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Impact and Assessment of Moisture-affected Timber-framed Construction

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Introduction

Timber-framed construction is robust and resilient when subjected to adverse and extreme conditions, including those associated with moisture.

During construction, issues may arise that bring building to a halt, leaving frames and other parts of a building exposed to the weather for a time. Bad weather can also lead to properties being flooded. In rarer situations, flooding is caused by storm tidal surges in coastal areas.

When timber-framed construction experiences the effects of moisture, there are no simple rules to assess the impact. Each individual case will need to be assessed to determine the extent of any degradation, and the rectification or repair required. Factors and variables that can influence the effect of moisture exposure and rectification include:

- macro and micro climatic conditions
- length of time of exposure
- number and intensity of rain days
- sun exposure
- drying conditions and prevailing winds
- temperature
- degree of protection from weather
- for flood or tidal surge, length of time of inundation
- if the water is contaminated with chemicals or sewage, etc.

When unfinished houses and house frames have been exposed to the weather, the level of degradation depends on a combination of these factors. Some structures will require extensive repair after a few months' exposure; others may be quite serviceable after 12 months' exposure.

Similarly, for flood-affected properties, short periods of inundation, typically 1-2 days, will not necessarily lead to any permanent, long-term damage to solid timber or engineered timber products, provided they are cleaned and allowed to dry out quickly.

When assessing moisture-affected buildings, consider the detail and extent of investigations. In many instances, the benefit of undertaking simple on-site assessments, with subsequent repair or replacement where necessary, may outweigh the costs associated with more detailed scientific site or laboratory testing and analysis, which may involve chemical analysis or strength testing, etc.

Scope

This Guide has been prepared to assist the building industry and owners understand the key issues and factors that need to be considered when assessing moisture-affected timber construction and to provide some guidance on how to address these considerations. The information contained in this Guide should not be considered in isolation; where appropriate, relevant expertise should be obtained to supplement any information in this guide. The Guide does not cover matters associated with the overall structural stability or adequacy of a building.

Regulatory Requirements

This publication focuses on the assessment of moisture-affected timber construction. It does not address structural adequacy of buildings or other requirements under the Building Code of Australia (BCA). From time to time the BCA is amended and individual States/Territories may also vary requirements. Users of this Guide should make themselves aware of any changes or differences and should develop a full understanding of the resulting implications. This Guide should be used only on this basis.

1

Timber-framed Construction Exposed to the Weather

Timber-framed buildings may be left exposed to the elements for many reasons, from relatively short-term normal weather exposure during construction to prolonged exposure, as sometimes happens when building contracts falter. When investigating the impact of the exposure, each case will need to be individually assessed to find the extent of any degradation and whether this needs to be repaired or rectified. In most cases, even frames that have been exposed for well in excess of three months can be easily and satisfactorily repaired where necessary. Many of the situations highlighted in this section represent extreme examples.

1.1 Inspection Considerations

Each case of exposure needs to be individually assessed to find the extent of any degradation and whether this need to be repaired or rectified.

When inspecting weather-exposed timber construction, the main issues to consider are:

Weathering/mechanical degradation of timber/components: The changing moisture content of timber and timber products exposed to cycles of rain and sun can swell and shrink the timber. The degree to which this occurs will depend on many factors, including the timber's inherent properties, such as shrinkage and density, as well as any protection, such as paint.

Shrinkage and swelling can result in the timber checking, cracking and splitting, as well as connections being loosened. Sheet products may also warp or bow between their supporting members. Where truss plates embedded in timber are exposed to the weather, they too can work loose and, in some extreme cases, may become totally dislodged.

Moisture content: Timber and timber products are hygroscopic so they will take up or lose moisture in harmony with their surroundings. The moisture content (MC) of solid timber and timber products such as laminated beams can be easily measured on-site using moisture meters (see Appendix 1). The use of meters to measure the moisture content of some treated timber products – as well as plywood, LVL and other wood-based boards including particleboard and OSB – is not reliable. In these cases, where a moisture content is required, consider oven dry testing (see Appendix 1).

Moisture content measurements are a useful indicator for a number of issues, such as potential for moulds, stains and decay as well as suitability of frames to be enclosed with linings or to have surface finishes applied.

Mould and fungal degradation (decay): Where the timber's moisture content exceeds about 20% for prolonged periods, there can be fungal degradation or decay, particularly in untreated timber of low natural durability. Fungal degradation should not, however, be confused with moulds or stains, which may look unsightly but may only just be on the surface of the timber, with the underlying wood unaffected.

Timber frames exposed to the weather for six months.

Exposed timber can become discolored and stained.

Potential for insect damage: Building assessments should consider the potential for insect attack, particularly termites, due to degradation of insect management systems used in the original construction. Termite management systems include the use of treated termite-resistant timber, chemical barriers applied to the soil and physical barriers. Some termite-treated timber products may only have warranties that are valid for normal periods of weather exposure and some ground line chemical barriers may be compromised where exposed to continuous moisture. Reinstatement of the original termite management system or provision of an alternative system may be required in some instances of prolonged exposure.

Corrosion: Corrosion of metal fasteners, from nails to heavier connections such as bolts or plates, can be accelerated where moisture is present, particularly where the connections are used in or on some timber treatment types such as CCA, ACQ and copper azole. Where necessary, some embedded fasteners may also need to be extracted to assess level and extent of corrosion. Corrosion of fasteners in construction close to marine environments may also need thorough inspection.

1.2 Specific Issues

1.2.1 Moisture Content Measurements in Framing

Moisture content 20% or above is conducive to decay and needs to be addressed.

The moisture content of framing should be measured using an electrical resistance moisture meter with a hammer probe that has insulated prongs. The readings will give a good indication of the current state of timber and an idea of future conditions that may arise or actions that may be needed to lower the moisture content to a level suitable for finishing off and lining frames, etc. A meter with a hammer probe and insulated prongs allows measurements at depth (say 10 to 15 mm) which will be a better gauge of actual moisture in the timber than just surface measurement.

Where the moisture content is less than 20%, and remains so, decay will not occur (or continue if it has started) although surface mould and stain may be present. An moisture content 20% or above is conducive to decay and needs to be addressed.

The areas of a weather-exposed frame likely to have the highest moisture content are bottom plates on slabs or sheet floors and the lower ends of studs on these plates due to wicking action.

When taking moisture content readings, chose a random selection of bottom plate and stud positions and record measurements for the plate, lower end of the stud and 500-600 mm up the stud. Take random measurements in other solid members such as beams, top plates, and truss or roof framing.

Water ponding on slab. Note wicking of moisture up the studs.

Where moisture contents are less than 16%, framing is considered suitable for installation of lining products such as plasterboard.

Table 1.1 gives a typical example of moisture contents taken from a site on a weather-exposed frame at bottom plates to slab.

The measurements in Table 1.1 indicate:

- High MCs in bottom plates and lower end of studs conducive for decay to occur. These need to be allowed to dry as quickly as possible.
- Lower MCs up the studs away from plates/slab, but some additional drying required.

Table 1.1: Typical moisture content readings

Position (various locations on site)	Deltron Resistance Meter Readings at 10 – 15 mm depth (%)		
	Bottom	Bottom stud	Stud at 500 mm up
1	16	16	14
2	23	21	17
3	>25	>25	18
4	19	21	17
5	23	22	18

Notes:
1. All studs and plates H2 Treated. H2 only protects against termites, not decay.
2. Plates MGP 10 pine and studs MGP 10 and MGP 12 pine.

1.2.2 Moulds, Stains and Decay

Unprotected timber exposed to the weather can show considerable discolouration (white chalky look, through to very dark blue stains) due to moulds and stains. These moulds and stains 'live' on the sugars and starches naturally present in the timber, particularly in sapwood. In all but extreme circumstances, they do not affect the mechanical or strength properties of the timber.

Their impact can be easily established by scraping back the timber surface. Where the timber just below the surface is similar to 'fresh' timber, there will have been negligible or no deterioration.

Decay fungi, on the other hand, have the ability to degrade timber and wood-based products by attacking the cellular structure. Decay affecting the timber's strength properties can be easily assessed on-site by 'picking', probing or drilling using a fine auger or drill bit.

With the 'picking' technique, decay near the surface of the timber is found by trying to prize a splinter from the wood using a pocket knife, small screwdriver or similar implement. If the timber is still sound, relatively long splinters should be able to be lifted out. If the timber has commenced to decay, the wood will break abruptly in a brash or carroty nature.

The probing technique compares the 'hardness' of sound, non-affected wood to that which is believed to be affected. Timber affected by decay will feel softer and more 'spongy' than sound timber.

Drilling using a fine auger or drill bit enables assessment deeper into the timber. Again, for the equipment being used, the force required to penetrate sound timber should be compared to the force required to penetrate affected timber. Timber that has decayed will be far more easily penetrated.

Reasonably reliable assessment using these techniques will take experience.

Assessment of timber decay takes experience; the force to penetrate both sound and affected timber should be comparable.

Significant discolouration due to stain but timber under surface is unaffected, with no decay.

Decay in bottom plate on particleboard floor. Note small drill holes on top of plate used to detect decay.

1.2.3 Sheet Bracing

Common forms of wood-based sheet bracing products include both structural plywood and orientated stand board (OSB).

With all sheet bracing types, the critical areas for evaluation are the sheet edges where the nail or other fasteners attach the sheet to the frame. Any degradation of the sheet edges will compromise the structural adequacy and shear capacity of the fasteners which, in turn, will affect the design capacity of the bracing.

The following photographs illustrate situations where the adequacy of sheet bracing has been compromised due to degradation of the sheets.

When assessing sheet bracing panels, one suggested method is to use a qualitative rating system such as:

- Rating 1 = Considered sound as exists, no need for rectification.
- Rating 2 = Minor concerns re delamination/appearance/bowing between studs.
- Rating 3 = Action required to bring up to standard.
- Rating 4 = Replace or repair as considered structurally inadequate.

Sheet edges are critical areas for evaluation.

Example of OSB sheet bracing showing edge swelling and flaking.

Plywood delamination at bottom plate in bracing panel. Note: The plywood used in the construction in the above example had no identification stamps or indication of certification schemes or Australian Standard for its manufacture.

Table 1.2 is a site assessment of plywood bracing undertaken on a house frame weather exposed for more than six months.

Table 1.2: Typical example of a sheet bracing rating assessment.

Bracing panel number	Rating	Comments
1	1	–
2	3 – 4	Double-sided (plywood bracing both sides of wall)
3	3 – 4	Double-sided
4	4	Double-sided – extensive delamination one side at bottom plate – other side not as severe
5	3	Bad delamination in corner plus spot delamination
6	4	Severe at critical points

Notes:
1. The panel numbers and rating were the results of this assessment at various locations.
2. The high moisture contents and prolonged exposure have also caused some buckling (and 'odd' nail popping) of the ply bracing, which at this stage is not considered serious. Fitting additional rows of nogging between studs and additional nailing will eliminate this.

1.2.4 Particleboard Flooring

Particleboard flooring exposed to prolonged weather is generally more sensitive to moisture uptake along sheet edges. Where possible, it is important to obtain the manufacturer's details (usually on the underside of the flooring) and identify the product type and other details, including original board thickness.

Assessing the particleboard on-site will be similar to all wood-based composites made from chips, flakes, strands or fibres: establish flaking or loose fibres and any swelling that has occurred.

Edge swelling can be assessed by using a straight edge across the sheet (approximate only as the measurement may be a combination of swelling or board deflection, etc). However, it is preferable to take a hole saw sample: measure the thickness of the sample and compare it to the manufacturer's stated thickness (usually 19 mm for 450 mm joist spacing or 22 mm for 600 mm spacing in residential housing). Hole saw samples can also be obtained from the body of the sheet where necessary.

An additional advantage of taking hole saw samples is that the moisture content in the board can be ascertained by oven dry testing. This also enables the thickness of the sample to be measured following drying to determine the extent of any non-recoverable swelling.

Taking a hole saw sample of particleboard flooring means you can compare the sample to the manufacturers stated thickness.

Typical hole saw samples.

Measuring the thickness of particleboard flooring at a hole saw sample location.

As a general guide, where the non-recoverable (after the flooring has been allowed to dry out) edge swelling in particleboard flooring exceeds about 2-3 mm within 50 mm of sheet edges (supports), the long-term structural adequacy of the floor is likely to have been compromised. It will need to be replaced or subjected to alternative rectification such as an additional overlay structural floor.

If there's doubt about the damage, 600 x 450 mm samples of flooring that has been allowed to dry can be cut from the floor and forwarded to a testing laboratory to ascertain if the flooring still has the required structural properties.

1.2.5 Plywood Flooring

Structural plywood flooring is less susceptible to moisture effects and edge swelling than particleboard. Provided there has been no delamination of veneers (unlikely in quality-certified structural plywood), the plywood will usually maintain its structural adequacy, even with prolonged weather exposure. Once dry, light sanding should remove any minor residual edge swelling.

NOTE: Particleboard and plywood floors that are retrievable may in some cases benefit from adding additional fasteners (screws, screw shank nails, etc). If additional fasteners are installed, minimise splitting of joists by using small diameter fasteners or by pre-drilling.

Where there is any concern regarding structural adequacy, the product manufacturer or a structural engineer should be consulted to advise on repair or replacement.

1.2.6 Tongue and Groove Flooring

It is unlikely that a feature tongue-and-groove (T&G) floor will have been installed in a house where the floor could still be exposed to the weather. If, however, this has occurred, the flooring can be assessed as described in Section 2.

1.2.7 Floor Joists (solid timber and engineered timber products)

Moisture can track down fittings into joists, creating local decay pockets.

The tops of solid, glued-laminated or LVL joists or top chords of engineered joists, particularly low-durability timbers, should be assessed for decay by initially drilling adjacent to floor fixings. Moisture can track down the fixings into the joists, creating local decay pockets around the fixing. Where this occurs, it will compromise both the floor fixing integrity as well as the structural adequacy of the joist. More general drilling for decay may also be warranted if this is found to have occurred.

For nailplate fabricated joists and nail-plated floor trusses, see Section 1.2.10.

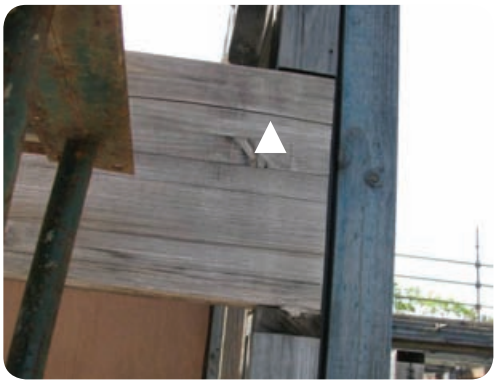
In addition to assessing 'I'-joists for decay, it may also be necessary to assess the integrity of the webs and the glued joint at the web to top and bottom chord intersections. Plywood and OSB webs can be assessed visually and also by using the hole saw technique described above.

Decay pockets (highlighted) around fixing points where sheet flooring has been removed after 12 months' weather exposure.

1.2.8 Glue-laminated and LVL Beams

A visual inspection of laminated or LVL beams will generally reveal any checking, splitting or delamination that has occurred due to the weather exposure. Where found, the extent (length and depth) of any splits or delamination should be further assessed and recorded using a ruler/tape and fine feeler gauge to establish depth.

Split (indicated by arrow) totally through one of the doubled glued-laminated beams. Depth of split indicated by ruler 35 mm plus.



Split (indicated by arrow) along second top laminate (does not follow glue line) at end of beam.

1.2.9 Finger-Jointed Products

Finger-jointed timber product performance depends on the type of glue (waterproof, water-resistant or other) used in its manufacture. Little degradation from weather exposure is expected with the phenolic or resorcinol types, compared to possible significant degradation with some melamine urea formaldehyde or cross-linked PVA types. The integrity of prolonged weather exposed finger-jointed framing should be assessed via random sampling from the site followed by mechanical testing.

1.2.10 Nail-plated Members (roof and floor trusses, etc)

Repeated cycles of wetting and drying of nail-plated (truss plates) timber products frequently leads to the nailplates 'withdrawing' from the timber due to the associated cyclic expansion and contraction in the timber. In extreme cases, the plates may totally disengage. Where the gap between the plates and the timber is more than 1-2 mm, which can be measured using feeler gauges, the structural integrity of the members or product may be severely compromised. If the structural integrity is in doubt, the nail plate/product manufacturer's advice on repair or replacement should be sought.

Repeated cycles of wetting and drying of nailed plated timber often leads to the nailplates loosening.

Loose truss plates where trusses exposed to weather for six months (prior to roofing being installed).

1.2.11 Loose Straps and Tie-down Connections

As shown in the example below, the weather exposure of frames can cause connections such as straps and tie-down rods to become loose. This can be due to either minor frame settlement and/or wetting and expansion of the timbers and subsequent drying and shrinkage. These situations will not usually be due to degradation of the timber in the frames and can be easily rectified. They should not present any real structural concerns.

Loose tie-down steps due to timber expansion and then subsequent shrinkage.

1.2.12 Termite Management

Termite management systems warranties should be checked to ascertain their positions on weather exposure.

Termite management can include physical or chemical systems. Chemical barriers can be compromised over time if fully exposed to the weather. Similarly, if timber frames are treated for termite protection using a H2/H2F/H2S treatment (refer to AS 1604), prolonged weather exposure can have a detrimental effect and may void any manufacturer warranty on the treatment.

For perimeter chemical barriers, a licensed pest control company should be engaged to reinstate perimeter treatments and to check any other management systems originally applied.

For termite-treated timber or wood-based products, samples of the timber can be sent to a testing laboratory to determine if the timber complies with AS 1604. Alternatively, a licensed pest controller can be engaged to install a different type of compliant termite management system.

1.2.13 Treatment of Mould

Mould and blue-stain can occur on weather-exposed timber. While unsightly, much of it will not be detrimental to the timber's long-term integrity, provided it is allowed to dry quickly. Moulds and stains may pose future concerns if not addressed with respect to health issues and the finishing of internal linings. When the surface is dry, a pH-neutral, boron-based mouldicide should be applied to the frames.

Commercial contractors are available to undertake this task and boron-based mouldicides have an added termite protection capability. However, it may not be recognised as an official termite treatment under Australian Standards when applied on-site.

2

Flood-damaged Timber and Timber-framed Construction

Before flood damage is assessed or repaired, a licensed electrician must undertake an electrical safety inspection. An appropriately licensed person should also carry out a plumbing safety inspection. In addition, an inspection and assessment of structural damage to buildings and houses should be undertaken by a competent person, such as a registered structural engineer, building certifier or licensed builder. Where there has been structural damage, repairs should be undertaken in accordance with, and under the direction of, professional advice.

2.1 Assessment of Damage

Important timber and timber-related issues to consider when assessing structural damage include:

- Scoured out footings/foundations and supports (check that dried out mud/silt not hiding damage)
- Damaged tie-down connections
- Cracked or broken members
- Damaged sheet bracing (lining materials)
- Loose joints and connections
- Damaged trusses and truss plates
- Adequate seating and bearing of members
- Truss plates not firmly seated in timber
- Gaps between support points and joints
- Girder trusses (trusses that support other trusses)
- Corrosion of fasteners/connections
- Corrosion of steel posts in concrete footings

NOTE: Where fast-flowing water has hit the dwelling, joists and bearers may have shifted/twisted and walls and windows may be out of square, etc. Any excessive misalignment should be corrected before new cladding or lining is installed.

Failure to address or correct these types of faults could severely affect the future structural performance of the building.

Footings scoured out by floodwaters (Image: BSA Queensland).

2.2 Timber and Moisture

This information on timber and moisture is in addition to the information provided in Section 1, which should also be considered in flood-affected construction.

2.2.1 Mould and Decay

Timber and wood-based products that have been totally immersed in water for prolonged periods will not decay or be subject to fungal deterioration due to the lack of available oxygen. When the water has receded, it is important to clean the timber of all silt and mud, etc, as soon as possible and then allow the timber and wood-based products to thoroughly dry out as quickly as possible with good ventilation. If power is available, fans, air-conditioners or dehumidifiers can assist with this process.

The space under suspended floors must also be immediately drained and dried out. Make sure all ventilation points are clear of debris and dirt and, if necessary, use forced mechanical ventilation (blowers) to assist in the process.

If timber or wood-based products remain damp or wet for prolonged periods and air (oxygen) is available, mould (dark staining) and eventually decay can occur, particularly in timber that has low natural durability such as untreated pine. Significant degradation or decay of timber is usually preceded by surface discoloration by moulds or stains, but if these are easily scraped off with a knife and the timber is sound underneath, it is not of concern. Degradation or decay in timber will be indicated if the wood has become soft and spongy or is easily penetrated with a knife or screwdriver.

Avoid using products such as chlorine (pool chemicals), etc, to prevent or treat mould due to possible corrosion of metal connectors and fasteners.

Avoid using chemical products to prevent/ treat mould as it can corrode metal connectors and fasteners.

Although quite stained and covered with mud and silt, when cleaned, the pine framing found to be unaffected

Locate decay by probing.

Decayed timber is soft and spongy and can easily be penetrated with a knife or screwdriver (see arrow).

2.2.2 Swelling and Shrinkage

Different types and species of timber will vary in the time they take to dry.

Timber and wood-based products that have been saturated will swell. When they dry out, they will shrink. The amount of swelling or shrinkage depends on the type and species of timber or type of wood product, and the time exposed to water. Where timber has swollen in, for example, flooring, it may also have secondary effects such as cupping and pushing out external walls or movement of joists and bearers.

The time it takes for fully saturated timber to dry to an acceptable level will vary considerably, depending on its thickness, density and the level of ventilation. Higher-density timbers, such as hardwood, will take longer to dry. 'Forced' ventilation as noted above can speed up the drying process.

Expansion in flood-affected timber flooring.

Expansion of the hardwood T&G floor above has caused the separation of double bearers (see arrows).

2.3 Kitchen Cupboards, Vanity Units and Laundry Units, etc

Where possible, undamaged parts of bench tops such as granite or stone, sinks, basins and tap ware should be retained for re-use.

If of relatively recent construction, these units are likely to have been made from a composite, wood-based board such as particleboard (chipboard) or medium density fibre board (MDF or 'Craftwood') with either an overlay (e.g. veneer, laminate, vinyl) or surface paint finish.

If these units have been inundated, and have swollen, they need to be replaced. The swelling in the wood-based composite is not recoverable. Also, the surface finishes and their attachment to the underlying board may have been damaged.

If water levels have only covered the kickboards and not wet the carcass of the cupboards, kickboards can be removed and the area under the cupboards cleaned and dried and new kickboards installed.

Moisture, silt and mud, etc, will also be trapped behind these units, so they may need to be removed to gain access for cleaning and drying out of the underlying cavities and frames.

2.4 Roofs, Walls and Floors

Where timber frames have been inundated, it is important that they are cleaned (washed down) and allowed to dry out as quickly as possible. For frames enclosed in cavities (behind wall or ceiling lining), the lining will need to be stripped and removed to allow access for cleaning, removal of insulation and to allow adequate ventilation for drying out.

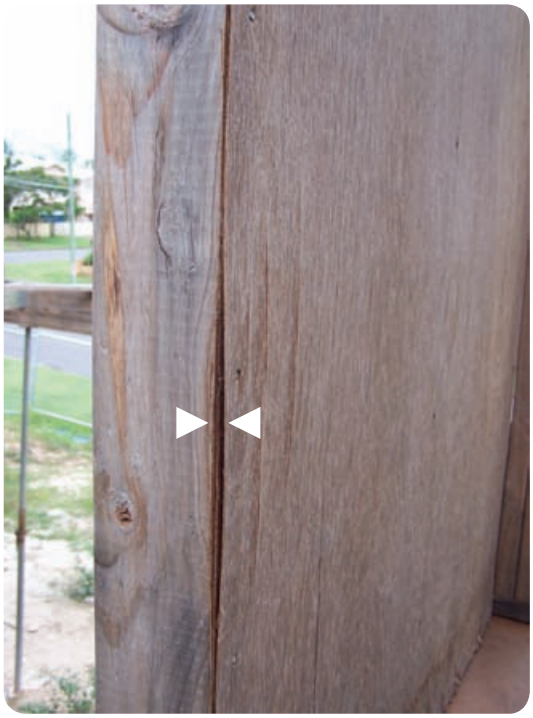
Irrespective of the need to access frames for cleaning, most lining products that have been inundated (T&G, V-Joint, plasterboard, plywood, hardboard ['Masonite'], medium-density fibreboard, etc) will need to be replaced.

Lining should be removed to at least 300 mm above the highest level of inundation (or further if required for adequate re-instatement of the lining, i.e. half or full wall height). Inundated bulk (batts) wall or ceiling insulation will need to be removed and replaced during cleaning and repairs.

Houses built after the mid-1970s may have wall bracing using wall lining materials (plasterboard, plywood, hardboard and fibre cement, etc) as the bracing members. Where wall linings are stripped, temporary diagonal timber braces (70x35 pine) at 30° to 60° should be nailed to the top plate, bottom plate and studs to each wall to maintain the house's bracing strength prior to reinstatement of permanent bracing and wall lining.

WARNING: some roof and wall sheeting and some vinyl flooring coverings in older houses may obtain asbestos.

NOTE: In older houses in particular, some roof and wall sheeting and some vinyl floor coverings may contain asbestos. Do not sand or cut these products. Removal and disposal of these products must be undertaken by appropriately licensed contractors.



Delamination of plywood sheet bracing (see arrows).

Plywood sheet bracing affected by moisture. Replacement required. Where necessary fix temporary braces.

2.5 Laminated Beams, Laminated Veneer Lumber (LVL), 'I'-Beams and Structural Plywood

These products are manufactured using waterproof glues so short-term inundation should not adversely affect their structural adequacy. An inspection can establish if there has been any delamination in the glue lines. If significant delamination has occurred, their structural integrity may have been compromised and replacement or repair will be necessary.

As these products dry out, it is possible that seasoning checks will develop. However, unless they are deep and continuous such as adjacent to glue lines in laminated beams, these checks should not affect structural integrity.

Structural plywood such as flooring and bracing (and exterior plywood cladding) that are manufactured using 'waterproof' (phenolic) glues, should not be structurally affected, but if there is 'bubbling' or delamination of veneers they will need to be replaced.

2.6 Timber Floors and Decks

NOTE: Before any timber floors are re-laid, the services of a professional floor installer should be used to measure and check the moisture content of any underlying substrates (plywood, particleboard or concrete) to ensure that it is suitable for the new flooring to be laid.

2.6.1 Solid T&G Strip Floors Direct to Joists on Bearers

The flooring may continue to swell or expand across the boards for a time, even after the water has subsided, as moisture moves deeper into the timber. After cleaning, assess the extent of swelling and or tenting of boards (lifting off the substrate/supports). Check to see if there is still clearance between the edges of boards and the bottom plates of walls (usually under the skirting board) and to see if the flooring has expanded and started to push wall frames out at the bottom.

If necessary, relieve the pressure on walls by removing or cutting out perimeter boards. Eliminate any trip hazards that may have arisen due to tenting of boards or lifting of nails, etc.

Allow the flooring a minimum of four months to dry out before re-assessing. Gaps between boards are highly likely as the floor dries out, however, the structural adequacy of the flooring is not likely to have been compromised and floors may be lived on in the meantime.

Following re-assessment, consideration can then be given to rectification in accordance with industry recommendations, which may include the following options:

- re-sanding and polishing
- overlaying with a new thinner overlay timber floor
- replacing the floor
- installation of alternative floor coverings.

Tenting of T&G floor due to prolonged moisture being trapped under the floor. This inundated T&G floor supported on a particleboard sub-floor 'tented' about one week after the flood water receded.

2.6.2 Plywood Floors on Joists and Bearers

Plywood, because it is cross laminated, is relatively stable (resistant to expansion) with respect to moisture uptake. Flooring plywood is also manufactured using waterproof glues so delamination of the veneers due to moisture is unlikely.

All flooring should be left a minimum of four months to dry out.

After cleaning, assess the extent of swelling and/or lifting of sheets off the joists. Check to see if there is still clearance between the edges of sheets and the bottom plates of walls (usually under the skirting board). If necessary, relieve the pressure on bottom wall plates by provision of relief cuts in the sheet edges as close to bottom plates as possible. Eliminate any trip hazards that may have arisen due to lifting sheets or nails and screws, etc.

Allow the plywood flooring a minimum of four months to dry out before reassessing and carrying out any rectification that may be required. The structural adequacy of the plywood flooring is not likely to have been compromised.

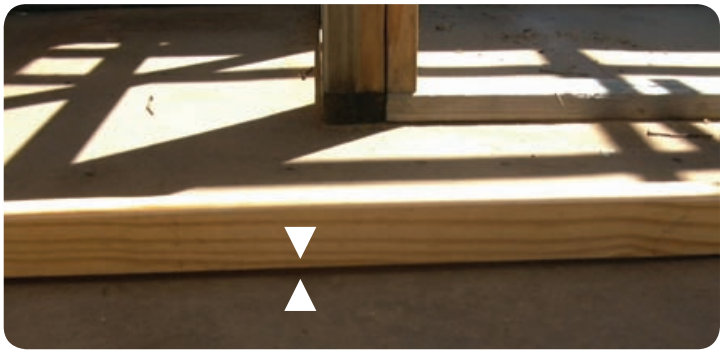
2.6.3 Particleboard ('Chipboard') Floors on Joists

Particleboard flooring is more susceptible to moisture-induced swelling than timber or plywood, particularly at sheet edges. Depending on the type of particleboard (some boards are manufactured using moisture-resistant glues), it may have suffered a loss of structural integrity. There will be only minor loss of swelling when the particleboard dries out.

After cleaning, assess the extent of swelling and/or lifting of sheets off the joists. Check to see if there is still clearance between the edges of sheets and the bottom plates of walls (usually under the skirting board). If necessary, relieve the pressure on bottom wall plates by provision of relief cuts in the sheet edges as close to bottom plates as possible. Eliminate any trip hazards that may have arisen due to edge swelling, lifting sheets or nails and screws, etc.

Allow the particleboard flooring a minimum of four months to dry out before re-assessing and carrying out any rectification that may be required. As a guide, if sheet edges have swollen more than 5 mm (i.e. would need to be sanded back by 5 mm or more to get a flat floor) then the structural adequacy of the flooring has been compromised and needs rectification by either replacement or installation of a new structural floor over the existing particleboard. Where there is doubt as to the structural adequacy of the particleboard floor, consult the flooring manufacturer.

Floors that are retrievable may benefit from the fitting of extra rows of noggings glued/fastened between the top of noggings and the under-side of the floor to help stiffen and eliminate squeaks.



Use a straight edge to estimate edge swelling in particleboard flooring.
Gap between straight edge and floor (see arrows) indicates edge swelling in particleboard flooring.

2.6.4 Timber Floors on Concrete Slabs (includes overlay, T&G on ply or battens, direct fix, etc)

With floors of this type, moisture, mud and silt will have become trapped under the floor surface. This will result in significant expansion in the flooring as it takes up moisture resulting in peaking and tenting. This will necessitate these floors to be removed and replaced as it is highly unlikely that an acceptable floor will be able to be obtained from the original floor.

Once the flooring system has been removed and the slab cleaned, leave the slab for a minimum of 3-4 months to allow for dry out (a rule of thumb is one month per 25 mm of slab thickness – consider the impact of edge and internal stiffening beams). The moisture content in the slab should then be checked by a professional floor installer to ascertain if it is sufficiently dry to enable a new timber floor system to be installed. Moisture vapour barriers over the slab should also be considered prior to laying the new floor.

2.6.5 T&G, Overlay or Floating Floors on Plywood or Particleboard on Joists

These dual-layer floors will take considerably longer to dry out than single-layer floors. In addition to the considerations noted above for solid T&G, plywood, particleboard and also floors over slabs, the upper flooring surface of these floors will probably dry unevenly with a moisture gradient (low moisture content on top surface to high on underside of the flooring/sheet floor interface) that will result in significant cupping of the top boards.

It is unlikely that the upper floor surface of these flooring systems will be able to be reinstated to a level of finish considered acceptable for a feature floor. It may, therefore, be prudent to remove the upper layer as soon as possible to enable the structural plywood or particleboard substrate to dry out and be assessed for suitability of laying a new flooring surface over the top when appropriate.

It must also be considered that removal of the timber floor, where adhesives are usually used, may result in significant damage to the plywood or particleboard subfloors and their fixing to joists. In some instances, the plywood or particleboard will need to be replaced.

Irrespective of whether the plywood or particleboard remains or is replaced, screw fixing to the joists is needed. Particular attention should be paid to ensure sufficient fixing is provided across the width of the sheets.

2.6.6 Wet Area (bathrooms, laundries, etc) Floors Laid Over T&G, Plywood or Particleboard Subfloors on Joists

Under current and recent building regulations, these floors are required to have a waterproofing system above the T&G, particleboard or plywood. Typical waterproofing systems include seamless vinyl flooring and, under tiled floors, waterproof coating systems such as fibreglass applied directly to the timber flooring substrate. These waterproofing systems significantly inhibit the ability of the timber substrate flooring to dry out quickly. These floors may require special attention to drying and/or repair/replacement.

2.6.7 Timber Decks

Due to their normal weather exposure conditions, timber decks are required to be constructed of durable timber and should only require a thorough clean and then be allowed to dry. If any decking has lifted or become loose, after it has dried out it can be carefully re-nailed or screwed. Then use a proprietary decking cleaner and follow with a compatible decking finish. If re-sanding the decking is contemplated, consider whether this will compromise the deck fixings used, i.e. galvanised coatings on nails, etc.

2.7 Timber Stairs

Solid timber stairs can usually be recovered after inundation if surface material are removed quickly.

Stair systems constructed using medium-density fibreboard or non-flooring grade particleboard can be significantly affected by inundation and will not normally be recoverable requiring replacement.

Stairs constructed from solid timber (hardwood or softwood), glued-laminated timber or structural plywood can usually be recovered provided any surface materials, such as carpet, attached to the underlying stair structure are removed, and the stairs are allowed to dry quickly. Because of their nature, with many housed joints, etc, forced mechanical ventilation or dehumification may be required to enable timely drying of the stair system.

After the stair structure has been allowed to dry, liberal application of a PVA or similar wood adhesive glue between risers, treads, end of treads, etc, and nailing with small diameter c-brads to help minimise splitting, will further stiffen and help reduce squeaks. Further gluing /nailing of existing cleats can also be considered.

Solid timber stairs stripped out and allowed to dry were recovered following inundation.

2.8 Termite/pest management

Flooding and inundation may have compromised the termite management systems used to protect homes and buildings. In homes or extensions and renovations carried out since 1990, a notice should have been fixed inside the meter box (or the cupboard under the kitchen sink) that describes the termite management system that has been used.

Floods can also trigger outbreaks of other insects such as cockroaches, silverfish, fleas, etc. While they are not detrimental to timbers, they can be dealt with before claddings and linings are restored by treating cavities. Rat and mice plagues can also be triggered by flood events. If left uncontrolled, they may lead to significant damage to electrical wiring, etc.

2.8.1 Elevated, lightweight timber homes with suspended floors on stumps

Termite management of these traditional forms of construction (unless built in underneath) is usually by means of ground separation and the use of physical barriers such as ant caps and metal termite shields. These barriers and shields should be inspected to ensure they are not damaged or covered by silt or mud, etc, and that the building and any attachments do not provide concealed access for termites to get into the house.

2.8.2 Single or two-storey houses on slabs or where houses have been built-in underneath on a slab

A licensed pest controller should inspect and assess the termite management system used and reinstate this in accordance with the requirements of the BCA, relevant Australian Standard (AS 3660.1) and manufacturer's recommendations. Systems that are likely to have been compromised due to water, silt and mud build up, etc, include all chemical barriers and physical barriers such as stainless steel mesh ('Termimesh') and graded stone ('Graniteguard').

Licensed pest controllers should inspect, assess and treat inundated properties.

2.8.3 Termite-treated framing

Some homes and buildings may have been constructed using H2 termite treated framing ('T2', 'True Blue' and other similar trade names such as 'Blue' treated timber framing) as a primary or secondary means of termite management. Refer to AS 3660.1 and AS 1604.1. Some of these treatments rely on an envelope of the termiticide preservative that is applied to the timber at the time of manufacture. Short-term water inundation is ***unlikely*** to have compromised this envelope, however, it is still recommended that a licensed pest controller carry out reinstatement of termite management systems using an additional physical or chemical termite barrier system as noted above.

2.9 Corrosion

Pay attention to potential impacts of corroded metal components.

When assessing timber construction, pay attention to the potential impacts of corroded metal components and connections. Pay particular attention to any non-galvanised items, including bright steel nails, bolts or screws and also to galvanised components such as SHS posts or stirrups that are embedded in concrete and will be susceptible to corrosion at the top of footing. It may be necessary to remove some items (screws/bolts, etc) to assess the extent of corrosion on the embedded portion of the fastener. Where rust is present but the posts are still viable, they should be cleaned, treated with phosphoric acid, and then sealed with a metal primer, followed by subsequent coats of a metal or bituminous paint product.

Significant corrosion of embedded galvanised steel post bracket.

3

Additional Considerations for Buildings Affected by Tidal Surges

Recent experience from assessments of properties in North Queensland affected by coastal tidal surges following Cyclone Yasi clearly indicated that houses and other buildings constructed on elevated floor platforms ('highset' style houses that were predominantly open underneath) performed very well. Conversely, adjacent lowset houses on slabs suffered extensive structural damage and in many cases total destruction.

3.1 Structural Effects

Storm and tidal surge can apply significant impact and hydrodynamic forces on houses, particularly on walls that are normal (right angles) to the direction of waves.

A number of optional design strategies can be used to address these actions, from the use of very robust foundation and wall materials to the more practical alternative of raising the floor levels of buildings above the expected height of the storm surge.

While assessment and repair of repairable parts of tidal surge-affected buildings generally follow the same recommendations as for flood-affected properties, the structural considerations need specific attention.

The Queensland Reconstruction Authority (RCA) has published a guide that can assist in this regard. Refer to 'Further Advice and Valuable Information' below for a link to download the free RCA guide.

Storm surge damage to a slab on ground house.
(Image: Cyclone Testing Station, James Cook University, Townsville)

Elevated houses suffered little storm surge damage.
(Image: Cyclone Testing Station, James Cook University, Townsville)

Storm surge structural damage. (Image: Cyclone Testing Station, James Cook University, Townsville)

3.2 Salt and Corrosion

All recoverable metal components and fasteners should - where possible - be washed with fresh water and allowed to dry.

An additional consideration with tidal surge is the potential for salt water to corrode metal components and fasteners. Buildings constructed in tidal surge areas are, by nature, usually close to the coastline so the original metal components and fasteners should be of highly corrosion-resistant materials including hot dipped galvanised and stainless steel, etc.

Irrespective of the original materials, where components and parts are deemed recoverable or repairable, metal components, fasteners and similar should – where possible – be exposed and washed down with fresh water to remove salt deposits and then allowed to dry.

3.3 Design Considerations

There are a range of other building design considerations that should be considered in the siting, orientation and design of buildings in surge-prone areas. Many of these are addressed in the RCA Guide referenced above.

A

Appendix A – Moisture Content

A1 Introduction

The following information on moisture in timber outlines the various methods used to test the moisture content of timber.

A2 Moisture Content

Moisture content (MC) 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 is important about the MC in timber is that a board's cross-section will increase with increasing MC and will decrease with decreasing MC. At the time of machining, cover width variations are usually minimal and subsequent variations that occur in board widths are usually due to changes in MC. It is often the current and future variations in board dimensions that are of primary importance and the purpose of moisture content testing is to indicate what future movement can be expected.

By simply looking at the dimensions of timber, such as cover width in flooring, it is often possible to obtain information about the timber's MC. For example, many dressed timber products are machined to nominal dimensions in the seasoned condition. Flooring, for example, may be originally dressed to a cover width of 80 mm, so if the width of flooring measured ***in situ*** is say 81.5 mm, this would indicate that the boards have taken up moisture since manufacture. If the dimensions were less than 80 mm it could indicate the boards were at a lower moisture content than at manufacture.

Australian Standards that cover the moisture content of seasoned products vary in their limits as this depends on the species and application. Table A1 provides some information on species, associated products and the moisture content tolerances set out in the applicable standard. The number of the standard is also provided.

Table A1

Species Group	Seasoned Product	Moisture Content Range (anywhere within x-section)	Australian Standard
Hardwood	Flooring. Lining, dressed boards	9 to 14%	AS 2796
	Decking	10 to 18%*	AS 2796
	Framing (seasoned)	– 90% pieces < than 15% – All pieces < 18%	AS 2082
Softwood	Flooring. Lining, dressed boards	9 to 14%	AS 4785
	Decking	10 to 18%*	AS 4785
	Framing (seasoned)	– 90% pieces < than 15% – All pieces < 18%	AS 2858
Cypress	Flooring, decking	10 to 15%	AS 1810

*A maximum moisture content of 15% is recommended.

How moisture content is measured

Moisture content (MC) is generally measured by either a moisture 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 to provide an estimate of the moisture content. Oven dry testing requires a set of scales and an oven from which the moisture content is determined from the change of mass as the sample dries.

Measurements by different methods

In any piece of seasoned timber the MC is likely to vary down the length of the piece and from the outer surfaces (case) to the centre (core). Some methods of measurement are able to measure case-to-core differences while others can only measure the average MC 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. In other instances, 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 MC of the sample placed in the oven; 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, any limitations and accuracy are described below.

Oven dry method

When is it used?

- Oven dry testing is often carried out where there are variations in the MC of the final product.
- It can have a significant affect on the performance of the product. In case of disputes, Australian Standards generally refer to this method as it provides measurements that are more accurate and reliable. For some products, such as preservative-treated timber or particleboard, it is the only method recommended.
- Manufacturers of board products often undertake oven dry testing as a check in the manufacture of their products.
- A number of organisations have the appropriate testing equipment and contract out these services.

Testing equipment and facilities

- The equipment required is an accurate electronic digital scales (+/-0.2 grams) and a laboratory oven that is able to maintain a temperature of 103°C ± 2°C.

Oven dry moisture content measurement.

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 MC. Wood temperature affects the readings, so 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 because two different timber species at the same moisture content may not have the same electrical resistance. Meters are generally set up relative to Douglas Fir (Oregon) and corrections are applied for other species.

There comes a point where the moisture in timber is so low that the resistance is difficult to measure accurately or, on the other hand, 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. Meters with longer pins are preferred where MC is required from deeper into the timber to gain a better understanding of the moisture profile and gradient. The sophistication of the meters varies greatly in terms of features such as in-built temperature correction, pre-programmed species calibration and depth indication. Many of the meters now come with a calibration box.

Using resistance meters

- The calibration of the meter should be checked prior to use. This is usually done with a test calibration box that contains electrical resistors that correspond to the moisture contents specified on the test equipment.
- Measurements are 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; with others the pins are to run across the board's width (check the manufacturer's manual).
- The pins are driven to the desired depth. As case and core measurements can be significantly different, 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 AS/NZS 1080.1 for temperature and species correction factors.

Limitations, accuracy and precautions when using resistance moisture meters

When using moisture meters, a common-sense approach is necessary. Each reading should be evaluated and, if not as expected, the reasons for this should be investigated. The meters generally provide a reasonable estimate of the moisture content to ±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 require consideration when using these meters:

- 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 the species can make species corrections difficult.
- Species such as Brush Box have 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, oven dry testing may be needed to more accurately estimate the moisture content.

Capacitance meter

Principle of operation

These meters measure an electrical property called the 'dielectric constant'. 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 MC and the density of the timber affect this electrical property. The effective range of capacitance meters is from approximately 0% to 30% MC.

The more sophisticated meters can be adjusted for timbers of different densities. Cheaper meters do not have density compensation and corrections to their 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

Features in capacitance meters 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, timber density (or specific gravity) adjustment must be considered.

Using capacitance meters

- The appropriate meter settings for density and board thickness, etc, should be applied and the meter checked for calibration.
- It is necessary to obtain from the meter supplier the figures applicable to the meter being used.

Species average densities at 12% moisture content can be obtained from numerous Australian Standards such as AS 1684.2 and AS 1720.2 as well as the grading standards.

- 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

As with resistance meters, common sense must prevail: investigate and evaluate readings when they are not as expected. Providing the density is accurately assessed, these meters also provide a reasonable estimate of the average MC in a board up to about 25%. Again there are a number of aspects that need to be considered when using these meters:

- Readings can be taken very quickly 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. This can result in significant variation in meter readings.
- 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, 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 are also considered to be less reliable with Brush Box.

Again, if readings are not in line with what is expected, oven dry testing may be needed to more accurately estimate the moisture content.

A4 Assessing Timber Moisture Content for Conformity

Australian Standard/New Zealand 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.

Measuring the Moisture Content of Treated Timber, LVL, OSB, Plywood and Particleboard – Meters do not provide an accurate and reliable measure of moisture content in these materials. Use the oven dry method to determine the moisture content of these materials.

A5 – References

Standards Australia

AS/NZS 1080.1 – Timber – Methods of Test – Method 1: Moisture content

AS/NZS 4787 – Timber – Assessment of drying quality

B

Appendix B – Site Assessment Tools and Laboratory Evaluations

B1 Some Tools for Site Inspection and Assessment

Moisture meter: A meter with a hammer probe and insulated prongs as shown below is very useful to determine on-site moisture contents of solid timber products.

Pocket knife, probe, battery drill, drill bits and augers: Use these tools to assess the extent of mould and stains versus decay and decay depth in timber.

Hole saw: Very useful for taking small samples of sheet timber products such as flooring, bracing and webs in 'I' beams. The thickness of the small samples can be measured with vernier calipers and compared to original manufactured thickness and they can also be wrapped in plastic on-site and taken away for oven dry moisture content measurement.

Vernier calipers: Measure the thickness of sheet materials and other timber dimensions including gaps, etc, accurately with vernier calipers.

Feeler gauges: Valuable for assessing the width and depth of cracks and splits, such as may occur in solid or laminated beams or ply products.

Tape: Use for general measurement.

Spirit Level/Straight Edge: Plumb and level can be checked and they also useful as a straight edge to assess deflections between points of supports and also edge swelling in sheet products, etc.

String line: Useful for assessing out of straightness over long distances.

Compass: It is usually important when undertaking site inspections and reports to be able to determine north. This assists with recording site locations of measurements and also can aid in understanding assessment issues that may arise on-site between one part of the building and another.

Typical range of site assessment tools.

Site notebook: Record findings on-site such as locations, measurements, sketches, moisture readings, etc. Don't trust your memory.

Digital Camera: As for site notebook. These will save a heap of time and may negate need to re-visit sites if some details are forgotten.

Ladder, if required: To enable getting up close for visual inspection.

B2 Off-site Testing and Laboratory Evaluations

Where it is necessary to undertake more detailed evaluations, there are numerous industry bodies, government agencies, private companies and individuals and universities that can provide these services on a commercial basis. These services include:

- species identification
- timber treatment analysis
- termite management assessment and remedial treatment
- moisture content assessment
- mechanical properties testing and evaluation
- glue-line bond evaluations.

Further Advice and Valuable Information

Queensland Reconstruction Authority – www.qldreconstruction.org.au

Wood Solutions – www.woodsolutions.com.au

Engineered Wood Products Association – www.ewp.asn.au

Australian Timber Flooring Association – www.atfa.com.au

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