually to the desired operating temperature. With an UFH system in place the optimum relative humidity range is between 45% and 60% year round with room temperatures of about 18°C to 24°C.

F

Appendix F – Installation Checklist

Assessing Packs of Timber Flooring

Flooring Manufacturer:

Pack Nos:

Species/Species mix:

Cover width:

Grade:

Wrapping is in good condition and there are no signs of the product getting wet. Yes No

Boards should be checked for:

- **Cupping** (Use a steel rule or similar)
- **Cover width variation** (Should not vary by more than 1 mm between boards)
- **Tongue and groove tolerance** (Snug fit to slightly loose)



Note: Cover width variation exceeding 1 mm, sloppy T&G fit, signs of moisture or cupping may indicate possible problems.

Records

Widest Boards	Moisture Content	Cover Width	Cupping	Narrowest Boards	Moisture Content	Cover Width	Cupping
1				1			
2				2			
3				3			

Note: Ensure that the appropriate moisture meter corrections have been applied. Moisture contents should be between 9% and 14% (average between 10% and 12% is common).

Site Conditions and Installation Environment

Site location:

Average 9 am RH:

Average ext EMC:

Note: If the external EMC is greater than 2% higher or 1% lower than the estimated average moisture content then additional provision for future expansion or shrinkage needs to be considered (see Section 2).

If applicable, are sub-floor conditions dry, ground levels beneath dwelling not lower than external ground and graded to prevent ponding, ventilation to recommendations and ground sloping away from dwelling?

Yes No

Note: If 'no' then these issues may need to be attended to or other measures taken prior to installing the floor.

If the floor is laid on joists ensure the joists are sufficiently level.

If the floor is over a concrete slab or sheet sub-floor, are the sub-floors adequately level, dry and in good condition?

Yes No

Slab moisture contents or checks undertaken with the following results:

Slab level checked and within \pm mm in 1.5 m throughout (plywood or batten system).

Note: Maximum is ± 3 mm

If sheet sub-floors have become wet prior to or during construction and may not have sufficiently dried then moisture contents need to be checked. Moisture contents are as follows:

Note: Plywood and particleboard moisture contents need to be determined with oven dry testing. Sheet sub-floors should be within 2% of the timber flooring moisture content being laid over it. Slab moisture assessed in accordance with Appendix C.

If the floor is over a concrete slab then check it for construction joints and determine whether it has a moisture barrier beneath the slab.

Note: If construction or similar joints are present in slabs then possible moisture penetration from capillary action needs to be considered. Older slabs may not have moisture barriers beneath the slab and are more prone to seasonal moisture fluctuations that can affect timber floors.

The following slab moisture barrier as applicable has been applied to or over the slab:

Expected Movement After Installation

If wide board flooring is being used greater shrinkage can be expected during dry times.

In moist localities high levels of expansion can be expected (ensure adequate additional expansion allowance).

Is the building design such that the floor will experience high levels of sunlight or has heating/air-conditioning systems? (Drier in-service conditions can be expected at certain times of the year – shrinkage gaps more likely.) Is the underside of the floor exposed to dry winds or mist? (Sealing or protection to the underside of the floor needs to be considered to assist in controlling both expansion and shrinkage.) Is the floor an upper-storey floor (drier in-service conditions can be expected – shrinkage gaps more likely) or below grade in shady conditions? (Moister in-service conditions can be expected – ensure adequate expansion allowance – refer Section 2.)

Installation Moisture Content and Acclimatisation

Based on the expected in-service movement the following pre-installation procedures have been undertaken:

Note: Acclimatisation (flooring stripped out or loose laid) or provision of additional expansion allowance, etc, should be recorded.

Method of Installation

This floor is being laid by the following method:

Choice of Finish System

Based on the movement expected and condition of the floor at the time of sanding and finishing some floor finishes are more appropriate than others. (Possible issues such as wear, grain raise, edge-bonding and white lines need to be considered.)

The finish system used on this floor is:

Note: The above is provided as a guide only. Additional testing may be necessary or there may be the need for other considerations.

G

Appendix G – Troubleshooting Guide

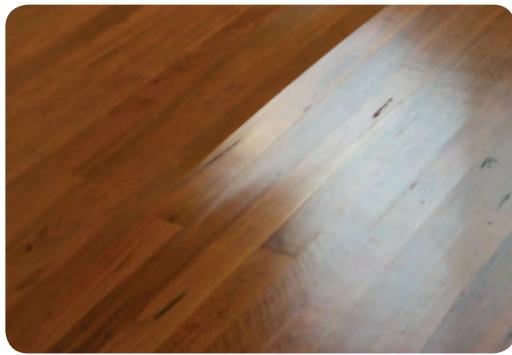
Performance of Timber Floors

In most instances timber floors perform well in a wide range of localities and with a wide range of installation practices depending on the sub-floor type. There can, however, be instances where the performance or appearance of the floor can be affected and the major contributing factors are:

- The manufacture of the product does not meet Australian Standards.
- Recognised installation and finishing procedures are not followed.
- Moisture ingress directly (e.g. leaks) or indirectly (e.g. seepage into sub-floor space).
- Aspects where the owner has not paid adequate attention to the floor.

The table below outlines some of the performance issues with timber floors, common causes and how they appear in the floor.

Performance Issue	Common causes	Appearance in the floor
Cupping	<ul style="list-style-type: none">• Moisture from beneath the floor.• Dry conditions above the floor.• High moisture contents in boards at time of manufacture.	<ul style="list-style-type: none">• Boards cup throughout the floor and the floor is tight.• Boards cup throughout but gaps are present at board joints.• Some boards in the floor will cup in the floor but not others.
Crowning	<ul style="list-style-type: none">• Moisture uptake and the floor sanded and finished in this condition.	<ul style="list-style-type: none">• During dry periods the floor gaps at board edges and develops a washboard look.
Peaking	<ul style="list-style-type: none">• High pressure on the upper shoulder of the board often resulting from atmospheric moisture uptake. Board tolerances and MC differences between supply and in-service also contribute.	<ul style="list-style-type: none">• The joints at board edges are raised. This can have the appearance of cupping.
Tenting	<ul style="list-style-type: none">• High expansion. May be directly related to high humidity or other moisture issues. May relate to inadequate expansion allowance, poor ventilation or inadequate fixing.	<ul style="list-style-type: none">• Adjacent boards in the floor rise at the joint above the level of the floor.
Buckling	<ul style="list-style-type: none">• High expansion. May be directly related to high humidity or other moisture issues. May relate to inadequate expansion allowance, poor ventilation or inadequate fixing.	<ul style="list-style-type: none">• A group of adjacent boards lift off the sub-floor.
Wide or irregular gapping	<ul style="list-style-type: none">• The finish gluing adjacent boards and the floor shrinking.• High moisture contents in boards at time of manufacture.• Boards inappropriately stored and have taken up moisture prior to laying.• Wide boards and dry conditions.	<ul style="list-style-type: none">• Loud cracking noises, irregularly spaced wide gaps and splits through boards.• Gaps at board edges associated with narrow cover width boards.• Frequent gapping and the measurement over sections of the floor is inconsistent.• Regular wide gaps.



Tenting resulting from atmospheric moisture uptake.



Wide gaps due to high moisture contents at the time of machining.

Sanding and Finishing Imperfections

A high standard of sanding and finishing can be expected, however some imperfections can be expected. The degree to which imperfections are apparent depends on many factors including timber colour and use of downlights, both of which can highlight such things as sanding marks and dust in the finish. Consequently, it is difficult to provide objective measures of finishing imperfections. Even so, it is known that a high standard of workmanship also provides an equally high standard of customer acceptance and satisfaction. When the appearance of a floor is being assessed, the assessment should be carried out in daylight hours with lights on and curtains or blinds in their usual position. Imperfections should be viewed from a standing position a few metres away and from various directions. If the imperfection is difficult to discern then the appearance is generally satisfactory. It should be noted that viewing any imperfection directly toward light sources, such as toward uncovered sliding external doors, will always exaggerate imperfections and this needs to be considered when evaluating the floor's appearance. In addition to this, aspects to be considered should include whether the imperfection is in excess of what would generally occur, whether it is likely to be covered by furniture or floor rugs and whether the imperfection will decrease in time with foot traffic. The table opposite outlines some of the sanding and finishing imperfections with timber floors, common causes and how they appear in the floor.



Rejection and contamination in the finish.

Appearance Issue	Common causes	Appearance in the floor
Rejection	<ul style="list-style-type: none"> Contaminants leaching out of the flooring affecting the curing of the finish. 	<ul style="list-style-type: none"> Ranges from a change in a localised gloss level to an 'orange peel' appearance.
Delamination	<ul style="list-style-type: none"> Movement of the timber at board joints or at the end of the board. Inappropriate sealers. 	<ul style="list-style-type: none"> The finish peels at board joints or board end.
Quilting	<ul style="list-style-type: none"> Surface coatings flow into the joints between boards. 	<ul style="list-style-type: none"> A lack of consistency of the coating over board joints highlighting the joints and giving a bed quilt appearance.
Contaminants	<ul style="list-style-type: none"> Floor not clean. Windy external conditions. Dust in gapped boards or under skirting. 	<ul style="list-style-type: none"> Small specks or insects in the finish which is often worse near poorly sealing external doors.
Ghosting	<ul style="list-style-type: none"> People walking on the floor at the time of sanding and finishing with certain types of boots and footwear or bare feet. 	<ul style="list-style-type: none"> After a period of 12 months to two years the appearance of a foot or boot print appears in the floor as a lighter colour.
Pimples	<ul style="list-style-type: none"> Fine air bubbles occurring during coating application. 	<ul style="list-style-type: none"> Popped bubbles in the finish.
White lining	<ul style="list-style-type: none"> The rapid stretching of waterborne finishes when boards gap. 	<ul style="list-style-type: none"> White lines appearing along board joints.
Edge bonding	<ul style="list-style-type: none"> Finish flowing into gaps at board edges and gluing boards together. Thinned finish used as a sealer and penetrating fine joints between boards. 	<ul style="list-style-type: none"> Wide irregular spaced gapping at board edges. Splits in boards.
Gloss variation	<ul style="list-style-type: none"> Weather conditions. Surface evenness of the boards. 	<ul style="list-style-type: none"> Shiny and dull patches in the finish.
Swirl marks	<ul style="list-style-type: none"> Rotary sanding particularly at the edges of floors. 	<ul style="list-style-type: none"> Circular swirling scratch marks.
Chatter marks	<ul style="list-style-type: none"> Vibration in the floor. Sanding technique. 	<ul style="list-style-type: none"> Undulations running across several boards.

For further information on the floor inspection process and many of the more common problems refer to the ATFA Publication 'Problems, Cures and Remedial Measures'.



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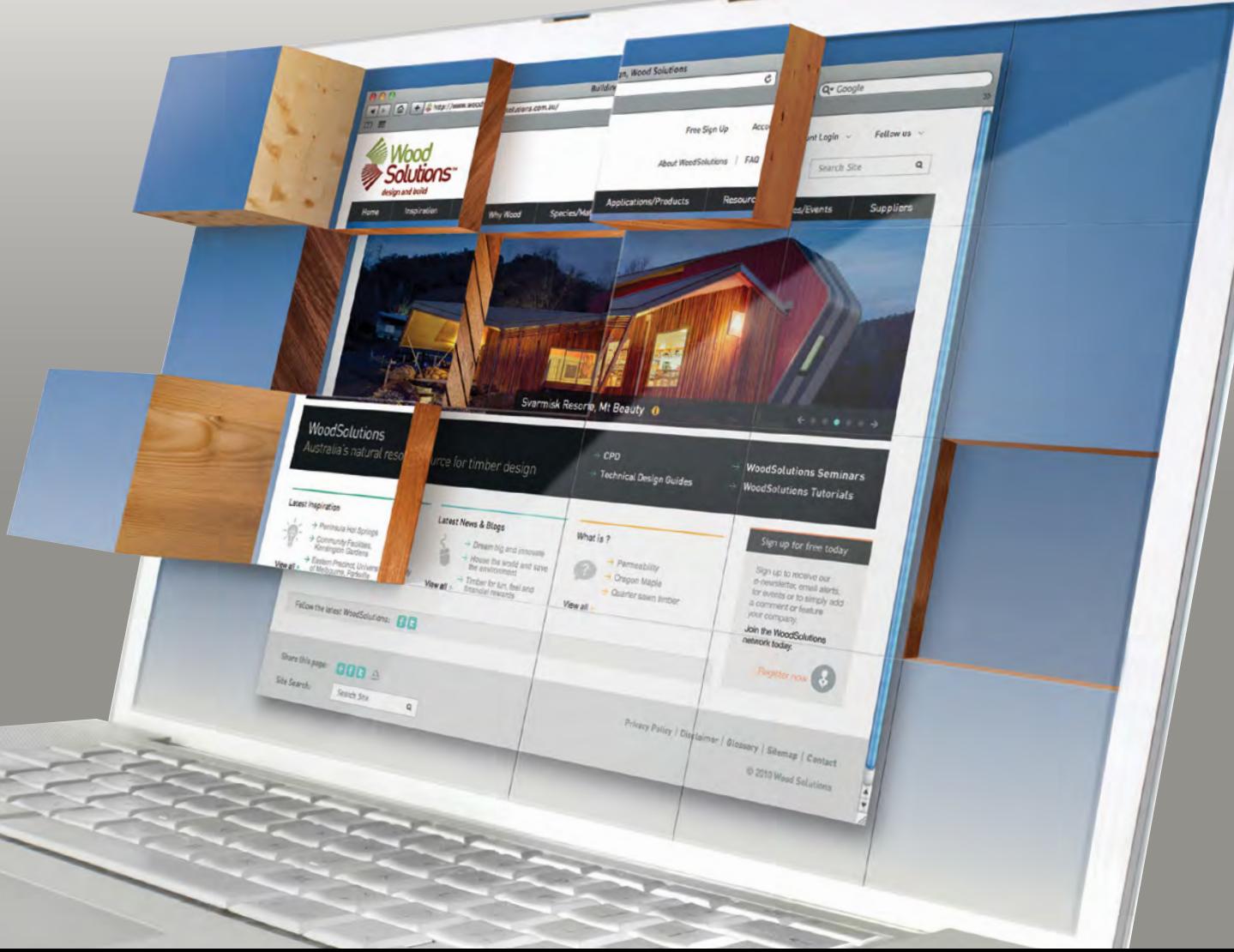
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