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Timber Windows and Doors

Technical Design Guide issued by Forest and Wood Products Australia

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This work is supported by funding provided to FWPA by the Commonwealth Government.

ISBN 978-1-921763-25-0

Prepared by:
Centre for Sustainable Architecture with Wood
School of Architecture & Design
University of Tasmania

First produced: December 2011
Revised: May 2012, September 2015

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Introduction

Timber is mainly atmospheric carbon assembled by natural processes into a versatile and attractive building material.

Why Choose Timber?

The building design and construction communities are increasingly aware of the need to consider thermal performance and environmental impact in the design and construction of buildings. This has increased demand for high-performance windows and doors that limit energy use in service and reduce greenhouse gas emissions associated with material production, fabrication and building construction (embodied carbon).

The use of timber windows and doors responds to environmental concerns as well as having many other desirable characteristics. Key benefits of using timber windows and doors are include:

Sensory attributes

Timber is a visually expressive, natural and tactile material ideal for applications that are seen and touched.

Flexibility

Timber is easy to cut, form and shape. It is available in a wide range of products, species, sizes, colours and textures. Timber allows design innovation and creativity.

Thermal performance

Timber in windows and doors can help reduce operational energy over the life of a building when it is part of a well-detailed and designed system, because of timber's low thermal conductivity.

Longevity

Timber is resistant to heat, frost, corrosion and pollution. The timber elements of a door or window will perform satisfactorily for the service life of any building if protected from moisture. Timber windows and doors perform well in extreme external environments with careful design, correct specification of species and finishes and regular maintenance. Timber windows and doors are resilient to degradation and wear associated with regular contact on internal surfaces if properly detailed and specified.

Renewable resource

Timber is a sustainable material obtained from trees which can be grown, harvested and regrown on a continuous basis.

Carbon storage and lower emissions

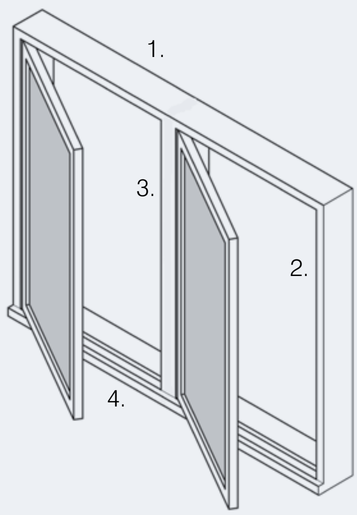
Growing trees store atmospheric carbon that remains sequestered in the timber throughout its service life. Using timber instead of materials that require significantly more fossil fuels in their production avoids substantial greenhouse gas emissions.

Window and Door Basics

A window is an opening in a wall or other surface of a building that allows the passage of light and transmission of varying amounts of air and sound. Windows consist of a frame, sashes, and panes of glass (or other transparent or transluscent material), intended to fit an opening in a building envelope. Windows influence the quality of the internal environment by admitting light and ventilation, excluding wind, rain and draughts, and mitigating noise transfer.

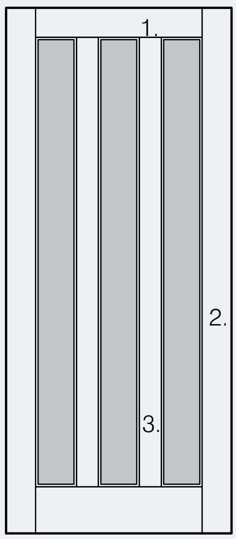
A door is a movable barrier, either solid or glazed, used to cover an opening or entrance way in a wall or partition of a building, or piece of furniture. Doors permit access and admit ventilation and light when open. A door can be opened and securely closed using a combination of latches and locks. Doors are used to provide access to a space and influence the physical environment within by creating a barrier. Doors mitigate noise transfer and are significant in preventing the spread of fire between spaces.

The terms used to describe the major components of windows and doors are common to both windows and doors. The frame is the assembled components that enclose and support the window sashes or door leaves. Frames are fixed to the surrounding building envelope.



The frame consists of:

1. Head – top horizontal component
2. Jambs – vertical side components
3. Mullions & transoms – intermediate vertical and horizontal elements (respectively) between sashes
4. Sill – bottom horizontal component.



Window sashes or door leaves are the moveable components of the unit supported by the frame. They consist of:

1. Rails, top rails and bottom rails – horizontal members of a sash, door leaf or screen
2. Stiles – vertical edge pieces
3. Muntins – intermediate elements of a sash or leaf.

1

Materials

Only carefully selected pieces from certain species will match the performance requirements of durability, stability and appearance required for windows and doors.

1.1 Introduction

Careful selection and combination of glass type, hardware type and timber species is required to create timber windows and doors that meet performance requirements and satisfy the design intent.

1.2 Timber

Timber is a natural, variable, non-homogeneous material that is susceptible to degradation and moves with changing moisture content. Understanding these characteristics will help the designer with the specification of timber windows and doors.

1.2.1 Timber Quality

Window and door joinery generally requires timber with straight-grain, seasoned to a consistent moisture content, and dimensionally stable throughout. Timber used in the external envelope should be relatively durable or be treated to be durable.

Solid timber suitable for windows and doors generally comes from large logs of slowly grown trees. Timber from smaller logs of more quickly grown trees tends to be less stable, more variable, and may also be less durable than older, more slowly grown material of the same species. Laminated sections of timber can be suitable for windows and doors if the timber elements to be laminated are well matched, stable, and if the timber is naturally durable, treated to be durable, or used internally.

Timber elements will deviate from the desired dimensions because of machining tolerances and timber's tendency to move with changing moisture content and with cutting, which relieves locked-in growing stresses. *AS 2047-1999 Windows in buildings – Selection and installation* applies constraints on the bow, spring and twist of particular elements for windows. The allowable limits are shown in Table 1.

Table 1: Allowable bow, spring and twist in timber for windows.

	Head, Jamb, Mullion and Transom					Sash	Sill			
Length	**Bow**		**Spring**	**Twist**		**All**	**Bow**	**Spring**	**Twist**	
Board width	**t=<(2/3) w**	**t>(2/3) w**		**100**	**150**				**100**	**150**
1.2	2	1	2	1	1	0	2	2	1	1
1.8	3	2	3	1	1	0	6	3	2	2
2.7	6	3	6	1	2	0	13	6	2	3
3.6	11	6	11	2	2	0	22	11	3	4

Source: AS 2047-1999 clause 3.2.2

1.2.2 Moisture Content and Stability

Timber is a hygroscopic material, which means it absorbs moisture and expands, or loses moisture and contracts, to achieve moisture equilibrium with its surrounding environment. The amount of expansion and contraction varies with the species, direction of the wood fibre, the way in which the timber is converted from a log, and the speed of growth of the tree. The most stable section will be from species with low percentage moisture movement, straight grain, growth rings perpendicular to the section, and from a slowly grown tree. It is essential that the movement associated with moisture content changes is limited and accounted for, because where windows and doors form part of the building envelope and feature moving parts, unanticipated expansion or contraction can lead to gaps opening or elements becoming jammed.

Timber to be used in a door or window would generally be fully seasoned with a moisture content complying with *AS 2796 Timber – Hardwood – Sawn and milled products* or *AS 4785 Timber – Softwood – Sawn and milled products.* Both AS 2796 and AS 4785 require a moisture content between 9% and 14%. *AS 2047 –1999: Windows in buildings – Selection and Installation* requires that moisture content of the timber is between 10% and 15% at the time of fabrication and delivery of the complete assembly.

Controlling the moisture content of the elements to be fabricated is important. Moisture content of all the elements in the door or window unit should be equal at the time of fabrication, delivery and installation, and should match the anticipated moisture content in service. The moisture content should be even throughout each element, because the timber can distort when it is moulded or as it dries out further if the inner core is wetter than the outside section. In-service moisture content for timber windows and doors built into an external envelope is likely to be as described in AS 2796 and AS 4785. However, the in-service moisture content of elements used internally will be as low as 8% for air-conditioned spaces and may be above 15% for naturally ventilated buildings in areas of high humidity.

The unit should be acclimatised to the final service environment before final assembly and installation if the equilibrium moisture content in service is likely to be significantly different to that of the timber during manufacture. Acclimatisation takes about three weeks for unpainted elements, but will vary depending on timber moisture content, species and target moisture content. A door or window may tend to continually bow or distort if the outside of the unit is continually wetter or dryer than the inside.

1.2.3 Feature and Colour

Features such as uneven grain, minor gum vein, colour variation, and small, tight, knots are part of timber's natural appeal and do not affect a piece's ability to satisfactorily perform. Features such as large or loose knots and major gum veins or voids can reduce durability and should be excluded. AS 2047-1999 constrains the features allowed in windows. These are presented in Table 2. Excluding material based on unreasonable appearance expectations can increase costs and waste material. Features can be confined to concealed surfaces or areas that are to be filled and painted if the appearance of the timber is critical.

Table 2: Features and characteristics permitted in windows in accordance with AS 2047-1999.

Element	Allowable Characteristics
Sashes	Exposed faces and edges are to be free of all knots.
All other timber	Exposed faces and edges are to be free of loose knots, splits, and resin, gum and bark pockets. Limitations are also imposed on slope of grain, surface checks, tight knots and pin holes. Finger-joints are not considered imperfections.
All unexposed faces	Other features are allowed given that they do not affect joint strength, unit fixing or operation.

Source: AS 2047-1999 clause 3.2.2

Natural timber has some colour variation between species, between elements of the same species, and within each piece. Unreasonable expectation of colour can lead to irresponsible waste. Apparent colour variation can be moderated by:

- grouping timber of similar colour together within units before assembly;
- using grain fillers selected to match the timber and the intended finish; or
- staining, either before the timber is finished or as part of the finishing process.

1.2.4 Properties of Major Species

Performance requirements such as stability, durability, hardness and workability, and consideration for aesthetic qualities will determine appropriate species selection for a given application. For example, joinery exposed to the exterior will require greater durability or protection than timber used internally.

The properties of major Australian-produced and imported species are included in Tables 4 and 5. Table 3 provides an introduction to the terms used in Tables 4 and 5. The properties presented in Tables 4 and 5 are key properties for commonly used species to aid the designer in appropriate timber species selection. More species information can be found at www.timber.net.au. The supplier of the window or door units, or timber, should be consulted for more information.

Table 3: Description of timber characteristics.

Term	Description
Name	Common species name
Origin	The region that is the general source of the timber
Colour	The colour of the majority of the heartwood of the timber (the sapwood may be paler)
Supply	A general indication of supply levels for the species
Forest certification	A general indication if the species is broadly available from certified forests
Durability	Durability class outside above ground to *AS 5604-2005 Timber – Natural durability ratings*
Density	kg/m^3 of wood seasoned to a moisture content of 12%
Hardness	Janka hardness to *AS/NZS 1080 Methods of testing timber*
Workability	The stability and general machining characteristics

Table 4: Properties of major Australian timbers.

Name	Origin	Colour	Supply	Forest Certification	Durability	Density (kg/m³)	Hardness (kN Janka)	Workability
Blackbutt	NSW & SE Qld	Yellow to brown	Readily available	Available	1	930	8.9 – Hard	Good
Hoop pine	NSW & Qld	Pale cream to yellow	Readily available	Available	4	550	3.4 – Soft	Very good
Jarrah	WA	Dark red	Available	Available	2	835	8.5 – Hard	Good
Karri	WA	Pink to reddish brown	Limited availability	Available	2	900	9 – Hard	Moderate
Radiata pine	All states	Shades of yellow to brown	Readily available	Available	4	~500	3.3 – Soft	Good
Silvertop ash	Tas, Vic, NSW	Pale to dark brown	Limited availability	Available	2	820	9.5 – Hard	Moderate
Spotted gum	Tas, Vic, NSW	Pale to dark brown	Readily available	Available	1	~950	10.1 – Very hard	Good
Tallow wood	NSW & Qld	Pale to dark yellow brown	Limited availability	Available	1	1010	4.5–8.0 – Medium	Good
Tasmanian oak	Tas	Straw to pale reddish brown	Readily available	Available	3	530–800	4.5–8.0 – Medium	Very good
Victorian ash	Vic	Straw to pale reddish brown	Readily available	Available	3	530	4.50 – Medium	Very good

Table 5: Properties of major imported timbers.

Name	Origin	Colour	Supply	Forest Certification	Durability	Density (kg/m³)	Hardness (kN Janka)	Workability
Amoora	SE Asia	Red brown	Available	Occasionally available	4	550	3.8 – Firm	Good
Douglas fir/ Oregon	USA/ Canada	Yellowish to orange	Readily available	Occasionally available	4	560–480	3–3.4 – Firm	Good
Hemlock	USA/ Canada	Straw to pale brown	Available	Available	4	500	2.7–3 – Soft	Good
Kapur	SE Asia	Red brown	Available	Unknown	2	750	5.4 – Moderate	Good
Kwila/ Merbau	SE Asia	Yellow brown to orange brown	Readily available	Occasionally available	1	830	8.6 – Hard	Moderate
Meranti	SE Asia & Pacific	Pale to dark red/straw to yellow	Readily available	Occasionally available	Generally 3–4	523–900	Varied	Good
New Guinea rosewood	Pacific	Golden brown or dark blood-red	Available	Occasionally available	2	650	4.7 – Moderate	Very good
Surian	SE Asia & Pacific	Light red to red brown	Readily available	Occasionally available	1	480	Very soft	Very good
Western red cedar	USA/ Canada	Pale to dark brown	Readily available	Available	2	380	1.5 – Very soft	Very good
White oak, American	USA/ Canada	Light to mid dark brown	Available	Available	4	750	6 – Medium	Very good
Yellow cedar	USA/ Canada	Pale yellow to cream	Available	Available	1	500	2.6 – Soft	Very good

1.2.5 Timber Sizes

Timber is cut or 'converted' from tree logs, and is then milled into rectangular sections that can be dressed into a finished size, or machined or 'moulded' into the desired shape. The practical maximum size of sawn and milled sections is governed by the size of logs converted. The maximum size obtained is typically 300 mm wide, 50 mm thick and 4.8 m long. Pieces up to 6 m long are viable but high-quality pieces of large-section timber are difficult to obtain and more susceptible to distortion. Smaller pieces can be glue-laminated into stable large-section timber, referred to as 'glulam'. Glulam sections are available in widths to 1.8 m, thicknesses to 0.6 m and long lengths. Maximum available lengths vary between manufacturers and with transportation arrangements.

Timber is referred to in standard or 'nominal' sizes, such as 100 mm x 50 mm. However, the actual section size may vary from the specified size depending on moisture content, machining and tolerance. The sawn dimension of timber is the size at which the board is cut to allow it to shrink during production to the nominal dimension. As shrinkage is not always uniform, the board is often marginally larger than the nominal dimension after drying. The machined dimension is the measured size of a piece of timber, once it has been milled to a dressed size. The machined size is smaller than the nominal size.

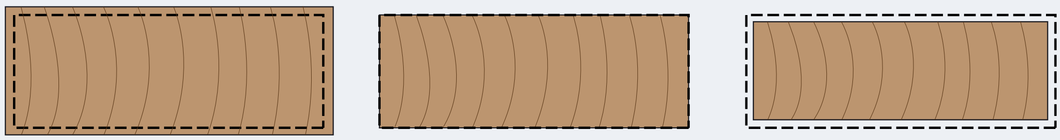


Figure 1: Timber sizing – sawn, nominal and machined.

1.2.6 Certification of Forest Management and Timber Supply

To ensure the timber used in building is a sustainable product it should be sourced from a sustainably managed forest. Forest certification and chain-of-custody certification are systems which aim to ensure the sustainability of timber products for use in buildings. The certification schemes benchmark processes used against internationally recognised best practices. The timber is tracked through the supply-chain from tree to retailer.

The two dominant international certification schemes are the Programme for the Endorsement of Forest Certification Schemes (PEFC) and the Forest Stewardship Council (FSC). Both schemes operate in Australia. PEFC has endorsed the Australian Forest Certification Scheme (AFCS) and the FSC operates in Australia under interim standards from internationally accredited FSC certifying bodies. Current information on the certification of forest and production companies and updates on the development of standards is available from the AFCS at www.forestrystandard.org.au, and from the FSC at www.fscaustralia.org.

1.3 Glass

Glass used in windows and doors must comply with *AS 1288-2006 Glass in buildings – Selection and installation.* The standard regulates the size and type of glass according to the required structural capacity of the glass, and ensures the safety of occupants by balancing risk posed and potential hazard.

Glass can be modified to reduce the danger of human impact, increase its aesthetic appeal, provide privacy, alter its thermal performance or change the amount of sunlight transmitted.

1.3.1 Safety Glass

Glass can break into dangerous shards. To reduce the risk of harm to building users AS 1288-2006 requires that safety glass be used in windows and doors susceptible to human impact. *AS/NZS 2208-1996 Safety glazing materials in buildings* establishes two grades of safety glass: Grade A offers a high level of protection against injury and includes laminated, toughened and toughened laminated glass; Grade B provides lesser protection and includes wired safety glass.

Laminated glass is two or more sheets of glass joined with adhesive inter-layers of transparent plastic. The glass adheres to the inter-layer if broken and generally remains in the glazed unit. Toughened glass is heat treated, which increases its strength beyond that of typical annealed glass and ensures that when shattered, it breaks into small, relatively safe pieces. Toughened glass is also called tempered glass.

The type and thickness of glass in windows and doors significantly influences thermal and acoustic performance, safety and security, and the amount of light admitted.

1.3.2 Modified Glass

Poor specification of glass and glazing can contribute to glare problems inside the building, the building overheating through solar gain, and heat loss on cold days. Solar transmission characteristics and thermal performance of the glass can be modified by applying a coating, colouring the glass, combining sheets of glass into sealed units, or a combination of all three. Manifestation uses markings adhered to or etched onto glazed areas for visual effect, or to ensure that the glass is visible to prevent accidental impact by people.

Table 6: Performance characteristics of different types of glass.

Glazing type	Visible light transmittance	U-Value [W/(m²K)]	Solar Heat Gain Coefficient
6 mm clear	88%	5.8	0.82
6.38 mm laminated	87%	5.7	0.78
6 mm low-e	81%	3.6	0.69
6.38 mm laminated low-e	82%	3.6	0.68
3/12/3; double-glazed; clear/air/clear	81%	2.7 (air), 2.6 (argon)	0.75
4/12/4; double-glazed; green tint/air/tint	73%	2.7 (air), 2.5 (argon)	0.55
4/12/4; double-glazed; clear/air/low-e clear	75%	1.9 (air), 1.6 (argon)	0.64

Source: Viridian Glass

1.4 Hardware

Timber windows and doors incorporate fixings, hinges, catches, locks, seals, etc, which are collectively known as 'hardware'. The range of hardware available is diverse in quality, function and cost. Categories of hardware include:

- moving hardware (hinges, friction stays, roller and tracks, pivots);
- securing the moving components (locks, catches, closers, bolts);
- handling and restraint (handles, hooks, knockers, pull and push plates);
- excluding air and water (seals and barriers); and
- providing protection and security (stops, kick plates, insect screens, security mesh).

Hardware is generally specified by the load capacity required, quality and sophistication in manufacture and operation. Most load-bearing hardware is designed to reliably carry or operate within a specific load or capacity limit. Correctly securing the timber to the metallic hardware is crucial for satisfactory performance under load.

Architectural intent, the economics of construction, and required thermal performance determine the selection of hardware. Hardware manufacturers should be consulted when producing a hardware specification.

2

Design options

2.1 Introduction

This section introduces the most common window and door configurations. Diversity in window and door design is generated by manipulating the configuration of the types presented, the timber arrangement and finish in primary elements, and the type of glazing used.

2.2 Frame Options

Timber windows and doors can be made from solid timber of a single species or combinations of different timber species, laminated timber, or composite sections of timber and another material.

2.2.1 Solid Timber

Solid timber elements are available in a wide range of species and sizes. Species can be selected to maximise utility and economy. For example, the designer could specify sills of a durable species, the remainder of the frame in a more economical timber, and sashes or leaves from a light and highly stable species. The size of quality solid timber sections available is restricted by the logs available and cutting methods adopted.

2.2.2 Glue-laminated Timber

Glue-laminated timber consists of pieces of timber assembled with an adhesive to create larger sections. Sections range from pairs of solid timber glued together to create a more stable section, to large-section glue-laminated elements of finger-jointed material. Glue lamination uses high-quality sections of timber efficiently. Profiles can be assembled to match the required shape so there is typically little waste. Glue-laminated material can be stronger with more consistent structural properties than solid timber.

2.2.3 Composite Timber Sections

Composite elements feature a frame of timber faced with a metal profile of extruded aluminium or bent stainless steel. The primary advantage of a composite frame is elimination of maintenance of the covered timber surface while retaining the thermal and acoustic benefits associated with a timber window. In Australia, several manufacturers produce windows and doors with external aluminium facings. The size of timber and aluminium composites is restricted by the size of available aluminium extrusions.

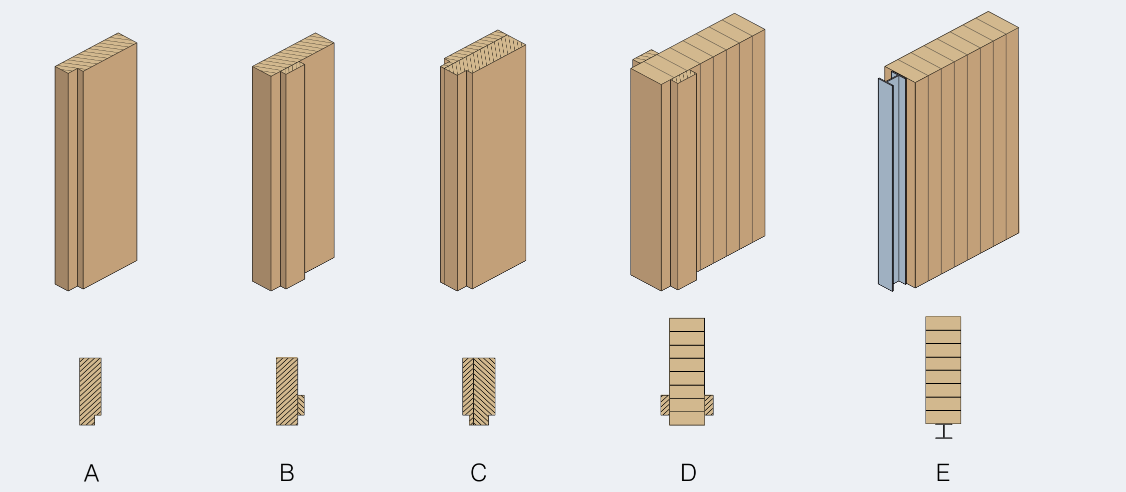
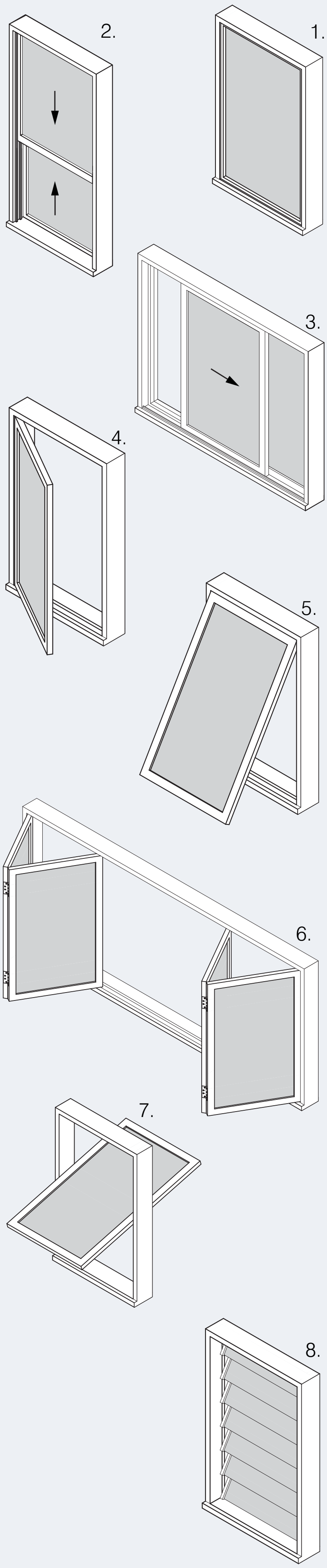


Figure 2: Timber frame arrangements:
(A) rebated solid timber (B) solid timber with a stop (C) rebated laminated timber
(D) glue-laminated timber with a stop (E) glue-laminated timber with an extruded glazing section.

2.3 Window Configurations



1. Fixed glass or light

A fixed pane of glass held in a timber frame. The glass can be set directly onto a rebate or 'stop' on the window frame, or set into a fixed sash (fixed light), and fixed in the frame.

2. Double-hung window

Two sashes set to slide past each other vertically within the frame. The weight of an individual sash is held by mechanical balances or counterweights on each side. The unit can also be arranged so that one sash moves over a fixed sash or glass.

3. Sliding window

Two or more sashes set to slide past each other horizontally within the frame. Several sashes can also slide past each other to stack to one side of the opening. The opening sashes should slide outside the fixed sashes for water shedding.

4. Casement window

A sash hung to open from one side, usually with hinges along the vertical edge of the frame, or friction stays on the top and bottom of the sash. The sash generally opens out, but can open in. Screens can only be fitted internally if opening out.

5. Awning window

A sash hung to open out from the bottom, usually with hinges along the top edge of the frame or friction stays along the sides of the sash. Some stays allow complete reversal of the window. Screening and security can only be fitted internally. Awnings hung to open out from the top are called hopper windows.

6. Bi-fold window

Two or more window sashes alternately hinged so they fold against each other to the sides of the opening, providing a full and unobscured opening. Bi-fold windows can be supported on an overhead track or, if there are only two sashes per side, hung without a track.

7. Pivot window

A sash that rotates on pivot hinges in either the horizontal or vertical plane. The pivot line can be central to the sash or off-set.

8. Louvre window

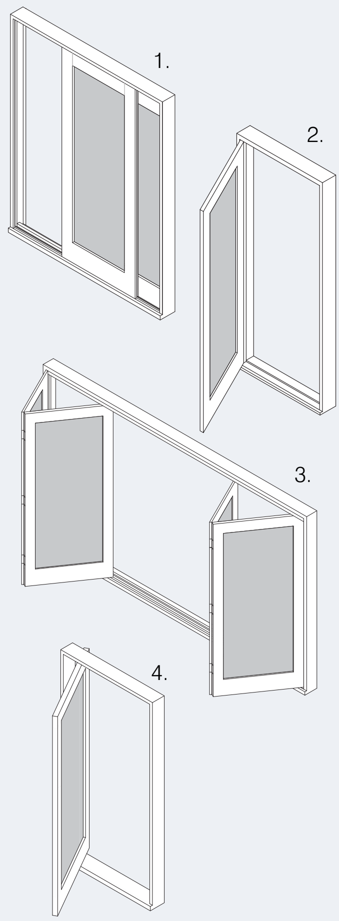
Sets of glass, timber or aluminium blades arranged horizontally across the frame. Fixed louvres can be rebated at each end into the frame. Moveable louvres fit into mechanical louvre galleries. With moveable louvres, the blades' angle of inclination is adjustable to allow more or less light or air into the enclosure.

Table 7 provides a qualitative comparison of standard versions of the window types presented above. For each window type there will be exceptions to these comparisons.

Table 7: Comparison of window configurations.

	Fixed	Double-hung	Sliding	Casement	Awning	Bi-fold	Pivot	Louvre
Economic	✔	✔ (Mechanical)	✔	✔	✔			✔
Simple to operate		✔	✔	✔	✔		✔	✔
Easy to clean at height							✔	✔
Provides ventilation		✔	✔	✔	✔	✔	✔	✔
Easy to weatherproof	✔	✔	✔	✔	✔	✔		
Easy to make airtight	✔			✔	✔			
Easy to make secure	✔	✔	✔	✔	✔	✔	✔	

2.4 Door Configurations



1. Sliding door

Two or more leaves set to slide past each other horizontally within the frame. Several leaves can also slide past each other to stack to one or both sides of the opening. They are suitable for large openings but the sliding leaves have to be stacked in the door frame, reducing the overall opening size.

2. Hinged door

A door leaf hung along a vertical edge of a frame with hinges and opening inwards or outwards. Pairs of doors hung on either side of the frame and meeting with a rebated central join are called French doors.

3. Bi-fold door

A series of doors, alternately hinged so they fold against each other on one or both sides of the opening, providing a full and unobscured opening. Bi-folds can be supported on an overhead track or, if there are only two doors per side, hung without a track.

4. Pivot door

Pivot doors rotate in the vertical plane on hinges at the top and bottom. They can pivot in either one direction or in both directions, giving a wide, generous opening.
Table 8 provides a qualitative comparison of standard versions of the door types presented above.
For each door type there will be exceptions to the comparisons.

Table 8: Comparison of door configurations.

	Sliding	Hinged	Bi-fold	Pivot
Economic	✔	✔		
Easy to operate	✔	✔		✔
Easy to weatherproof	✔	✔	✔	
Easy to make airtight		✔		

3

Meeting performance requirements

3.1 Introduction

Timber windows and doors are key components in the environmental performance of a building envelope by excluding water; providing ventilation; controlling air infiltration and sound; and contributing to the building's thermal and acoustic performance.

3.2 Designing for Moisture Control

Preventing water from entering the building is an essential part of window and door design. Designing for moisture control should consider:

- shedding standing water from the frames;
- controlling the entry or seepage of water into the building; and
- preventing water from entering the building envelope where the unit and envelope meet.

3.2.1 Shedding Standing Water

Water needs to be shed from any surface of window and door frames to prevent standing water. Any water build-up can cause deterioration in the finish, the timber and the joints of the unit. Water is shed by ensuring:

- the top of glazing beads are sloped to at least 1:6;
- the surface under the actual glazing or glazing unit is sloped to 1:10;
- any horizontal, exposed surfaces have a minimum slope of 1:8; at 1:8 slope water will drain off even with a moderate amount of opposing wind pressure;
- corners of the top of all horizontal or sloping faces feature rounded arises to improve water run-off and adhesion of finishes; and
- sills include a drip-line of a saw-cut or groove with a nominal 3 mm radius, 10 mm back from its outside edge.

The organisms that break timber down require a moisture content of above 20% in the wood to survive. Dry timber generally remains serviceable for centuries.

3.2.2 Water Entry into the Building

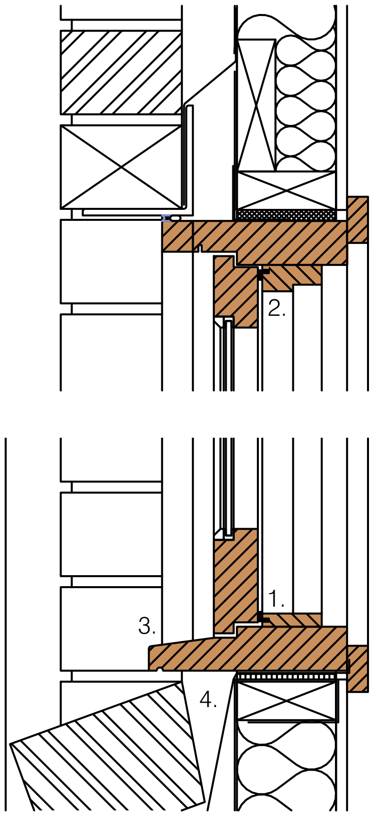


Figure 3: Window sash and frame section.

Controlling the flow of water on and through the window or door unit is essential to prevent water seeping into the building. Unwanted water seepage can be unsightly, a safety hazard, and can lead to the deterioration of the building fabric. AS 2047-1999 establishes the test method and test pressures to ensure that windows for domestic buildings resist water penetration through the assembly and detailing.

Water ingress through the unit is prevented by careful detailing of upstands, returns and seals. The configuration of these will vary between window and door types. For example: (1) the sill up-stand acts as a barrier to help prevent water ingress with the moving sash or leaf is shut in casement windows and doors. Compressive seals (2) should be fitted on adjacent faces which close together such as the top rail of awning windows.

Adhesion and wind pressure can push water across the underside of sills and across the outside face of the frame of the window or door to the joint between the unit and the building envelope. Saw cuts on 3 mm minimum radius should be used on the downward faces surfaces to facilitate dripping and prevent capillary action (3).

If water enters the joint between the unit and the surrounding envelope it has to be collected at a flashing and directed to the outside face of the external cladding (4). Flashing around the opening is a critical part of window installation.

3.2.3 Condensation

Condensation usually forms on (or in) a window or door when warm moist air comes in contact with a colder surface. Timber frames do not heat up or cool down quickly and are not as prone to condensation as metal frames (which are thermally conductive).

Condensation in a timber-framed unit generally occurs on the glass in colder climates. When the external temperature drops, the glass cools, and warm internal air meets the cold inside surface of the glass, causing condensation. If the glass is cold enough and the inside humidity high enough, sufficient water can condense on the glass and run down the glass and pool on the inside of the sill. The condensed water can discolour timber, damage finishes and encourage mould to grow.

In hot, humid climates, condensation can occur on the outside surface of the glass when the inside space is air-conditioned and significantly cooler than the outside air. Condensation can also form between the timber and the aluminium on composite sections.

Condensation can be limited by reducing the relative humidity of air adjacent to the window through ventilation, using low-e coatings on glass and insulated glass units (IGUs), and in colder climates by limiting convective air movement around the glass. However, the edge seal can deteriorate on IGUs with age, compromising the internal air space. Absorbent material in the edge spacers stops incidental small amounts of moisture becoming a problem but continuing moisture can migrate into the air gap and condense on the surface of the exterior pane. The moisture cannot be removed in sealed units and the unit should be repaired or replaced. Unsealed units are typically vented, which should allow moisture to escape.

3.3 Designing for Thermal Performance

The insulation value of windows and doors is generally much lower than that of the surrounding walls, floors and ceilings, making them highly influential in the thermal performance of a building. The thermal conductivity of timber is significantly lower than that of aluminium. In a direct comparison, timber is a better insulating material than aluminium. For an aluminium frame to achieve a thermal performance similar to a timber frame requires the use of complex shapes with seals and isolators. These elements provide a thermal break, and reduce heat transfer. The timber-framed equivalent can be relatively simple, which is typically reflected in the cost, particularly for bespoke designs.

Standard float glass has relatively high thermal conductivity and is therefore a poor insulator. Its insulation performance can be moderated with coatings or additives, or by arranging the glass in an insulated glazed unit (double- or triple-glazed sealed units). However, even with these improved measures the glazing will typically be the element with the least thermal resistance in a building envelope.

Table 9: Thermal values of various materials.

Material	U-Value [W/(mK)]	Relative Resistance (R) Value [(m^{2}K)/W]	
		6mm	40mm
Glass wool insulation	0.038	0.158	1.053
Softwood	0.135	0.044	0.296
Hardwood	0.175	0.034	0.229
Concrete	0.930	0.006	0.043
Glass	1.000	0.006	0.040
Steel	45.300	0.000	0.001
Aluminium	221.000	0.000	0.000

The National Construction Code Part J of Volume 1, and Section 3.12 in Volume 2, present requirements for a building's thermal performance. Limits are set on the amount of glazed areas included in the facades of a building, with the limits dependent on the building's location and the orientation, shading and thermal properties of the glazed unit. The glazed unit's U-value and solar heat gain coefficient (SHGC) is needed to show compliance to the National Construction Code. The U-value and SHGC of a glazed unit is highly dependent on the configuration of framing material and the particular type of glass used. The results of generic tests are included in Table 10. What is apparent from this table is that the choice of glazing system will be informed by climate. The generic 3/12/3 timber framed window has a 40% improvement for climates requiring heating and a 51% improvement for climates requiring cooling.

Note: In Table 10 Uw is the whole window U-value which incluldes the relative surface area of frame and glass, SHGCw is the whole window solar heat gain coefficient, and Tvw is the whole window visible (light) transmittance.

Key:

Glazing ID	Glazing description
3Clr	3 mm single clear
6.38CP	single solar control, pyrolytic low-e
5toned	5 mm toned
5supertoned	5 mm supertoned
3/6/3	3/6/3 clear IG, air fill
3/12/3	3/12/3 clear IG, air fill
5supertoned/6/5	5/6/5 supertoned IG with air fill

Source: WERS 2011 Generic Product Directory (www.wers.net)

Table 10: Performance of different window types.

		Cooling	Heating	Total Window System Values NFRC			
Glazing ID	**Frame**	**% impr.**	**% impr.**	**Uw**	**SHGCw**	**Tvw**	**Air Inf.**
GENERIC STANDARD INDUSTRY TYPICAL WINDOW – SINGLE-GLAZED							
3Clr	Generic: aluminium	2%	0%	7.4	0.77	0.80	5.00
3Clr	Generic: timber	21%	24%	5.5	0.69	0.72	5.00
5toned	Generic: timber	38%	16%	5.4	0.50	0.39	5.00
5supertoned	Generic: timber	40%	15%	5.4	0.47	0.59	5.00
6.38CP	Generic: timber	52%	33%	3.7	0.41	0.47	5.00
GENERIC STANDARD INDUSTRY TYPICAL WINDOW – DOUBLE-GLAZED							
3/6/3	Generic: aluminium	22%	27%	5.3	0.69	0.72	5.00
3/6/3	Generic: timber	38%	47%	3.3	0.61	0.65	5.00
3/12/3	Generic: timber	40%	51%	3.0	0.61	0.65	5.00
5supertoned /6/5	Generic: timber	55%	37%	3.3	0.41	0.34	5.00

Source: WERS 2009 Generic Product Directory (www.wers.net)

3.4 Controlling Air Infiltration

AS 2047-1999: Windows in buildings – Selection and installation establishes maximum air infiltration rates for particular window or building types. Maximum allowable air infiltration rates under the test procedures defined in the standard are shown in Table 11. However, limiting air infiltration is fundamental to ensure adequate thermal performance. Research has documented that as the thermal performance of the external fabric (walls and windows) is improved, the relative heat losses from infiltration increases. In the United States, up to 35% of heating and cooling losses have been attributed to infiltration. Several nations have set minimum window system infiltration rates much lower than those presently in use in Australia for residential construction. The use of long-lasting flexible seals between the fixed and operable portions of the window is contingent to the reduction of infiltration.

Table 11: Maximum air infiltration rates.

Building or window type	Pressure directions	Maximum air infiltration($l/s\ m^2$)	
		Test pressure 75 Pa	Test pressure 150 Pa
Air-conditioned	Positive, negative	1.0	1.6
Non-air-conditioned	Positive	5.0	8.0
Louvre window	Positive	20.0	n/a
Adjustable louvres, residential and commercial building	Positive	20.0	32.0

Source: AS 2047-1999, Table 2.3

3.5 Designing for Acoustic Performance

Windows and doors are typically the most acoustically transmitting part of the building envelope. The most transmitting part of any window or door will be any unsealed gaps through which air can move. The type of unit should be selected which can close tightly onto one or two rows of seals which sit on a frame, such as a casement window.

The sound reduction through an element is linked to its mass. Increasing the mass in the glazed area through increasing glazed thickness will improve the sound reduction. The sound transmission will vary through an element at different frequencies. The sound reduction performance of IGUs can be improved by using inner and outer leaves of different thicknesses to avoid the two leaves vibrating at the same frequency. Laminated glass will provide a greater sound reduction than the equivalent solid thickness because the inter-layer between laminates acts to dampen the glass vibration.

Table 12: Sound reduction by glass type.

Glass	Decibel level reduction (dB)
3 mm	30
6 mm	32
IGU (6/16/6)	35
6.38 mm laminated glass	33
10.38 mm laminated glass	36

Source: Viridian Architectural Glass Specification Guide

3.6 Designing for Durability

Durability is a key consideration when specifying timber windows and doors. Timber windows and doors should be designed and detailed to meet the thermal, structural, acoustic and aesthetic performance requirements for the intended design life. There is no simple rating or guarantee of the durability of a timber window or door. The reputation of the manufacturer and the warranties they provide will be an indicator of the unit's reliability.

Several factors govern the durability of a window or door unit, including its exposure to the external environment, the individual durability of the assembled components (mainly the timber frame and glazing) and the maintenance regime.

3.6.1 Exposure

The service life of window and door units in the external envelope will be directly related to their level of exposure to rain, wind, sunshine and persistent moisture. Exposure needs to be considered at several scales: the macro scale of different climatic areas, the location scale of the site, the building scale, and the micro scale of the element or detail.

Climate scale

Timber exposed to a climate that is regularly damp or wet will generally decay faster than timber in a regularly dry climate. The rate of decay is exacerbated by heat and moisture. Hazard zones for the decay of timber above ground are shown in Figure 4. Hazard zones for embedded corrosion of fasteners are shown in Figure 5 and give broad guidance on the longevity of embedded fixings in exposed timber joinery and probably also for exposed hardware. More information can be found in FWPA Timber Service Life Design Guide.

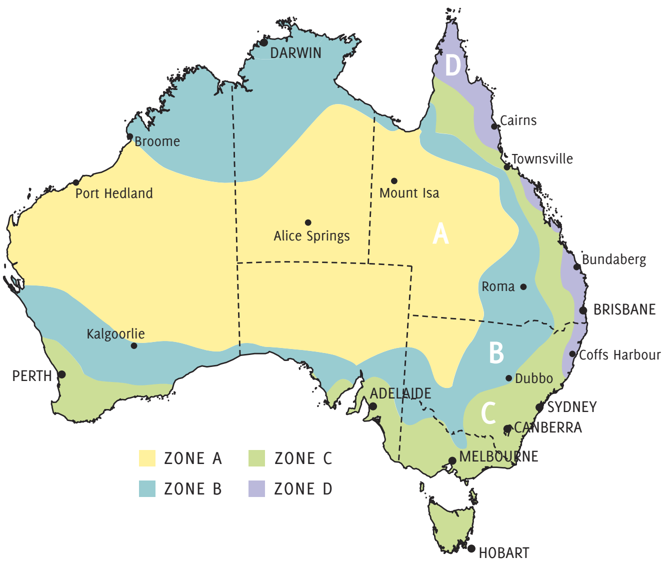


Figure 4: Above-ground decay hazard zones. Zone D has the highest decay hazard.

Climate can affect the performance of timber, embedded fastenings and any applied finishes.

Figure 5: Hazard zones for embedded corrosion. Zone C has the highest hazard.

Source: FWPA Timber Service Life Design Guide

Location and building scale

Local site conditions include topography, vegetation and the proximity of lakes or ocean. These modify the local climate, potentially reducing or increasing exposure to rain, wind, sunshine and persistent moisture, and can introduce additional hazards. The south side of hills in temperate, wet climates will generally be damper than the north side and more conducive to decay. Proximity to the sea, especially salt spray near the ocean, will influence the performance of hardware.

The position of a window or door unit in the building affects its durability. Units on the south side of a building are generally protected from direct sunlight. In hot climates, this can significantly increase the service life of finishing systems. In cool and wet climates, the regularly higher moisture content of the timber on the south side of the building can potentially expose it to an increased rate of decay.

Element and detail scale

An effective means of increasing the durability of timber windows and doors is to limit their direct exposure to the elements by providing an eave, overhang, sunshade or verandah over the facade or the unit. These reduce the level of sunlight, the force of wind and the amount of rain driven onto or running across the joinery unit, significantly increasing service life.

In windows, the window sill, bottom rail of any sash, and the joints between the sill and the rest of the frame endure the most exposure and therefore are at the highest risk of deterioration. In doors, it is the bottom rail of a panel door, the bottom 300 mm of any door and the joints between the sill and the rest of the frame.

These surfaces are generally angled more towards the sunlight, exacerbating the effect of heat on the timber or the paint finish and the rate of breakdown or decay, and are further away from any protection given by eaves or sunshades. Water runs down onto these surfaces from above; it can also be splashed up onto doors or full-height windows from the surrounding floor or ground. Dust and water accumulates on these surfaces.

3.6.2 Durability of the Timber Frame

The durability of the timber frame is affected by hazards in the surrounding environment, the resistance of the timber to decay and weathering, the arrangement of species, the quality of assembly, and any coating or treatment on the timber.

Hazard classes

The timber can resist decay and weathering naturally or with preservative chemical treatments.

AS 1604-2005 Timber – Preservative-treated – Sawn and round identifies the degree of hazard for timber in construction. For timber in window and door joinery, the relevant hazard classes are:

- Hazard Class H3 for units exposed outside above ground; and
- Hazard Class H1 for units exposed inside, fully protected from the weather and termites.

Hazard Class H3 includes a wide range of conditions from under the shelter of eaves to full exposure to the sun and wind. However, while the whole unit is rated as Hazard Class H3, in practice the different parts of the window or door are exposed to different hazard conditions.

Decay, weathering and insect attack

Decay is the decomposition of timber by fungi and can occur if the moisture content of the timber is maintained above 20% and the temperature is between about 5°C and 60°C. While the temperature on the outside of a building is hard to control, the timber can be kept dry by shedding water, keeping moisture out of the joints and allowing wet timber to dry out. Decay can occur on any surface of timber but tends to attack the end-grain of any unprotected piece most vigorously. Absorption through the end-grain of the piece can be much quicker than through the surface grain and the higher moisture content sustains the fungi.

Weathering is the greying and minor cracking of a timber surface caused by light, dust or recurrent wetting and drying. Weathering affects appearance, the performance of finishes and eventually the decay rate, as water retained in any indentations in the surface of the wood or under any fractured finishing coat can nurture the growth of fungi.

Insects, such as termites and lyctid borers, can attack the timber. Exclusion of termites is a whole-of-building issue and should be addressed as set out in the relevant Australian Standard. The lyctid borer attacks the sapwood of susceptible hardwood species. The adult insect lays its eggs in the pores of wood and the insect larva attacks the starch-rich sapwood, leaving behind fine, powdery dust, or frass, and small holes on the timber's surface. The starch level in the heartwood of the timber is generally not high enough to sustain the larva and is not attacked. AS 2047-1999 and timber marketing legislation in several states preclude the sale or use of lyctid-susceptible sapwood in timber. All susceptible sapwood has to be excluded or treated. Industry practice in Australia is to mill the timber without sapwood or to treat the timber of susceptible species to H1 under AS 1604, often with a boron-based or synthetic pyrethroid preservative.

Timber's natural resistance to hazards

The natural durability of a piece of timber is generally a characteristic of the species. Timber species are rated in one of four durability classes in *AS 5604-2005 Timber – Natural durability ratings. Durability classes are* based on years of comparative tests of timber samples. Durability ratings are given for two types of exposure: durability in-ground contact and durability exposed out-of-ground contact (Table 13). Durability ratings only refer to the performance of heartwood. Sapwood is either excluded or treated. The untreated sapwood from all species is rated as Durability Class 4.

Table 13: Timber durability life expectancy.

	Probable heartwood life expectancy (years)	
Natural durability class	**Hazard class 1 Fully protected from the weather and termites**	**Hazard class 3 Above ground exposed to the weather but protected from termites**
Class 1 (highly durable)	50+	40+
Class 2 (durable)	50+	15–40
Class 3 (moderately durable)	50+	7–15
Class 4 (non-durable)	50+	0–7

Source: AS 5604-2005

Preservative treatment to resist decay, weathering and insects

Timber's natural resistance to decay and insects can be enhanced by adding preservative chemicals. AS 1604-2005 specifies the requirements for preservative treatment, including the penetration and retention of chemicals in the timber. Treatment options are generally targeted at achieving resistance in particular hazard classes. For example, low-durability timber can be treated to H3, meaning it is suitable for use outside above ground.

The main types of preservative treatments for joinery timber in Australia are combinations of insecticides and fungicides, applied by dip diffusion or by commercial pressure treatment. The major treatment options are:

- waterborne preservatives applied to unseasoned timber, generally boron-based mixtures; and
- light organic solvent-borne preservatives (LOSP) applied to seasoned timber and finished product. Current commercial treatments include azole or tri-butyl tin combined with a pyrethroid.

Not all timber can be successfully treated to the level required by AS 1604 using currently available commercial processes. Generally, the sapwood of all species can be treated to H3 but the heartwood of most species resists consistent treatment because the preservative cannot penetrate into the timber sufficiently or consistently enough to provide the level of chemical retention required. Such pieces only receive surface coating. If cut, the exposed ends of treated timber should be dipped in preservative to maintain the envelope protection.

Research carried out by CSIRO sought to gauge the comparative durability of six test window frames constructed from timber species of differing durability with varying finishes. The timber was tested untreated, treated with boron when unseasoned, or treated with LOSP when seasoned, painted and unpainted.

After eight years of exposure, the windows were examined and rated on an 8 to 0 scale based on the amount of cross-section lost to decay. A rating of 8 means the frame was sound while 0 equalled a destroyed frame. A specimen rated 3 or lower was regarded as unserviceable.

Table 14 presents a summary of results from the research. Timbers with relatively low inherent durability and thus poor untreated performance can be seen to perform similarly to the higher durability species when treated with either boron or LOSP (AZOLE). The use of 'no-rot' rods in the frames, which provide a slow impregnation of preservative, significantly improved the service life of the units. Painting either as a sole finish or in combination with other treatments can also be seen to significantly improve the service life of the units. The results of this research are not reflected by current codified practices, but the research provides evidence of what may be achieved with such treatments.

The appearance of timber windows and doors is often a critical part of a design concept and the selected finish of the unit strongly influences its appearance.

Table 14 Summary comparison of performance.

Species	Durability	Treatment	Mean performance (std dev.)
Western red cedar *(T. pilcata)*	2	untreated, painted	7.4 (0.8)
Mountain ash *(E. regnans)*	3	LOSP (azole), painted	7.4 (0.3)
Mountain ash *(E. regnans)*	3	LOSP (azole), unpainted	4.5 (2.5)
Mountain ash *(E. regnans)*	3	untreated, painted	0.9 (1.0)
Mountain ash *(E. regnans)*	3	untreated, unpainted	0.6 (0.8)
Mountain ash *(E. regnans)*	3	boron, painted	7.4 (0.5)
Messmate *(E. obliqua)*	3	boron, painted	7.4 (0.3)
Alpine ash *(E. delegatensis)*	3	boron, painted	7.0 (1.6)
Silvertop ash *(E. sieberi)*	2	boron, painted	6.0 (1.4)
Mountain ash *(E. regnans)*	3	No-rot rods	8.0 (0.1)

Source: Cookson 2007

Finishing

There are four common approaches to finishing timber windows and doors: natural or unfinished; coated with a stain or clear finish; coated with an opaque paint; or clad with an extrusion in a composite system, usually aluminium or stainless steel. Finishes can be combined on the same unit to maximise protection while maintaining design intent. Windows and doors can be finished differently internally and externally. Window and door elements within a unit can be finished differently, for example frames may be painted while sashes left unfinished.

The selection of an appropriate finish for the application can be critical to the unit's service life. Coating external timber with a well-maintained paint or a high-build translucent finish sheds water off the unit's surface quickly, slowing the uptake of moisture and reducing the chance of decay. Detailed specifications should be developed in consultation with a manufacturer.

The expected life of finishes depends on the quality of the coatings, care taken in application and ongoing maintenance regime. Quality products should be used and applied and maintained strictly to the manufacturer's recommendation to maximise service life. Even if coatings are of the same type, their composition and performance can be quite different and so should not be mixed across brands or systems.

Natural or unfinished

Timber windows and doors can be left unfinished, exposing the natural texture and tone of the wood. Well-detailed unfinished windows and doors will need little maintenance, reducing the potential environmental impact associated with coating and subsequent refinishing. However, an unfinished element will not remain as the installed colour. Over time, the surface of the timber will start to weather, first darkening as moisture mobilises extractives in the wood, and then turning grey. The expectations of client and the building users should be managed with respect to the ongoing colour of the timber. Local precedents can be studied. Another approach is to paint the timber with a temporary coat of grey that fades as the wood itself greys. Key considerations for a natural or unfinished approach are:

- Take care in species selection and detailing of unfinished joinery. Uneven exposure and wetting can lead to variable weathering, staining, bleaching and localised surface mould as shown below.
- Select species with suitable durability to match with the element exposure. Do not use low-durability timbers without treatment or younger and more unstable species without a coating.
- Unfinished timber will absorb and lose moisture more readily than finished timber so clearance between opening sashes and the frames should be increased to allow for any moisture-induced movement.
- Glazing seal materials need the capacity to expand into increasing gaps between the glass and bead, or have sufficient flexibility to bond to both the glass and timber if glazing beads are to be left uncoated. Putty should be painted.
- Metal elements such as hardware should be stainless steel or other corrosion-resistant metals to resist climatic exposure and reaction with timber-extractives.
- Elements should be painted on the concealed surfaces, with the remainder coated with a temporary water-repellent coating in the factory. This temporary coating will break down quickly on the exposed surfaces, but will continue to protect the covered surfaces for some time.

Figure 6: Differential weathering and decay on a facade.

Transparent coatings and stains

Transparent coatings and stains protect the timber while allowing the grain and texture of the timber to show through. Coatings suitable for external applications usually include preservatives, fungicides and colourants with an oil that soaks into the timber and a tougher medium- or high-build surface coating. The oil improves appearance and adhesion, while the surface coating protects the timber from occasional wear and excludes moisture. The preservatives and fungicides in these finishes protect the finish and the timber directly in contact with it. However, while they may be marketed as preservatives, they are not substitutes for factory-impregnated timber treatment.

Transparent coatings shed water and reduce other impacts but the surface of the timber is usually exposed to ultraviolet light and can weather over time. The resulting timber breakdown allows the finish to lose adhesion and crack or peel. Semi-translucent stains that pigment the surface of the timber without necessarily obscuring its natural features can provide better ultraviolet resistance. Simple oil-based coatings may contain preservatives and fungicides but are generally not long-lasting in external applications, especially those regularly exposed to sunlight. The oil can be a ready food source for fungi and cause surface mould. Simple clear varnishes are not suitable for outside applications, as the timber quickly weathers and the finish crazes and can trap water under the coating.

Coatings for internal finishes do not have to face the rigours of external coatings and more variety is available. There are three main types for internal applications: clear polyurethane finish (or varnish); a combination of an oil and a surface coating such as polyurethane; or an oil or wax preparation.

- Polyurethanes are available in two major types: moisture-curing and water-based. Moisture-curing polyurethanes produce a clear, very hard surface in a matt, satin or high-gloss finish. However, they darken with age. Water-based polyurethanes can produce a clear, hard surface in a matt, satin or gloss finish. Water-based polyurethanes produce less fumes during application and curing, but are more expensive than moisture-curing polyurethanes.
- Modified oil coatings are clear varnishes, generally made from a mixture of resin and oil. These are easy to apply and penetrating, are more visually subtle than polyurethanes, but are not as hard-wearing.
- Oils are penetrating finishes that are generally less hard-wearing than modified oils or polyurethanes. They produce a subtle, natural appearance but require regular maintenance in high-contact areas.

The consequences of any breakdown of the finish can be severe. Once the surface of the finish splits, water can enter and be trapped next to the wood. This can lead to further breakdown of the finish, more ingress of water and hastened decay.

Paints

Paints protect timber from water, sunlight and abrasion and are able to conceal flaws in the surface of the timber. These finishes last much longer than translucent coatings because ultraviolet light cannot reach the surface of the timber to cause weathering.

The choice of colour is important. Light-coloured paints typically last longer and give greater protection to the timber than dark-coloured paints because dark colours absorb and retain heat from sunlight, straining the paint. Once the surface of the finish splits, water can enter and be trapped next to the timber which can lead to further breakdown of the finish, more ingress of water and hastened decay.

The paint needs to be flexible and remain flexible because timber expands and contracts with changes in moisture content. When paints become hard and brittle, usually associated with prolonged exposure to sunlight, they can break down and flake away from the timber. Quality paints, properly applied and maintained, can be long-lasting and accommodate moisture-induced movement without fissuring or flaking.

There are two main types of paints commonly available for windows and doors: oil- (or solvent-) based paints and water-based acrylics. Oil-based paints were traditionally used with all external joinery. They have better flow characteristics than water-based paints, and were believed to provide a better adhesion to the surface. However, older solvent-based paints did not have the long-term flexibility of modern systems, and tended to become brittle and chalky and crack away from the timber.

Older acrylics were believed to form a plastic wrap on the wood, and cause sticking in sashes and doors. They did not have the durability of contemporary solvent-based paints. However, with advances in acrylic technology, acrylics are now preferred for coating external windows and doors. Acrylics do not have the chemical emissions commonly associated with solvent-based finishes, are easier to apply and clean up, and have a shorter recoat time.

Joints and fixings

The quality of assembly can assist in keeping the timber in the joints of the frame dry and protected from decay. The joints between the sill and the rest of the frame should be completely sealed to exclude water. Joints in the frame should be protected by:

- treating the cut ends of any treated or low-durability material. A minimum three-minute dip immersion of the end-grain in an azole-based LOSP treatment can significantly increase the frame's service life.
- sealing the end-grain of the pieces with paint before assembly which slows water entering the timber;
- sealing the joint with a flexible, waterproof sealant to fill any gaps that water may enter; and
- shaping joints so that they do not trap water unnecessarily.

Corrosion of metal fasteners can split the timber and retain moisture. AS 2047-1999 requires that all steel fixings should be hot-tip galvanised steel in accordance with service condition No. 2 of *AS 1789-2003 Electroplated zinc (electrogalvanised) coatings on ferrous articles (batch process),* or stainless steel. Do not use uncoated steel fixings on any part of the frame.

Flashings

Flashings are needed at the head, sill and jambs of the opening to prevent water entering the 'dry' side of the water barrier around the joinery frame. Incorporating only storm beads or sealing the external cladding to the unit is inadequate because they inevitably fail, allowing water to enter the building. The final configuration of the flashings changes with the frame, the external cladding type, the position of the unit in the opening and the architectural intent.

Arrangement in the frame

Durability characteristics of species can be aligned with the deterioration risk of different components of the window or door unit as presented in Table 15. As a minimum, AS 2047-1999 requires that timber windows be constructed of:

- Durability Class 1 or 2 timber;
- timber treated in accordance with AS 1604-1997; or
- timber of any durability class provided that it is protected from ingress of moisture by appropriate joint details, and either the application of a protective coating or installation under a protective shelter, such as a verandah.

Table 15: Preferred species arrangement for commercial and Exposure Zone D residential projects.

Element	Relative exposure	Building exposure	Finish	Timber**
Sill	High	Normal	Painted or stained	Durability Class 1 or 2 timber
Sill	High	Normal	Painted	Durability Class 1 or 2 timber or commercially treated LOSP (azole) hardwood
Frame (excluding the sill)	Medium	Normal	Painted or stained	Durability Class 1 or 2 timber, or commercially treated LOSP (azole) hardwood, or VPI boron-treated hardwood
Frame (excluding the sill)	Medium	Normal	Painted	Durability Class 1 or 2 timber, or commercially treated LOSP (azole) hardwood, or VPI boron-treated hardwood, or H3 treated softwood
Sash or door*	Medium	Sheltered	Unfinished	Durability Class 1 or 2 timber
Sash or door*	Medium	Normal	Painted or stained	Durability Class 1 or 2 timber, or commercially treated LOSP (azole) hardwoods, or VPI boron-treated hardwood, or H3 treated softwood
Sash or door*	Medium	Normal	Painted	Durability Class 1, 2 or 3 timber, or H3 treated softwood

** Timber for sashes and doors has specific stability requirements that need to be met.*
*** If any treated timber is cut, the end-grain needs to be re-treated to maintain the treatment envelope.*

Design for durability internally

Finishes on windows and doors wear away with regular hand contact, or can be damaged where units are kicked or hit by trolleys or bags. Identifying points of wear and detailing to protect them will extend the life of surfaces and finishes. Replaceable inserts or protective coverings can be applied. Push and kick plates protect the timber from indentation.

3.6.3 Durability of the Glass and Glazing

Clear glass is a durable and chemical-resistant material with a very long service life if protected from impact or heat stress. Deep scratches in toughened glass can induce failure. The coating of low-e and heat-reflective glasses is subject to wear and potentially staining, especially during construction.

The service life of insulated glass units is influenced by the quality of design, manufacture and installation, and exposure to the elements. Wind loads and pressure fluctuations load the seals between and around the glazing panes which leads to fatigue in the seals and can reduce the thermal performance and permit air to enter. Consult manufacturers of specialist coatings and insulated units for advice on the correct installation and maintenance in order to maximise the service life of the units.

3.7 Designing for Bushfire

Bushfires expose buildings to extreme heat and wind-blown embers which affect timber windows and doors. Windows and doors can fail when the glass cracks, shatters or moves in the frame to form a gap that allows embers and potentially flame into the building. Buildings should be designed in compliance with *AS 3959-2009 Construction of buildings in bushfire-prone areas.*

AS 3959 specifies requirements for the construction of new buildings, or significant alteration to existing buildings, in State or locally defined bushfire-prone areas in order to improve their resistance to bushfire attack from burning embers, radiant heat, flame contact and combinations of these three forms of attack.

3.7.1 Bushfire Attack Levels and Material Selection

Compliance with AS 3959 requires establishing the threat level for the site and then detailing the building envelope to resist that threat. The standard establishes six possible Bushfire Attack Levels (BAL) for a site. The design BAL applied to a proposed building or renovation is based on an assessment of the threat posed to the site by nearby organic fuels and other factors.

Greater restrictions are placed on the materials used in the construction of the external envelope with increasing threat level. Timber species suitable for use with the different bushfire resisting classes can be found in Appendix E of AS 3959-2009, an extract of which is included in Table 16. Timber species can be regarded as bushfire-resistant due to the natural properties of the material, or by coating or impregnation with fire-retardant chemicals. Timbers rated as naturally bushfire-resistant after testing are included in Table 17. Timber can be impregnated with fire-retardant chemicals or coated with fire-retardant systems to comply with AS 3959, Appendix F.

Table 16: Bushfire requirements for doors and windows.

Bushfire Attack Level	External doors	External windows	Bushfire shutters
BAL LOW	No special requirements	No special requirements	No special requirements
BAL 12.5 & 19	Bushfire shutters or screen and any timber frame or door assembled with bushfire-resisting timber or timber species from E2 (AS 3959)	Bushfire shutters or screen and any timber frame or window assembled with bushfire-resisting timber or timber species from E2 (AS 3959)	Non-combustible material, bushfire-resisting timber or timber species from E1 (AS 3959)
BAL 29	Bushfire shutters and any timber frame or door assembled with bushfire-resisting timber	Bushfire shutters and any timber frame or window assembled with bushfire-resisting timber	Non-combustible material or bushfire-resisting timber
BAL 40 & FZ	Bushfire shutters and any timber frame	Bushfire shutters and any timber frame	Non-combustible material

Table 17: Density and fire resistance of major species.

Requirement	Compliant species
Bushfire-resistant	Blackbutt, spotted gum, red ironbark, river red gum, silvertop ash, turpentine, kwila (merbau)
Timber species* from E1 – density 750 kg/m^3 or greater	Silvertop ash, blackbutt, brownbarrel, Sydney blue gum, grey gum, manna gum, river red gum, spotted gum, grey ironbark, red ironbark, jarrah, kwila (merbau), messmate
Timber species* from E2 – density 650 kg/m^3 or greater	All species from E1 (above), also alpine ash, mountain ash, white cypress, shining gum, celery-top pine, slash pine

3.7.2 Detailing against Ember Attack

External vents, weepholes and gaps through which a 3 mm diameter probe can be passed penetrating the building envelope or into the building cavity should be screened with a mesh with apetures less than 2 mm. More detail can be found in *AS 3959-2009 Construction of buildings in bushfire-prone areas*

3.7.3 Bushfires, Glass and Openings

Toughened or safety glass is required in glazed areas within 400 mm of the ground or decks because these are deemed liable to flame exposure. Mesh screens are required for the openable section of windows from threat category BAL 12.5 and higher. Mesh requirements vary between openings glazed with normal annealed glass and those glazed with toughened or safety glass. AS 3959-2009 should be consulted for details.

3.8 Designing for Safety

3.8.1 Safe Movement and Access

Volume 1 Part D.2, Volume 2 Part 3.9 of the National Construction Code and AS 1926 impose requirements to ensure safe movement and access to pool areas. The implications for the specification of windows and doors include requirements for child-resistant doors sets, limiting the opening of windows to 100 mm or protecting the openable windows with bars or mesh, and limiting the extent to which upper-storey windows can open.

Doors and windows on the external wall of an upper storey form part of the system of barriers that prevent occupants from falling out. As such, they need to comply with general provisions for balustrades included in the National Construction Code. These require that a continuous balustrade or other barrier be provided across the window if its level above the surface beneath is more than 4 m and it is possible for a person to fall through it. The height of a balustrade or other barrier must be not be less than 1 m above the floor and it must be constructed so that any opening in it does not permit a 125 mm sphere to pass through it. To comply, a window must provide the same performance: any sash less than 1 m above the floor needs to be constrained to limit its opening so that a 125 mm sphere cannot pass through.

3.8.2 Safe Glazing

All glass used in windows and doors in Australia needs to comply with AS 1288-2006 **Glass in buildings – Selection and installation**. The standard regulates the size and type of glass according to the required structural capacity of the glass and the safety of occupants. AS 1288-2006 recognises two grades of safety glass manufactured to AS/NZS 2208-1996. Grade A offers a high level of protection against injury and includes laminated, toughened and toughed laminated glass. Grade B provides lesser protection and includes wired safety glass.

Building occupants can be injured or killed if they hit or run into the glass in windows and doors. In order to reduce possible risk and hazard, AS 1288-2006 regulates the types of glass used in areas susceptible to human impact such as:

- glazing in doors and sidelights;
- windows capable of being mistaken for an opening, and glazing within 500 mm of the floor;
- glazing generally or within 1 m of the floor in schools and childcare buildings;
- shop fronts and internal partitions; and
- windows in bathrooms.

Mechanical protection can be provided to the glazing, and the glass can be made more visible or obvious. AS 1288-2006 requires that glass that may be mistaken as an opening be marked to increase its visibility.

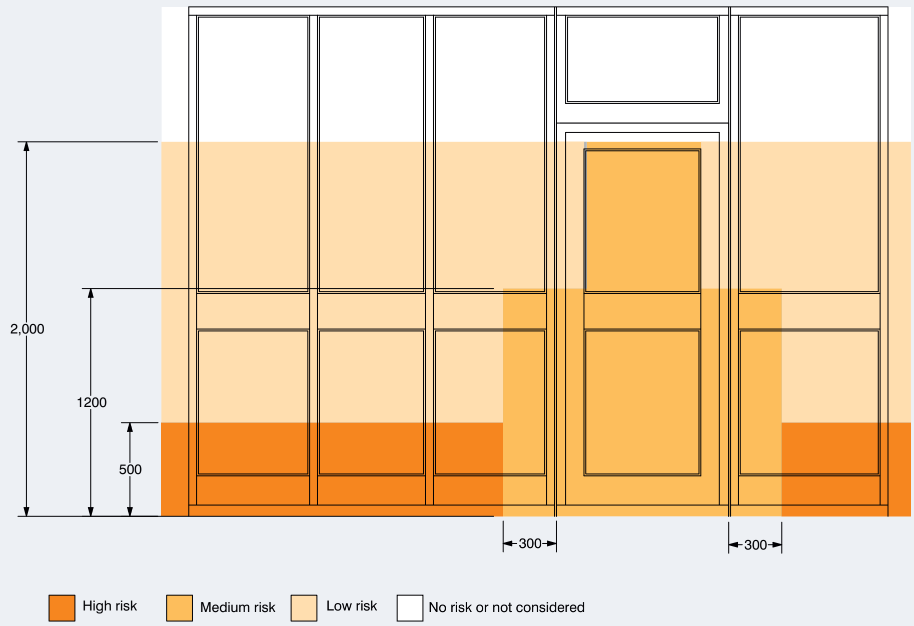


Figure 7: Level of risk of injury from human impact.

Source: AS 1288-2006

3.9 Structural Considerations

Generally, timber window and door units do not carry structural building loads but act as non-loadbearing insertions into the loadbearing frame of the building. If the joinery units are to carry structural building loads, member sizes and jointing must be determined in accordance with *AS 1720 Timber structures*, *AS 1684-2006 National Timber Framing Code – Residential timber-framed construction* and allied Standards.

Windows and doors may generate significant loads onto the surrounding structure, as wind loads or direct gravity loads. This is particularly the case with bi-fold and top-hung sliding units where the windows and doors are supported directly from the lintel. In these cases, the allowable deflection in the lintel needs to be limited to below the level that will affect the unit's operation.

Windows and doors have to resist wind loads applied to the assembly. AS 2047-1999 *Windows in buildings – Selection and installation* requires windows to perform satisfactorily to particular design wind pressures. These pressures are provided in *AS/NZS 1170.2-2002 Structural design actions – Wind actions for buildings other than housing.* For housing, the design and ultimate strength test pressures are shown in Table 18.

Table 18: Window ratings for housing.

Window wind pressure rating	Serviceability design wind pressure (Pa)	Ultimate strength wind pressure (Pa)
N1	500	700
N2	700	1,000
N3	1,000	1,500
N4	1,500	2,300
N5	2,200	3,300
N6	3,300	4,500

Source: AS 2047-1999, Tables 2.1 & 2.5

Under the applicable design wind pressures, Table 19 shows the maximum allowable deflection of a structural element in the unit:

Table 19: Allowable deflection under design wind pressure.

Building Class	Deflection limit
Class 1 (residential)	Span/150
Class 2, 3 or 4 (multi-residential apartments, hotels etc)	Span/180
Class 5, 6, 7, 8 or 9 (commercial and public buildings)	Span/250

Source: AS 2047-1999

3.10 Reducing 'Whole-Life' Energy Costs

The 'whole-life' energy costs associated with buildings consist of embodied energy in construction, energy in operation, maintenance and end-of-life processes, such as demolition and disposal. 'Whole-life' energy costs should be as low as possible in order to limit environmental impact. Three significant strategies that can be adopted to reduce the whole-life energy costs include:

- Design for longevity – using highly durable materials.
- Design for flexibility – recognising the human need for change and making buildings flexible enough to adapt to changing needs.
- Design for disassembly and replacement – designing elements so that materials may be re-configured and used again, and recognising that some parts of the building will have longer effective service lives than others.

The three approaches listed above are commonly adopted for internal joinery. Internal doors and similar joinery are regularly refreshed in place, removed, renovated or recycled. The reuse of old windows and doors can be limited because of increasing performance requirements. Some new designs incorporate a means of replacing the most vulnerable sections, particular the sill, without significant effort or change to the unit.

4

Assembly and installation

Timber brings flexibility to the design and fabrication of windows and doors. Timber can also be easily shaped or moulded to suit a particular project or assembled into much larger units, either with glue or mechanical fixings.

4.1 Introduction

The section size of timber frame required is influenced by required clearance, glass thickness, timber species, structural performance, and the fabrication of robust connections.

4.2 Containing the Glass

Glass in a timber frame has to be adequately supported and provided with sufficient clearance to allow for movement in the frame, expansion or contraction of the timber due to changes in moisture content, or movement of the glass due to changes in temperature.

4.2.1 Glazing Clearance

Table 20 lists the minimum clearance, cover and rebate depths required by AS 1288 for glass in frames sealed with glazing putty or non-setting glazing materials. Table 21 lists the clearance and cover distances required by *AS/NZS 4666-2000 Insulating glass units* for an insulated glazing unit (IGU). The required minimum rebate depths do not necessarily allow sufficient depth to install front putty or fix a glazing bead.

Table 20: Clearance, cover and rebate depth for single-glazed units.

Glass thickness	Front and back clearance (min.)	Edge clearance (min.)	Edge cover (min.)	Rebate depth (min.)
Putty Glazing				
3 (panel <0.1 m^2)	2	2	4	6
3 (panel >0.1 m^2)	2	3	6	9
4	2	2	6	8
5	2	4	6	10
6	2	4	6	10
Non-setting compounds				
3	2	3	6	9
4	2	2	6	9
5	2	4	6	10
6	2	4	6	10
8	2	5	8	13
10	2	5	8	13

Source: AS 1288, Table 8.1

Table 21: Clearance cover and rebate depth for IGUs.

	Face and back clearances (min.)	Edge clearance (min.)	Edge cover (min.)
Sills	2	6	12
Head and jamb (unit length <2 m)	2	3	12
Head and jamb (unit length >2 m)	2	5	12

Source: AS/NZS 4666-2000

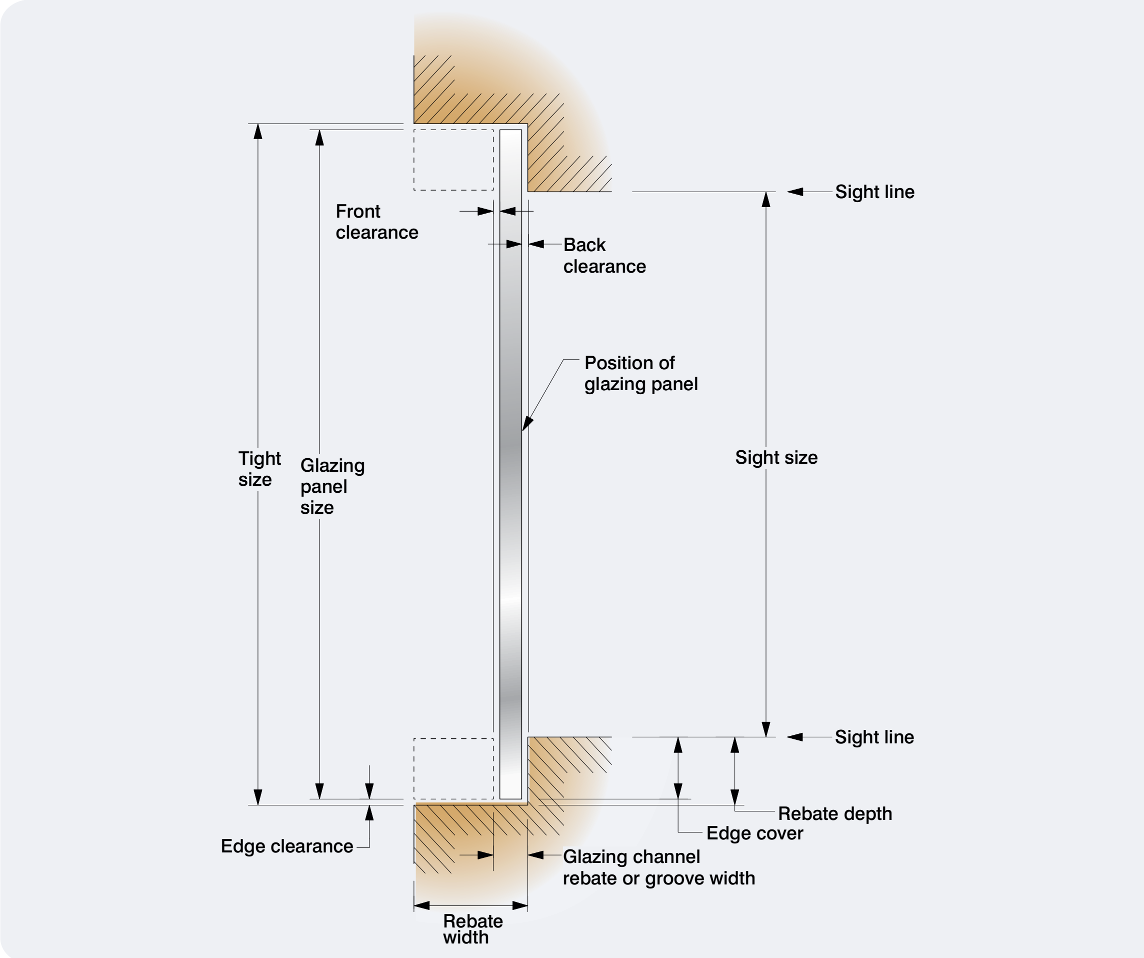


Figure 8: Rebate depth and clearances.

4.2.2 Glass and Sash Thickness

The thickness of the selected glass or IGU influences the thickness of the timber required for window and door sashes. Common sash sizes will accommodate standard glass and common IGU sizes. Table 22 gives general limits to the thickness of glass or glazing units used with available solid section timber thicknesses giving consideration for the up-stand of the rebate and front beading. Check this with the manufacturer because the capacity of the selected timber and the size of the sash and selected beads may vary and will influence the final maximum glass thickness. Note that typical nominal sizes available of Australian timber are smaller than sizes available in North American timbers. It may be necessary to adopt glue-laminated timber if the required glass thickness exceeds that of available stable solid section material available.

Table 22: Timber and glass thickness for IGUs.

	Timber thickness		Glass
	Nominal (mm)	**Dressed (mm)**	**Thickness limit* (mm)**
Solid section Australian timber	50	40–42	16
Solid section North American timber	50	42	16–18
	65	54	28
	75	65	38

**Confirm this limit with your manufacturer*

4.3 Connecting the Frame

The size of the frame and sash elements required is influenced by glass thickness (as described above), structural adequacy, section stability, and jointing. Making sufficiently robust joints is often the governing factor in determining section size. Most manufacturers use a set of standard profiles and element dimensions to build units of particular types and sizes, developed through experience with particular species and conditions. Some manufacturers will work with architects and specifiers to produce individual frames for specialist projects.

4.3.1 Carpentry Joints

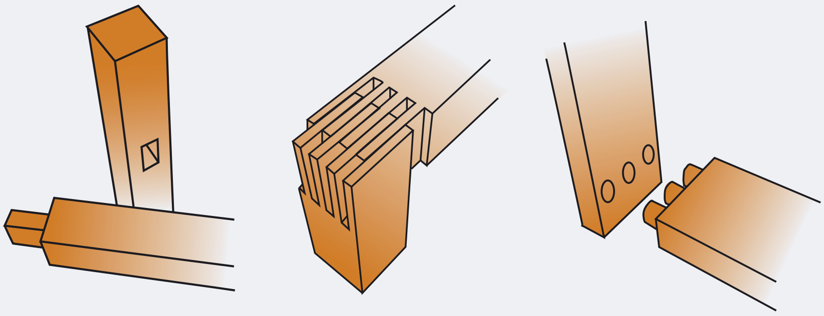


Figure 9: Types of joints – tenon, open-slot mortice, dowel joints.

The main joint types used in the construction of timber frames, sashes and doors are variations of the traditional mortice and tenon joint. A tenon is a projecting piece of timber shaped to fit into an enclosed slot or mortice in the other piece of timber. The mortice can be a 'through' mortice, which goes from one side of the piece to the other and, once assembled, the end of the tenon is visible from the outside face, or a blind mortice which has a enclosed slot that does not go all the way through the piece. Wedges can be inserted around the tenon or into the tenon to tighten the joint so that the tenon cannot be withdrawn once assembled. The joint may also be glued.

A variation on the traditional mortice joint is an open-slot mortice which includes at least one slot that goes through the sides and the end of the piece and receives the tenon. In this arrangement the joint has to be glued and possibly pinned. Multiple slots and tenons can be included in a joint to form a comb-type connection.

Dowel joints can also be used to assemble the frame elements. Aligned holes are made in the pieces to be joined which receive a timber or other dowel. The dowel is glued into place as the pieces are assembled.

Each of these joints has particular advantages and disadvantages. The shoulders on the pieces of the traditional mortice and tenon increase racking resistance, stabilising the joint. The comb-type open-slot mortice provides a greater surface area for glue and can be easier to make. Dowels are economical, using less timber and fewer milling operations. The manufacturer will be able to advise on which of these to use based on factors such as the chosen timber's ability to bond with adhesives.

4.3.2 Adhesives

Adhesives are used in timber windows and doors to glue-laminate members of the frame together or to bond the joints of the frame, sashes and door. The service life of an adhesive is influenced by the type of adhesive, the type of connected elements, and the exposure.

Timber glue-laminated for general structural applications is manufactured to the requirements of *AS 1328-1998 Glue-laminated structural timber*. Commercially produced glue-laminated timber made to this standard generally features Type A waterproof phenolic bonds with a distinct dark-brown glue-line.

Timber in the joinery for non-loadbearing windows or door frames does not need to meet the same standard and can be glued with adhesives that comply with, or are at least equivalent in performance to, adhesives complying with *AS 2754.2 Adhesives for timber and timber products – Polymer emulsion adhesives*. The adhesive needs to achieve at least a Type B bond to *AS/NZS 2098.2-2006 Methods of test for veneer and plywood – Bond quality of plywood (chisel test)*. Joints made with adhesives that do not give this performance have to be held together by other means if the glue fails.

Correct installation is critical to the service life of the unit, as incorrect installation can lead to premature failure of the glass, especially in IGUs.

Two glues commonly used in window and door joinery are polyurethanes and polyvinyl acetate (PVA) emulsions.

- Polyurethanes are thermosetting glues that include two components that react with the moisture in the wood to produce a clear polyurethane resin. They have good strength and some gap-filling capabilities, though their performance is improving with further research.
- PVAs are thermoplastic glues made by polymerising vinyl acetate alone or with other polymers. Most cure at room temperature and set rapidly. They are easy to use, result in a clear glue-line, and have good gap-filling properties, though steady pressure on the joint is required. Cross-linked glues have better moisture resistance than other types.

4.4 Installing Glazing

Glass inserted into a timber frame has to be weatherproof, restrained to resist the design load imposed, and supported, while still allowing for movement, expansion or contraction. AS 1288-2006 sets out minimum requirements for the installation of single glass into a frame, while AS/NZS 4666-2000 establishes the requirements for IGUs.

Units can be glazed in the factory or on-site. Site glazing after installation reduces the weight of the units being handled on-site, but can also decrease performance, especially with IGUs. Glazing under factory conditions can significantly reduce the possibility of early IGU failure. The process of glazing involves making the correct clearances and cover in the frame to suit the glass, preparing the rebates, installing positioning blocks and sealing the unit.

4.4.1 Preparation

The rebates or stops that are to receive the glass or IGUs need to be clean, flat and smooth to provide good adhesion for the sealant material. They should be free from moisture or contaminants. If the window is to be painted, they should be primed or sealed.

4.4.2 Positioning

Setting blocks, location blocks and distance pieces are used to maintain the clearances required between the glass and the frame. Setting blocks are resilient non-absorbent blocks used to support the dead load of the glass on the rebate and prevent the bottom edge of the glass from coming into contact with the frame. Location blocks are similar blocks used to prevent glass-to-frame contact in other parts of the frame due to movement caused by thermal change or distortion in opening and closing the unit.

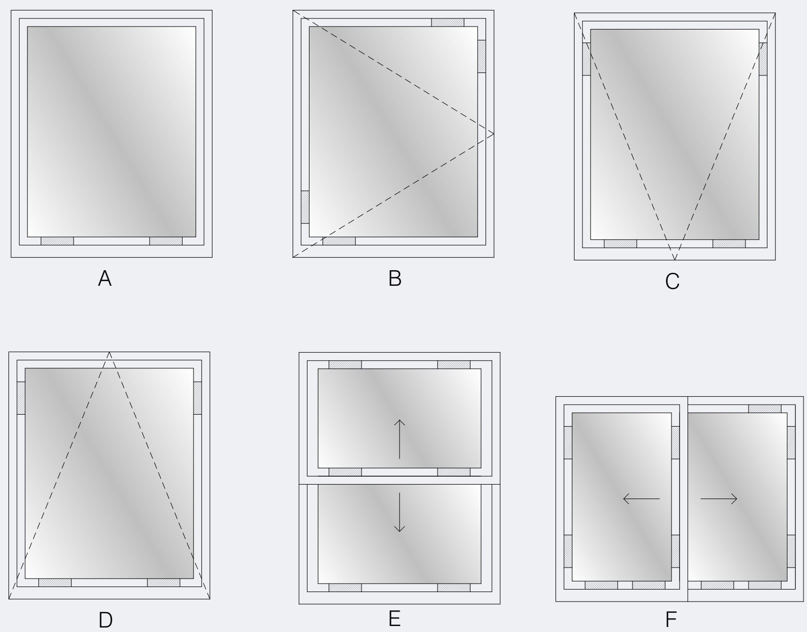


Figure 10: Position of location blocks:
(A) fixed (B) casement (C) awning (D) hopper (E) double-hung (F) sliding.

Glazing tapes are suitable for both single glazing and IGUs. They can accommodate considerable wind load, and generally eliminate the need for distance pieces.

Each setting block needs to be a minimum length of 25 mm for each square metre of glass in the unit, with a minimum length of 50 mm. Location blocks are positioned around the head and jambs between the glass and the frame. These blocks also need to be resilient, generally equal to extruded rubber with 55–65 shore-A hardness (AS 1288-2006). Each location block is to be at least 25 mm long.

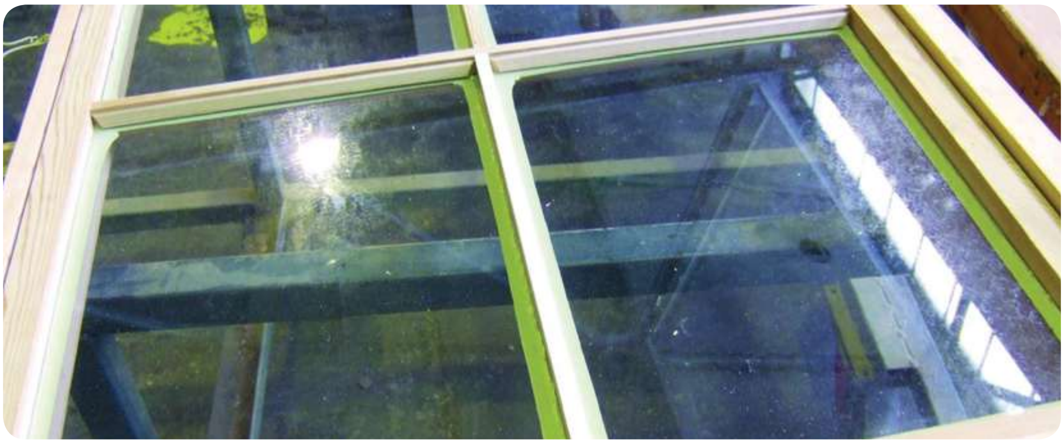
Distance pieces are small blocks of resilient non-absorbent material used to prevent the displacement of the glazing compound or sealant on the face and back of the glazing unit. Distance pieces should be 25 mm long and of a size to match the rebate depth and required face and back clearances. They are placed opposite each other, generally 50 mm from each corner and not more than 300 mm apart.

4.4.3 Silicone and Beads

The glass can be set in a bed of neutral cure silicone and retained by timber beads. The silicone should be installed to provide a full adhesive bond to frame, while maintaining the necessary face and back clearances. In Australia, timber beads are almost always on the outside face of window and door joinery. They can be clear or paint finished. Beads allow immediate handling and painting and are easier to remove if re-glazing is required. The backs of beads should be primed or sealed before they are fixed in place. Installing beads on curved work can be expensive and difficult.

IGUs should be installed so that the gap between the unit and the sash or door frame is free to drain, with the unit sealed between the glass and the face of the rebate or the glazing bead. Sealing between the edges of the IGU (around the seals) and the frames can tend to pull the seals out of the IGU and cause it to fail.

Timber beads restraining IGUs should be at least as high as the timber rebate, and at least as wide as they are high. The top and side beads should preferably not overhang the face of the sash. The bottom bead can overhang the bottom of the sash to provide some protection to the bottom weep holes.



4.4.4 Glazing Sealants and Tapes

Glazing tapes are compressible, generally butyl adhesive tapes that are applied around the faces of the glass before it is installed in the rebate. Once the backing film is removed, the glass can be fitted into the frame. The tape adheres to the face of the rebate, and to the glazing beads when they are installed. It can be trimmed back to the edge of the frame. Some glazing tapes are designed to be capped with sealant.

4.4.5 Glazing Putty

Linseed oil putty was used traditionally for glazing almost all external joinery. Modified oil and synthetic resin putty is available as an alternative. These putties can be used with or without glazing beads. If used without glazing beads, the glass needs to be restrained with glazing pins, and include at least 12 mm of tapering front putty. Putty is weather-tight but can commonly take some weeks to become firm and is prone to site damage. Unhardened linseed oil is very attractive to birds and animals.

Putty requires several days to set before it can be transported and may sag in hot weather. It should be painted not less than two weeks and not more than four weeks after glazing. Putty is used as standard for curved work. However, it should not be used with laminated glass as it can attack the inter-layer and lead to delamination. It is not suitable for glazing IGUs, and is not recommended for use with heat-absorbing glass. Putty should be painted in all external applications so is unsuitable for units with external timber stain or clear finishes.

4.5 Applying Finishes

Coating systems are designed to be solely factory applied or site-applied (site-applied coatings can also be factory applied but not vice-versa). Coating timber windows and doors requires control of the preparation of the substrate, the order and application rate of the coatings, the curing time between coatings, the temperature of the surrounding environment during curing, and protection of the finished item until the painting system has hardened and cured fully.

Timber windows and doors can be satisfactorily finished on-site. However, site conditions can leave a system application vulnerable to mistakes or problems. Primers and top coats, which should be matched, may be mixed and come from different suppliers, compromising adhesion and rendering warranties void. Extended delay in applying a top coat can lead to a deterioration of the primer. Temperatures and dust contamination can be hard to control, and the finished unit can be damaged while the coating is still soft and vulnerable. Care should be taken in ensuring the finishes are applied in accordance with the manufacturer's recommendations.

Coating the frames under controlled conditions in the factory removes many of these risk factors and is more likely to achieve a high-quality and maintenance-reduced application of the selected paint system. Some longer-lasting coating systems can only be reliably applied in a factory.

4.6 Installation

Installation needs to ensure that the units can perform as designed and the integrity and performance of the building fabric is maintained at the junction between units and the building's envelope.

4.6.1 Window Installation Diagrams

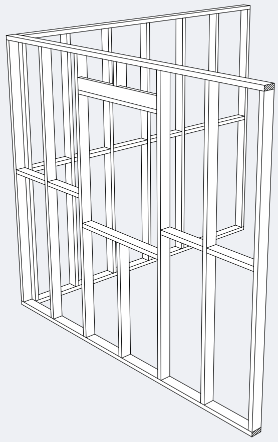


Figure 11(a): Frame with lintel.

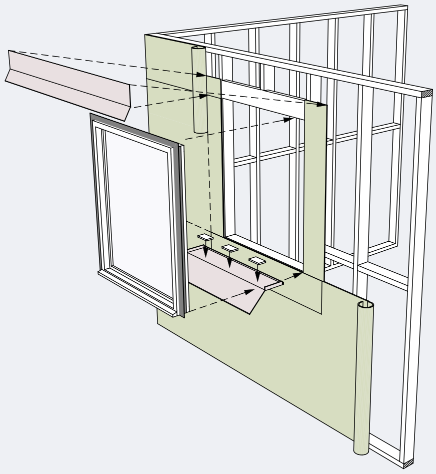


Figure 11(b): Window and flashing with sarking.

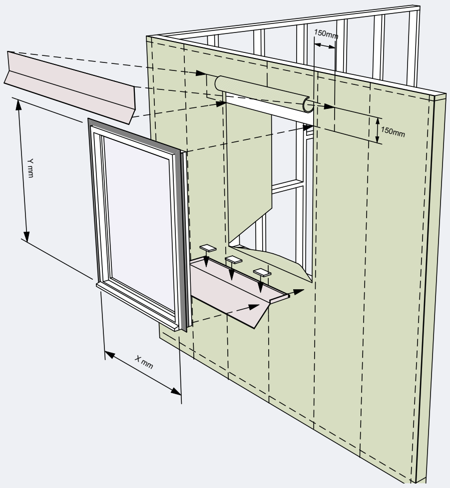


Figure 11(c): Window and flashing with wrap.

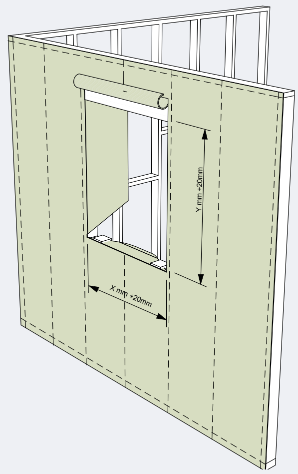


Figure 11(c): Opening sizes and wrapping.

4.6.2 Door Installation Diagrams

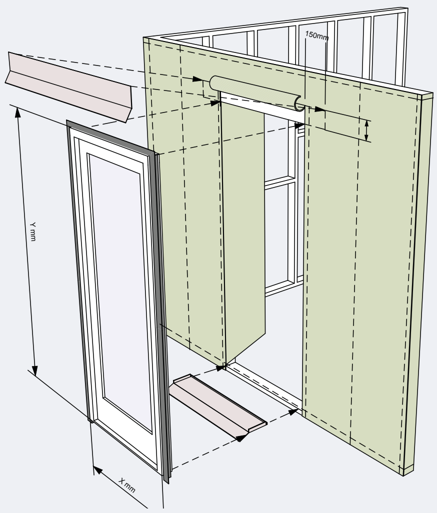


Figure 11(e): Door and flashing with wrap.

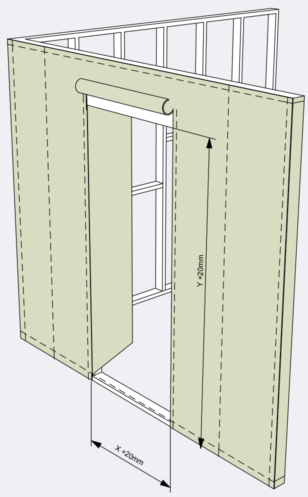


Figure 11(f): Opening sizes and wrapping.

5 Maintenance

5.1 Introduction

Windows and doors perform a vital role in maintaining the integrity of the building envelope and require regular maintenance to keep them performing optimally for their service life. Maintenance includes cleaning and minor repair, occasional recoating, and timely upgrading of components.

5.2 Cleaning

Cleaning should be factored into the management plan for the building. The windows, doors and glass should be washed two or three times a year and any built-up dirt and grime removed. Washing may need to be more frequent in coastal or high-pollution areas. Tracks for sliding windows and doors and any weep holes should be cleaned and any build-up removed because dirt on the roller tracks can cause premature wear and damage. Any pooling of moisture or significant discolouration should be investigated to ensure that sills have been fitted at the correct angles for drainage, and flashing has been fitted correctly.

5.3 Regular Minor Maintenance

Hardware and moving parts should be lubricated regularly. Lubrication should be more frequent in coastal or high-pollution areas. Malfunctioning hardware should be replaced. Seals should be in place and performing efficiently. Coating or paint finish and condition of the timber frame should be inspected regularly. Insulated glass units should be inspected regularly for condensation. IGUs should be replaced if the seals have failed.

5.4 Finishes and Coatings

Windows and doors fully exposed to the sunlight or weather, especially coastal winds, will need more frequent maintenance than those more protected from the weather.

The expected life of paint or other finishes depends on the quality of the original and subsequent coatings, and the care taken in application. Good-quality finishes increase the service life of the unit. Re-coating should take place before the existing finish has deteriorated to the extent that it exposes bare timber. Poorly maintained paint film can accelerate decay by trapping moisture adjacent to the timber. Expected service life of the major coatings systems is given in Table 23. Manufacturers should be consulted in developing the maintenance regime for the coatings in a building.

Ensure any new finish is compatible with previous coatings, especially factory-applied ones. Consult the suppliers of the original finish or a reputable paint supplier for advice. Follow the manufacturer's instructions closely.

Table 23: Expected service life of exterior wood finishes: types, treatments and maintenance.

Finish	Initial Treatment	Appearance of wood	Maintenance procedure	Maintenance period of surface finish	Maintenance cost
Paint	Prime and two top coats	Grain and natural colour obscured	Clean and apply top coat or remove and repeat initial treatment if required	7-10 years*	Medium
Clear (film forming)	Four coats (minimum)	Grain and natural colour unchanged if adequately maintained	Clean and stain bleached areas and apply two more coats	2 years or when breakdown begins	High
Water repellent**	One or two coats of clear material, or preferably dip applied	Grain and natural colour; visibly becoming darker and rougher textured	Clean and apply sufficient material	1-3 years or when preferred	Low to medium

** Using top-quality acrylic latex paints.*
*** With or without added preservatives. Addition of preservative helps control mildew and mould growth.*

5.5 Glass

Manufacturers of particular glass products with special surface coatings should be consulted for advice on the required maintenance of their specialist products.

Silicone sealing and security glazing tapes may have high levels of adhesion which may make removal difficult without irreparably damaging the frame. In such a case, replacing the sash may be necessary in the event of broken glass.

5.6 Timber Elements

Gaps in joints or around glazing beads can allow water to enter, encouraging corrosion and decay. Such gaps need to be carefully cleaned out and repaired. Decayed or damaged timber should be repaired by cutting back the affected timber and patching with new compatible timber. The repair of the timber element could require re-fitting parts of the frame if the timber has deteriorated and joints have decayed.

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