Timber windows and doors

Guide to the design and specification of timber windows and doors in Australia

INSPIRATION INFORMATION IN-DETAIL

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introduction

Wood is Australia's major renewable building material.

Timber windows and doors are the premium choice for thermal and environmental performance and design flexibility.

This manual supports Australia's architects, builders, building owners and manufacturers in their use of timber framed windows and doors in commercial, industrial and residential buildings.
It establishes the principles governing the design of timber windows and doors and provides guidelines for successful practice. Following this introduction, the manual is structured in three sections:

- Inspiration, presenting thematically the potential and precedence of using timber windows and doors in Australia and overseas;
- Information, providing overviews of the major considerations for the design of timber windows; and
- In – detail, supplying detailed timber, design, installation and handling information.

While the guide is relevant to all types of timber windows, it focuses primarily on solid timber and joinery styles of doors.

Defining timber windows and doors

A window is:

- an opening in the wall or other surface of a building that allows the passage of light and, if not closed or sealed, air and sound. Windows are usually glazed or have inserts of other transparent or translucent material.
- the frame, sashes, and panes of glass, or the like, intended to fit such an opening.

Windows are used to control the physical atmosphere within a space admitting light and ventilation and excluding wind, rain and drafts. They act as a barrier to noise.

Windows also have an aesthetic role in creating an impression of what lies beyond the room or space, establishing a connection between the internal and external: framing or revealing views, and admitting or obscuring sunshine and daylight. Stained glass windows introduce light dependant colour to a space. The term 'window' frequently appears in literature, often suggesting a clear but confined glimpse or opportunity.

A door is:

- a movable barrier, either solid or glazed, used to cover an opening or entrance way found in walls or partitions of a building and in furniture. When open, they permit access and admit ventilation and light. A door can be opened and closed more or less securely using a combination of latches and locks.
- a doorway.

Doors are used to provide access to a space and control the physical atmosphere within it by enclosing it. They act as a barrier to noise and a filter to sound. They are significant in preventing the spread of fire between spaces.

Doors are also used to screen areas of a building for aesthetic purposes, keeping different areas separate, while creating an impression of what may lie beyond. Doors can be symbolically endowed with ritual purposes and being granted access can have special social significance. The terms 'door' and 'doorway' frequently appear in literature, often suggesting a portent of change or a symbol of passage.

The sill is the element most exposed to weather and wear. It has to be selected and detailed with particular care.

As movable components, sashes and leaves need to be stable elements and not prone to distortion.

Window and door components

A window or door is a combination of two primary elements: the frame with a sash or sashes for windows, and the frame with a leaf or leaves for doors.

The frame is the assembled timber components that enclose and support the sashes or leaves, and are fixed to the surrounding building envelope. The frame consists of:

- the 'head', the top horizontal component,
- the 'sill', the bottom horizontal component,
- 'jambs', the vertical side components, and
- 'muntins' and 'transoms', the intermediate vertical and horizontal elements.

Windows sashes or door leaves are the generally movable components of the unit supported by the frame. They consist of:

- 'stiles', the vertical edge pieces,
- 'rails', the horizontal members of a sash, door, screen or other assembly. Depending on their location, they may be called top, bottom or chair rails, and
- 'muntins', the intermediate elements in the sash or leaf.

While the sashes or leaves can be solid and opaque, glass or other transparent or translucent material is often set into them to provide light and a view outside.

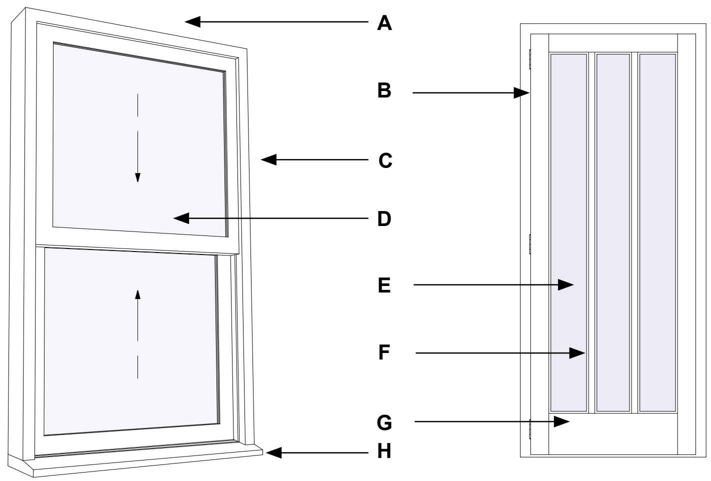

Figure 1. Unit components

(A) head, (B) stile, (C) jamb, (D) sash, (E) leaf, (F) muntins, (G) rail, (H) sill

Wood and timber

In this guide, the terms ‘wood’ and ‘timber’ are used interchangeably and mean the sawn timber and other wood products recovered from sustainably harvested trees of species grown in Australia and overseas and useful for building windows and doors.

While referred to simply as ‘wood’ and ‘timber’, the appearance and properties of the material can differ considerably as timber’s primary characteristics: colour; hardness; and durability, are highly variable between species: from soft to very hard, and from pale yellow to deep red brown. Since the terms ‘wood’ and ‘timber’ cover a wide range of species, definitive statements about performance are difficult. Most statements in this manual will be conditioned by such words as usually and generally. Given the variety of timber that nature makes available, there is almost always a species that proves the exception to any broad rule.

Recognising and allowing for this diversity is one of the wonders and challenges of using timber in building.

Timber windows and doors have been used effectively in Australian building since the first colonial building.

Sustainable design is changing perceptions of acceptable window and door performance.

Timber units are being recognised as the superior solution.

Timber as the preferred material choice

Sustainable design is gaining prominence in architecture and building.

Driven by concerns over climate change and prompted by increasing government regulation, building design professionals are seeking to reduce the impacts of their design decisions on the broad environment. In their designs, they are increasingly using preferably renewable resources and materials in solutions that improve energy efficiency, conserve water and provide healthy indoor environments.

This change in practice is having an impact on the selection and performance requirements for windows and doors. Demand is increasing for high performance windows and doors that contribute to reducing greenhouse gas emissions and energy use in building. Careful window and door selection is seen as a means of limiting demand for artificial light and air-conditioning, providing building occupants with suitable daylight and accessible ventilation control. To reduce the materials impact on the environment, designer are choosing a renewable material that is predominantly carbon neutral and preferably from sustainably managed and certified sources, timber.

There are six fundamental advantages to selecting timber windows and doors for residential, commercial and other buildings applications.

1. They are attractive. They look and feel right. Those encountering wood in a building understand its origins, its connection to the natural world, and its history of use.
2. They are available in a wide range of designs, colours and finishes. Timber's flexibility in design, allows innovation and creativity.
3. They are more thermally efficient. Timber acts as an insulator to reduce the thermal bridge that windows or doors inevitably create between the internal and external environment.
4. They are economic, have a long service life and can be refreshed or repaired efficiently,
5. They are made from sustainable and renewable materials. Wood can be regrown on a continual and sustainable basis.
6. They store atmospheric carbon. The growth of a tree absorbs carbon, which is stored in the timber throughout its service life. Emissions from using high-energy materials are avoided.

For further details, see
Information: Materials

1. Attractive, and feels right

Timber is an extraordinary material for any home, office or shop. Naturally renewable, it is beautiful, light and strong, welcoming, and warm to the touch.

Timber window and doors have an innate attraction to building designers and occupiers. Timber in joinery and surfaces contributes to a more livable environment. It attracts the eye, and expresses a contemporary beauty, that is rooted in nature and a respect for the environment. Wood possesses an attraction and appeal far beyond its simple form or functionality. This is not just based on an aesthetic reaction to the wood but includes important associations of wood with nature, its approachability of form and assembly, and senses of continuing culture.

Designers recognise wood as a medium for creating more friendly and approachable environments for living. For renowned Finish architect, Alvar Aalto, wood was a primary means of expressing nature's impact upon the build environment and its capacity to maintain and even enrich life. Alto (1956) felt that wood's 'biological characteristics, its limited heat conductivity, its kinship with man and living nature, the pleasant sensation to the touch it gives' made timber a suitable material for the design of a sympathetic world and used wood extensively in his work.

Wood's ease of use is also part of making more livable environments. Those living in wood-rich environments intuitively understand the origins and character of their surrounds. Timber is easy to work and this provides most people with the opportunity to make and enjoy making wooden objects of beauty and usefulness for themselves.

There can be more ingrained cultural association. Authors such as Banhan (1972) believed that 'our hands become immemorially conditioned to the grasp of wood and it has acquired for us an ancient familiarity. The grasp of wood is probably as basic to human culture as the making of fire and the writing of language.'

Wood included in any visible surface or structural element carries these associations but it is strongest in elements close to the eye, the hand and the touch, such as the sash of the window, the stile of the door, or the edge of matching furniture.

2. Flexibility in design

Timber enjoys a flexibility in window and door design that other material find hard to match. Easy to work and available in a wide range of products, species and sizes, timber encourages innovation and creativity.

With timber, designers are not bound to use only the common extruded sections or finishes found in most projects. Wood can be easily shaped, moulded laminated or bent to suit a particular project or assembled into much larger units, either with glue or mechanical fixings. While size can be a constraints on the length of individual pieces of timber, it is not a limit on the size of timber components, especially glue laminated ones. In reality, only transport constraints govern the size of timber elements that can be delivered to site.

Manufacture is innately flexible. Designs can be easily modified. The size, shape and configuration of elements are flexible and the detail of assembly can easily accommodate glass of different thickness, or walls of different types. Recognising this, the use of wood in windows and door still require careful consideration. Wood is relatively soft. Points of impact need to be protected. Concentrated loads need to be spread over a wide area. While strong, members and joints have to be designed to accommodate expected loads. Wood is biodegradable, so detailing and protection from constant moisture is important.

Timber units have a wide range of finishing options. The most long-lasting is a factory applied coating but site finishing is also an acceptable solution. The units can be left unfinished to weather naturally, clear coated, stained or painted a wide variety of colours. Also, the colour can be changed on site, simply by repainting.

3. Thermal properties

Timber in windows and doors helps reduce operational energy over the life of a building.

Timber provides superior thermal insulation: 15 times better than concrete, 350 times better than steel and 2000 times better than aluminium. So, timber windows and doors are intrinsically more thermally stable than those made from other materials. Timber doesn't provide the ready thermal bridge that allows expensively generated heat to escape into the colder outside air, or let the outside heat in.

As a result, a timber window or door will have a significantly higher insulation value and better thermal performance than an aluminium window or door of the same size and glazing. As a rule of thumb, a generic single-glazed timber framed window will have a similar thermal performance to a generic double glazed aluminium window.

This is significant. The construction and operation of buildings use up to 40% of all the energy consumed globally. To contain this demand and the greenhouse gas emissions it generates, all new buildings in Australia have to meet regulated and regularly increasing thermal performance requirements. Controlling heat loss and gain through the windows and doors is a major factor in compliance.

Improved thermal performance in the windows and doors will increasingly affect building resale. In Europe and the Australian Capital Territory, home owners now need to produce an energy rating certificate for their houses before they can be sold. Other Australian states are likely to follow in the near future. Houses likely to have high-energy costs will become increasingly difficult to construct and inhabit economically. Existing houses that have high-energy costs will be increasingly difficult to sell, or will attract a lower price. Commercial construction is following the same path.

Table 1. Thermal values of various materials

MATERIAL	U-VALUE(W/mK)	R-VALUE(100mm)	DENSITY(kg/m^3)
Glass Wool Insulation	0.038	2.6315	52
Softwood	0.135	0.7407	550
Hardwood	0.175	0.5714	700
Concrete	0.93	0.1075	2300
Steel	45.3	0.0022	7850
Aluminium	221	0.0004	2740

For further details, see
Information: Environmental Control

Table 2. Performance of different window types					
		COOLING	HEATING	Total Window System Values - NFRC	
Glazing ID	Frame	%impr.	%impr.	Uw	SHGCw
GENERIC STANDARD INDUSTRY TYPICAL WINDOW - SINGLE GLAZED					
3Clr	Generic: Aluminium	2%	0%	7.4	0.77
3Clr	Generic: Timber	21%	24%	5.5	0.69
GENERIC STANDARD INDUSTRY TYPICAL WINDOW - DOUBLE GLAZED					
IGU 3/6/3	Generic: Aluminium	22%	27%	5.3	0.69
IGU 3/6/3	Generic: Timber	38%	47%	3.3	0.61

Source: WERS 2009 Certified Product Directory - AFRC

4. Economic, long life and repairable

> In 2003, a consultancy working with the London Borough of Camden Council conducted research on window costs. KSC Partnerships discovered that high-performance timber windows cost on average 14 per cent less than PVC windows, when comparing an identical specification… A "whole life cost" appraisal… took into account maintenance and replacement costs and shows that high performance timber and aluminium clad timber windows cost 23-25 per cent less than PVC over a 60-year life span. (Thompson 2005)

Timber windows and doors have been part of effective and economic building solutions since ancient times. In Australia, they have been used since the first colonial building. Many remain in service after hundreds of years in service. Timber doors remain the benchmark for quality construction. The mainstay in building until the 1950s, timber windows are regaining that position in quality projects in appreciation of their superior thermal performance and their innate aesthetic appeal.

Wood is resistant to heat, frost, corrosion and pollution. Protected from moisture, a timber door or window will perform satisfactorily for the life of any building, assuming that the hardware remains serviceable. With regular maintenance, carefully designed and finished timber windows and doors can perform in the toughest external environment, and provide a resilient response to internal wear and tear.

Timber windows and door can be repaired, refreshed or upgraded. This has its own environmental and architectural benefits. As timber joinery can be refurbished efficiently and remain in service, the impacts generated by acquiring new materials are avoided. Architecturally, refurbishment reinforces culture and place-making in design as the refreshed element can retain a reassuring patina of use, echoing continuity and tradition.

5. Renewable wood

Timber can be regrown on a continual, sustainable and renewable basis.

Wood grows in trees. For the trees to grow, they only need soil, air, water, sunlight and time. If the process is well-managed, trees can be grown, harvested and regrown on a continuous basis to provide a renewable resource. This is in stark contrast to other building materials made from finite and non-renewable resources.

Australia has 149 million hectares of forest, managed for timber, environmental protection and other uses. About 16% of Australia's native forests are in formal nature conservation reserves, including nearly three-quarters of all known old-growth forests (BRS 2009).

Table 3. Area of old-growth forest in areas surveyed for RFAs ('000 hectares)

	NATIVE FOREST IN REGION	AREA OF OLD-GROWTH IDENTIFIED	AREA OF OLD-GROWTH IN FORMAL AND INFORMAL RESERVES [a]	PROPORTION OF OLD-GROWTH IN RESERVES
NSW [b]	8989	2536	1742	69%
Qld[b]	3230	270	196	73%
Tas.	3116	1229	973	79%
Vic.[c]	5774	673	460	68%
WA[d]	1909	331	331	100%
Total	23018	5039	3702	73%

Note: Old-growth forest has not been assessed in the Australian Capital Territory, Northern Territory and South Australia.

a Includes nature conservation reserves and informal reserves on other tenures.

b Area surveyed in Queensland did not lead to establishment of a RFA. New reserves have been established in New South Wales and Queensland since this information was prepared. The 'area of old-growth in formal and informal reserves' is therefore an underestimate.

c The area of old-growth was reduced as a result of conversion to regrowth by fires, predominantly in 2003.

d Original RFA old-growth mapping.

e Proportion of total area for the five states listed.

For timber to be renewable, forestry management and field practices must be sustainably based. The 2008 State of the Forest Report highlighted Australia's world-class forest conservation reserve network that helps to protect native forests. Production forests outside this network are subject to a closely monitored sustainable forest management regime. This regime is supported by codes of practice for harvesting and environmental management and, increasingly, by the independent certification of high-quality forest management.

Assessing the sustainability of forestry practice can be highly complex. However, credible forest certification schemes are now available that reduce this complexity for timber users by requiring independent third party auditing of accredited forestry practices against internationally recognised standards. The bulk of Australia's production forests are now certified under international recognised forest certification schemes. In June, 2009, the management processes for 9.2 million hectares of Australian forest were certified; 8.7 millions hectares, including most state forestry agencies, under AFSC, and 0.5 million hectares under FSC. 0.25 million hectares had recognition under both schemes.

So, specifying the use of certified timber can remove much of the doubt surrounding the social and environmental impact of species selection.

Trees take time to grow. As they grow, the properties of the wood in them changes and the size of the usable log recovered from them increases. As a general rule, timber from older trees is more stable and regular and is available in larger sizes than timber from younger trees. Native forest-grown Australian hardwoods generally need at least about 60 years to grow logs of a usable size, while 80 and 90 years is preferable in some regions. Future needs for building timber are likely to be mainly sourced from plantations. Softwood is already predominantly supplied from plantations. The use of plantation hardwoods in building is in its infancy, but will increase as the plantations mature and the technology for processing them improves. Plantation hardwoods and softwoods grow much more quickly but their timber can be more variable than older, slower grown trees of the same species.

6. Timber as carbon store

"Wood products can displace more fossil-fuel intensive construction materials such as concrete, steel, aluminum, and plastics, which can result in significant emission reductions (Petersen and Solberg, 2002)"

The 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Nabuurs et al. 2007) noted a dramatic increase of global greenhouse gas (GHG) emissions between 1970 and 2004. Carbon dioxide (CO2) emissions grew by about 80% during the period and in 2005, its atmospheric concentration was 379ppm. The report suggests this increase was 'very likely' to be due to human activity, mainly the use of fossil fuels and clearing land for agriculture reducing the amount of trees.

Since the first of the IPCC's reports, strategies to address greenhouse gas-induced climate change have been demanded and developed. These have included changing building regulations and guidelines to address the impacts that building construction and operation have on the environment, particular generation of greenhouse gas emissions.

Timber in windows and doors reduces carbon emissions in three ways:

- the carbon stored in growing trees is retained and stored in the timber for at least the life of the building. Timber in buildings extends the period that the CO2 captured in forests is kept out of the atmosphere;
- using wood instead of energy intensive materials avoids the emissions associated with producing those materials; and
- increased timber use supports the economic expansion of forests through the landscape. These are significant carbon sinks.

As a tree grows, it absorbs carbon dioxide from the atmosphere and, using the energy from sunlight, combines it with other elements into the sugars and chemical ingredients it needs to make new wood. The carbon is then stored in this wood, and remains in it. While harvesting trees for timber reduces the amount of carbon stored on any particular site, it doesn't necessarily affect the carbon stored in the larger forest estate. While one area of a sustainably managed estate is being harvested or prepared for replanting, other sections of the forest are growing and storing additional carbon in the trees and soil.

Each cubic meter of timber in a building sequesters between 250 and 300 kg of atmospheric carbon. This is equivalent to 0.9 to 1 tonne of CO2. In 2004, it was estimated that wood products in service in Australia stored 97 million tonnes of carbon, equivalent to 61% of Australia's total annual emissions (Ximenes 2009). In addition, recent studies by the CRC for Greenhouse Accounting in Australia have found that wood retains its carbon stores even after being in landfill for many years. Only when wood is burnt or decays in the open air is the CO2 released back into the atmosphere.

Not all the log that enters a mill can be used in a building product. However, almost all is used. Sawing waste and chips can be usefully burnt to supply energy. If wood is burnt as an energy source replacing a finite fossil, this at least is a carbon neutral activity rather than one that adds carbon to the atmosphere overall, as is produced with burning coal or oil.

Using wood instead of other energy-intensive materials avoids additional substantial emissions. The amount of energy used to make alternative materials: their embodied energy. can be very high and much of that energy is produced from greenhouse-gas producing fossil fuels. By comparison, the amount of energy used to make wood and timber is low, whether the comparison is by weight, volume or utility. On the basis of European studies, using one meter of timber also averts another 1.1 tonnes of CO2 emissions (CEI-Bois).

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

Using timber and wood avoids the GHG emissions associated with energy-intensive materials.

The embodied energy of timber and wood products is low, whether measures by weight, volume or utility.

A house lot of timber windows* can typically store 225 kg of carbon, equivalent to 830 kg of atmospheric CO2.

Timber production encourages forestry, and forestry has significantly less environmental impacts than other resource acquisition processes. Growing forests and plantations for timber sequesters more atmospheric carbon. Australia's Kyoto-compliant plantations are expected to store about 21 million tonnes of CO2 a year by 2010, even while some are being harvested. Native forests and other plantations will also be continuously adding to this storage (AGO 2006).

Table 4. Characteristics of major building materials

MATERIAL	EMBODIED ENERGY (mj/m^3)	CARBON STORED (kg/m^3)	DENSITY (kg/m^3)
Softwood	880	242	550
Hardwood	1550	308	700
Concrete (30 mpa)	3180	0	2300
Steel	251200	0	7850
Aluminium	515700	0	2740

Source: www.victoria.ac.nz

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inspiration

australian architecture

Figure 3. Rectangular timber sections, ornate mouldings, speciality mouldings, glulam beam.

In the 2006 architectural publication, New Directions in the Australian House Anna Johnson, describes an Australian movement towards the idea of architecture as object, rather than one primarily concerned with place. It may be that this is partly an expression of the interest in prefabrication: a direction stimulated by the growing sustainability imperative as a means of providing flexibility in housing and an exploration of the idea of 'living lightly' on the land. Whatever the reasons, Johnson identifies two central points of origin that she says are both rooted in modernism. The first is geometric; the second is more expressionist and experimental.

In contrast, the work described in the book Local Heroes by Peter Hyatt, presents contemporary Australian architecture as very context oriented in its design direction. The architecture is typified by visually light structures that are the opposite of Johnson's described monoliths, and that blur the borders between inside and outside with open facades and a segmented building layout.

The reality is that Australia is so immense, and has such diverse climatic and landscape conditions within it that there are different expressions of Australian architecture throughout the country. Whatever form these expressions take, there is ample evidence that Australian architecture is innovative. With design innovation comes the challenge of working with existing materials, existing forms and modes of manufacture to meet new requirements for shape, colours, textures and performance. With engineering innovation comes the opportunity to develop new materials and technologies to allow for innovation in design to be realized. With innovation in practice, in particular with regards to value chain thinking rather than supply chain thinking, comes the opportunity for concurrent engineering techniques and shared expertise to open up new ideas that may not have otherwise occurred.

Australian architects in the northern states have long used timber expressively in building because of its availability, economy and because it lends itself to the pole home construction typical of the vernacular Queenslander style. The continued use of this traditional construction typology means that Queensland builders are experienced with this material. In the southern states, where the different climate has resulted in a more insulated, closed structure approach, timber has withdrawn from the overt expression it enjoyed through to the 1930's to be used frequently but concealed behind a skin of masonry. Unlike domestic construction, industrial structures have historically produced excellent examples of Australian's ability to innovate with timber, with large span structures, that are repeated throughout Australia's history.

curves

The use of organic curves in modern architecture began with Art Nouveau in the early part of the 20th century. Gaudi was the high profile international architect of the time who broke with tradition in his designs to explore almost unprecedented organic shapes in building. Design does not stand still. It evolves as our society's values and understandings evolve. It reflects advances in materials and production techniques that allow us to extend our ability to realize the design ideas of our imagination. Australia's iconic Opera House is a perfect example of imagination combining with innovations in engineering. Striking curves in architecture have also been created in Australia in recent years, with high profile projects such as the new Southern Cross Station in Melbourne demonstrating the visual impact possible with curved forms. Innovative forms illustrate advances in production and construction, and changes in thinking. In concert with developments in engineering technique, the increasing use of software by architects, allows for complex designs to become more easily explored, understood and tested prior to construction.

More than merely playing with form, curved design reflects the move into post-modernism, where architecture is used to structure human relations based on the premise that the starting point for design should be the human experience combined with the relationship of the building to its environment. With the increasing sustainability imperative and our increased understanding of the role that timber can play in reducing our reliance on non-renewable construction materials, curved structures will increasingly be made in timber. The new challenges in addressing such organic forms in wood are being met by the developments in engineered timber products, composites that can be made to fit complex shapes and undulating surfaces. There is evidence that these challenges are already being addressed in Australia in the innovative architecture that has emerged over the last few years. Pushing the boundaries of curved forms creates opportunities for innovative buildings.

Glass can be cut flat into circles.

Glass can be curved by reheating and slumping it over a mould.

Timber in curves can be:

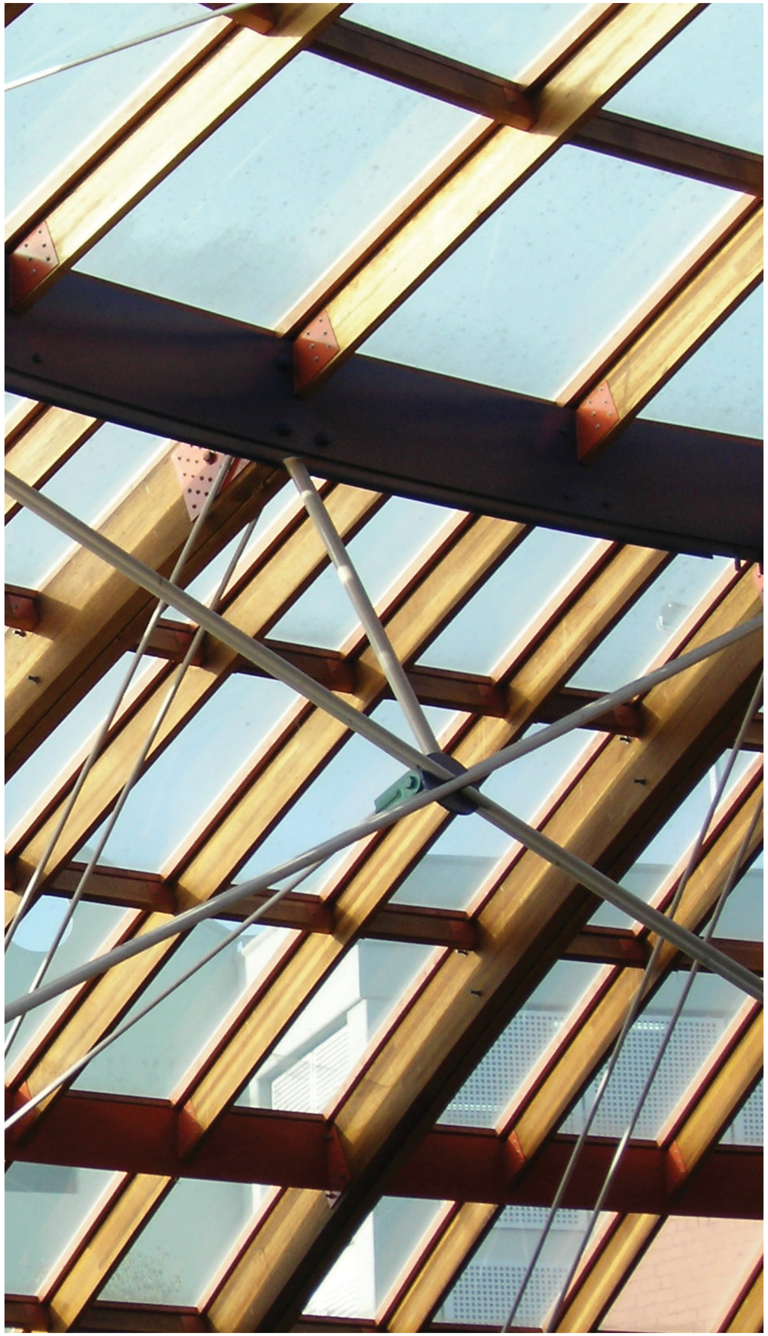
1. Glue laminated, from thin, layered strips bent in a mould and glued together
2. Segmented, built up from short sections of wood to create the desired shape
3. Cut from a larger section of solid timber, simple but potentially wasteful.
4. Steam bent, the curve follows the grain of the wood but consistency depends on the uniformity of the piece.

Exploring new ways of thinking through curves may involve a re-evaluation of our approach to building technique, and necessitate a particularly open-minded, collaborative development of project work between architects, their clients, engineers and manufacturers. Australian construction has demonstrated a capacity to adapt and innovate.

Relating window forms to curved surfaces with the benefit of new technology, software and engineering, allows for opportunities to explore organic shapes inspired by nature. Engineered timber can be built up in curves, and even extruded to allow for innovations in design thinking.

Traditional curved forms in timber windows can be executed accurately and more cost effectively then in the past because of improvements in machinery and working practices. Individual manufacturers will have experience in different forms, so matching the requirements of the project to the skills and experience of the manufacturer will be important as early in the design process as possible.

The spacer bars traditionally used in Australia for insulated glazing units are made from aluminium strip. The strip can be curved but not to 360 °. The capacity of this spacer to bend without damage can be a limiting factor in specifying curved windows that are double-glazed.



surfaces

Developments in architectural software and the widespread use of CNC routers allow for the creation of highly accurate multiple shape forms in different planes. This opens up the design of structures in relatively small budget architecture, as well as large scale commercial concerns, to mathematical experimentation and the exploration of complex facades. The use of computer simulations: naturally evolving processes to create digitally patterned geometric structures, can be applied to a range of design work from furniture to buildings.

Simple geometrics can be cut in glass to work within faceted surfaces.

Complicated geometric shapes are possible if the design is split down into basic forms using splitting bars, called mullions.

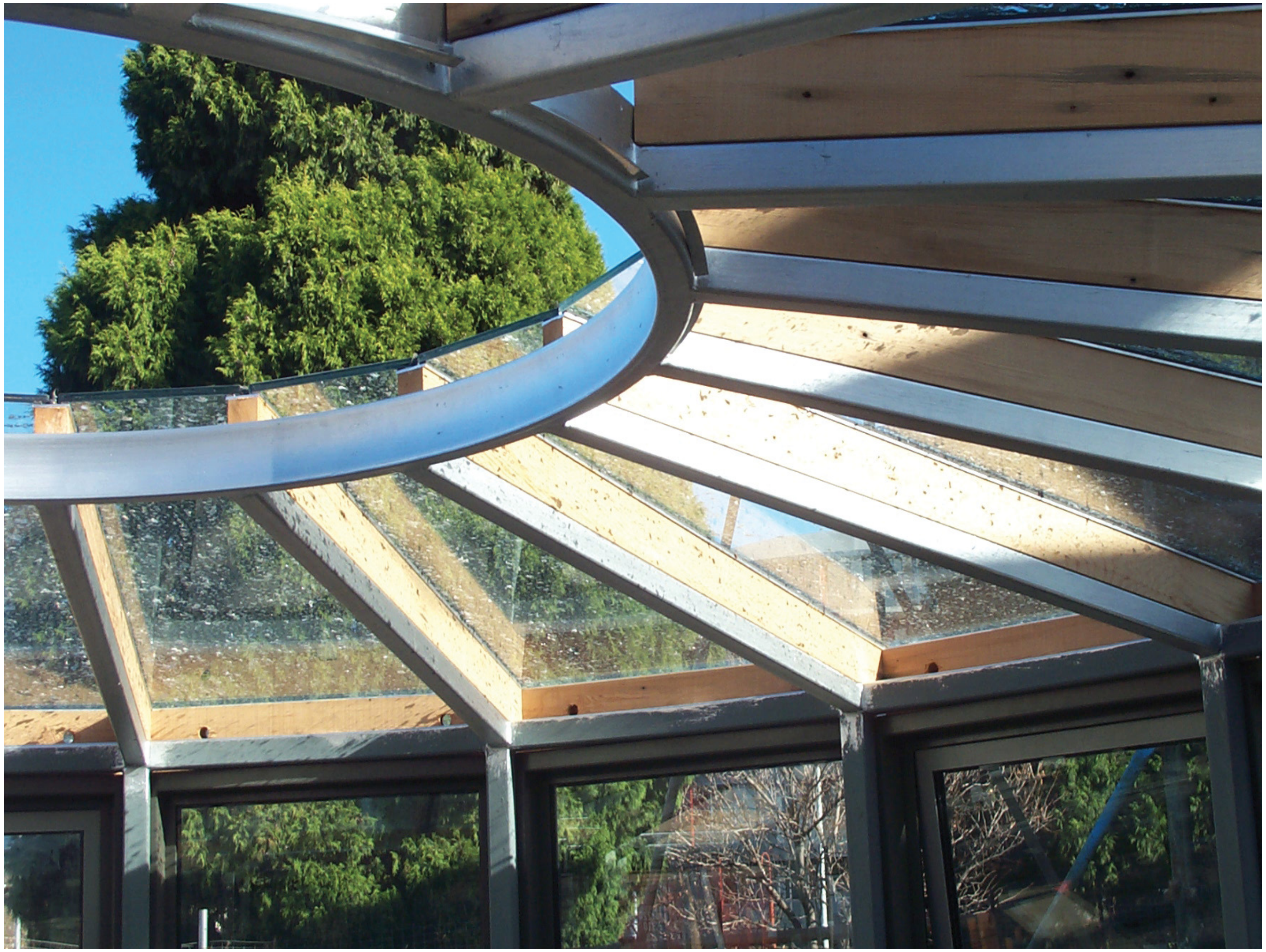
The design principle is the same as when creating a cut stencil, glass needs to be scored so that the cut itself runs off the edge of the glass, rather than being stopped with a change of direction within the sheet.

CNC routers are increasingly used in conjunction with hand finishing skills to allow for a greater range of decoration than was formerly cost prohibitive. Hand carving and marquetry skills have not been lost, with craftsmen often employed alongside computerised production.

Timber has been used in Australia to create complex surfaces for ceilings but grid windows in commercial buildings are more often made from metal than timber. However, with the growing sustainability imperative to reduce embodied energy, replacing construction components usually made with metal with wood, is an effective way of meeting targets.

creative corners

Externally, the visual impact of a building is heightened by the definition of its external lines. Cutting into the mass of the structure creates opportunities for sight lines through a building and an ambiguity in its form that adds interest. Using glass to break up or extend in an unexpected direction the dominant shape of solid forms goes beyond the basic function of windows for lighting, ventilation, heat transfer and vision, to contribute to the aesthetics of the building and the way its occupants experience it.



Designing corners for timber windows involves consideration of how the glass meets. Seamless, or nearly seamless glass corners are possible, or the corner can be made into a strong feature.

Alternatively, the windows can meet at the corner, but when open can provide an unusual clear space.

screening

Protective elements, such as screen and shutters contribute to the thermal performance of a building. They also improve the long-term performance of materials, such as timber, finishes and insulated glass units, aiding their embodied energy rating for life cycle assessment. Protection for the timber windows and doors from exposure to rain and the sun can be in the form of solid sheeting, transluscent sheeting, latticed or mesh screening or from natural elements in the landscape, such as the shade of trees or vines.

The life cycle assessment of buildings is now a fundamental consideration in architectural planning and design. The development of strategies to vary the thermal performance of different facades, is a climatic response to the site orientation and exposure. Understanding the performance of a building as a whole includes control over passive solar heat transfer. Flexible screening and sheltering such as overhangs can be designed to protect vulnerable points in the building, in particular windows and doors.

In designing for a tent-like approach rather than a closed, insulated approach, Queensland architects have created distinctive screening elements to their work. When designing with screens, designs that allow occupants to alter the density and arrangement of these structures at any time gives greater flexibility to respond to the local conditions. This strategy has created a design aesthetic that can be seen in architectural practice in coastal Queensland. Architects have employed variable screening to enhance building performance, and divide internal spaces with an attention to detailing that includes consideration of shadow patterns. Flexibility in the use of internal space is echoed in flexibility in the transitions between the interior and exterior spaces. Innovation is evident in the material choice as well as in the structure of screening that will contribute to the design intent.

The choice of window configuration will also help to define that link and how it operates for the occupants. Doors can be specified to open individually or to fold back onto themselves, revealing an uninterrupted view of the surrounding garden.

Even inside the building, doors can be used to demark space, either as permanent divisions or to fold back completely to provide a flexible internal space. By splitting the design; mullions can form the bridging between cut glass shapes, allowing complex designs to be created.

Screens contribute to a building’s thermal performance and the window’s service life.

Screens can be solid or translucent.

Screening helps to promote a link between the interior and outside of a building.

angles

A British company Pilkington Brothers revolutionized the use of glass in architecture after World War II when it invented a production method for creating sheets of glass. Molten glass was poured onto a flat surface, then rolled and polished both sides. To improve the finish, this was further developed by pouring the molten glass over rollers and then onto a flat bed of molten tin. This gave it an immaculate finish. The glass was made in continuous ribbons that allowed for the production of very large sheets in depths from 4 to 25 mm. The sheets were toughened through repeated cooling and heating. Texturing was added with patterned rollers.

> "If you want to assemble simple windows, first mark out the dimensions of their length and breadth on a wooden board, then draw scroll work or anything else that pleases you, and select colours that are to be put in. Cut the glass and fit the pieces together with a glazing iron. Enclose them with lead calms, and solder on both sides. Surround it with a wooden frame strengthened with nails and set it up the place where you wish." Theophilus, ad 1100

Because glass can be easily cut in straight lines, angles that are severely acute can be cut without difficulty. Timber frames can be created to accommodate even severe angles with joints such as scarf joints supporting narrow points.

decorative doors

While a door can be a bland and neutral access point to a room or space, it can also be a medium for expression and meaning: welcome or exclusion, openness or security, utility or ceremony, enclosure or connection. Doors impart these meanings due their position as the barrier to entry and their form, arrangement and fittings.

Doors for access between spaces have a minimum practical size, 2040 mm high and 620 mm, enough to allow comfortable access. The maximum size is limited only by the project and, inevitably, fabrication and transportation constraints. In reality, the door can be a wall that moves.

The physical arrangement of the door and the composition of elements, fittings and hinges is limited by the functional constraint of opening. Unlike windows that are invariable glazed or translucent to admit light, doors do not have the same constraint. They can be solid, partially or fully glazed to suit the occasion. Ornate hinges and door furniture can be used to heighten the ceremony of entry, enhance the composition of a space, or to match heritage requirements.

Given the diversity of shape and assembly that wood provides, timber doors feature prominently in applications of all types. Solid wood can be routered or carved to detail. Colour and grain can be selected to calm or excite the space. Different timbers can be mixed to add character to a panel.

Timber in large spans can be:

- Solid timber lengths
- Glue laminated elements
- Laminated veneer lumber
- Assemblies of any of these materials

combinations

While a window or door can be a discrete item in an architectural surface, the architectural surface itself can be a combination of windows and doors. This inversion of wall, window and door typology demands appropriate consideration of the arrangement of form, and the distribution of loads across a range of building elements, especially in larger spans.

Arrangement of form

Abandoning load-bearing walls for the freedom of columns and supported floor plates liberates the arrangement of the external envelope. The opaque and translucent can combine in ways free from the needs to support overhead elements. Only imagination, skill and budget contain arrangement. Windows and doors can be combined to form walls or in ways in which the separate concepts of door, window and wall lose their meaning and the occupant perceive only separation between the interior and exterior.

Load in larger spans

These combined arrangements in large openings demand engineering skill. While freed from gravity loads from above, the unit must still resist horizontal wind loads. Timber can be engineered to cope with the structural requirements imposed. Design intent and size limits the type of timber used. If the design requires a single element and a solid length of timber, there are restrictions on available length, due to the supply of suitable straight-grained timber and the strength of the chosen species. Flexibility in species selection and acceptance of engineered products and assemblies removes these constraints. The size and capacity of glue laminated timber and LVL is only really limited by design and manufacturing skill. If a window or door unit can be transported, or assembled on site, a stable, structural timber frame can be created for it.

References

Johnson, A 2006, ‘New Directions in the Australian House’, Pesaro Publishing, Sydney.

Hyatt,P 2000, ‘Local heroes: architects of Australia’s Sunshine Coast : Gabriel Poole, John Mainwaring, Lindsay and Kerry Clare.’ Craftsman House, Sydney.

information

The requirement of each project and the local production capacity will influence design detail.

Locally sourced timber has less embodied energy.

Each species has different material characteristics. Consult with suppliers on availability.

design

Sustainable design is gaining prominence in architecture and building.

Building design professionals are seeking to reduce the impacts of their design decisions on the broad environment. This change is impacting the selection and performance requirements for windows and doors in the building envelope. Demand is increasing for high performance windows and doors that contribute to reducing greenhouse gas emissions and energy use in the building.

Timber windows and doors can satisfy these increased requirements, providing high performance solutions drawn from a renewable resource. However, to ensure the maximum environmental return (or the minimum impact) timbers and detailing have to be selected with care to suit each application.

Design and specification

As a component in a building solution, the design and performance requirements for timber windows and doors are determined by the streams of considerations that influence the detailed design of the full building; mainly the design intent of the project, the type of building and the regulations and standards that apply because of that type, the constraint or requirement imposed because of the project's location, mainly climate and the availability of particular timbers, and the availability of manufacturers.

Design intent

Every project has considerations that guide or drive decision-making in design and shape the design intent. Frequently framed from the client's brief, observations of the architects, or the character of the site, these considerations can often be expressed as qualitative visions for the building when it is completed. Statements such as 'this is going to be an environmentally responsible building' and 'this new home will be warm and comfortable' describe these aspirations and guide design decisions.

As the process of design continues and decisions on planning, function, material and performance are made, reviewed, and revised, these considerations can coalesce into a coherent design intent. This design intent guides detailed decisions about the timber windows and doors.

Timber is favoured in solutions where concepts of environmental responsibility and human responsiveness and comfort are intergral to the design intent.

Regulation and standards

Buildings in Australia must comply with the nation's planning requirements and building regulations. Planning requirement can influence the form of windows and doors. Usually determined and enforced by state or local governments, these requirements are not covered in this guide and should be determined locally for each project.

The Building Code of Australia (BCA) is the nation's building regulations. This suite of regulations establishes performance-based requirements with agreed national minimum requirements set for health, safety, amenity and more recently environmental sustainability for buildings of each type. The BCA also references key Australian standards as compliance benchmarks. The BCA and referenced standards include specific requirements relevant to the performance of windows and doors. Some state-based heritage and other requirements also apply.

For further detail on design intent, see:
INSPIRATION

Standards are referenced throughout the text. For further detail, see:
Regulations and Standards

For further detail, see section:
Materials: Timber
Design: Environmental control

Location: Climate and exposure

Australia's buildings have to accommodate climates that vary from cool temperate conditions in the south to cyclonic, hot, humid and tropical conditions in the north. These differences have generated a wide range of traditional building responses, from the breezy 'Queenslander' house to the more snug designs of southern Australia. While still providing useful guideposts to practice, traditional building responses to climate have been forced to give way to regulated thermal performance. The BCA now establishes specific thermal performance requirements for many types of building. Importantly, the regulated thermal performance of buildings has increased over recent years and will likely continue to rise, driving further changes in construction practice and market expectations. Designers are becoming accustomed to evolving requirements in design: where an acceptable basic design standard now is unlikely to be acceptable in the near future.

Australian conditions can be very hard on building materials. The variety of climate experienced is one factor, but the particular characteristic of the climate is another. Australia has particularly strong sunlight, regular bushfires, and aggressive wind and dust. It is probably unreasonable to expect systems designed for northern hemisphere conditions to naturally perform satisfactorily here.

There is a ready supply of high quality hardwoods from Australia's forests and these have traditionally been used in windows and doors, particularly near their area of harvest. Most Australian grown softwoods are now sourced from plantations and only broadly suitable for external joinery if laminated and preservative treated. There is an established timber import industry in Australia, bringing species such as Western red cedar from North American and tropical hardwoods from south-east Asia and the Pacific. Acceptance and preferences for individual species vary between states.

While this diversity of timbers offers designers' variety in species, care is needed to ensure sustainable forest management and limit transport-generated impacts.

Production capacity

Industry has the skills and experience to contribute to the design process.

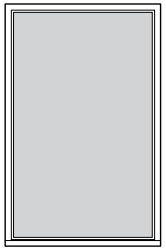
Manufacturers of timber window frames in Australia work independently, with skills and technology that has developed in response to the customer needs in the area and the availability of expertise. In designing and specifying window frames, particularly for innovative commercial work, it is essential to take a concurrent engineering approach and work with the manufacturers who have the required skill set from the start of the design process rather than delivering a finalised design without thorough formative consultation.

Configurations of windows and doors

The variety available in the appearance and performance of timber windows and doors can appear daunting. However, the units share similar primary elements, the frame and sash or sashes for a window, and the frame and leaf or leaves for a door. Diversity is generated by manipulating the configuration of these primary elements; the timber arrangement and finish in primary elements, and the type of glazing used.

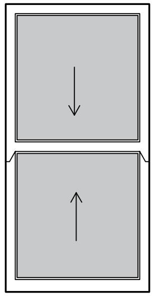
Windows configurations

Fixed glass or light



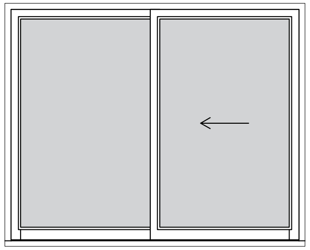
A fixed pane of glass held in a wood frame. The glass can be set directly onto a rebate or stop on the window frame, or set into a fixed sash (fixed light), and fixed in the frame.

Double hung window



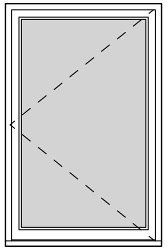
Two sashes set to slide past each other vertically within the frame. The weight of a individual sash is held by mechanical balances or counterweights on each side. The unit can also be arranged so that one sash moves over a fixed sash or glass.

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. To shed water efficiently, the openings sashes should slide outside the fixed sashes.

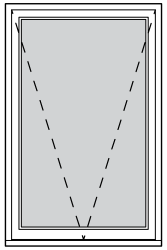
Casement window



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. If opening out, screens and security can only be fitted internally.

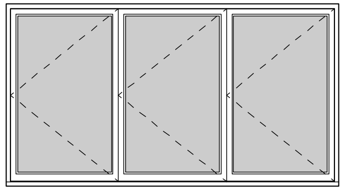
For further details, see:
INDETAIL:
Window and Door types.

Awning window



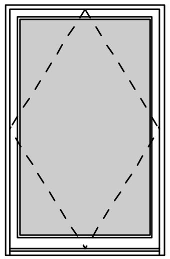
A sash hung to open out from the bottom, usually with hinges along the top edge of the frame or friction stays along the sides of the sash. Some stays allow complete reversal of the window. Screening and security can only be fitted internally. Awnings hung to open out from the top are called hopper windows.

Bi-folding window



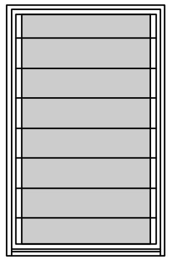
Two or more window sashes alternately hinged so they fold against each other to the sides of the opening, providing a full and unobscured opening. Bi-folds can be supported on an overhead track.

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.

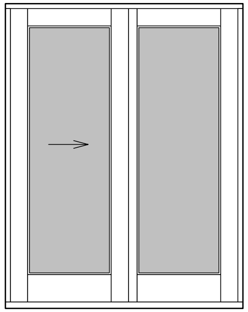
Louvre window



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.

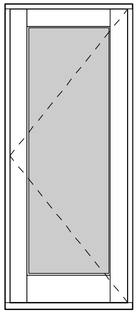
Door configurations

Sliding doors



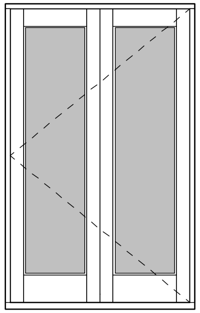
Two or more leaves set to slide past each other horizontally within the frame. Several leaves can also slide past each other to stack to one, or both sides of the opening. They are suitable for large openings but the sliding leaves have to be stacked in the door frame, reducing the overall opening size.

Hinged doors



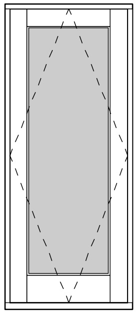
A door leaf hung along a vertical edge of a frame with hinges and opening inwards or outwards. Pairs of doors hung on either side of the frame and meeting with a rebated central join are called French doors.

Bi-folding doors



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 per side, hung without a track.

Pivot doors



Pivot doors rotate in the vertical plane on pivots at the top and bottom. They can pivot in either one direction or in both directions, giving a wide, generous opening.

Overall door sizes are generally standardized to a minimum of 2040 high and widths of 620, 720, 760, 770, 820, 870 and 920 mm. Many other sizes can be made.

For further details, see:
INDETAIL:
Window and Door types

The frames of a unit can be single peices of saolid timber, glue laminated timber or composites of timber and other materials.

Basic assembly and performance allowances restrict the minimum size of the timber components.

Availability may restrict the maximum timber sizes that can be used.

The size of timber and aluminium composites is restricted by the available aluminium extrusion.

Combining species or materials can exploit the best characteristics of both materials.

For further details, see sections
Materials: Timber
Materials: Glass.

Timber components

The frames, sashes and leaves of timber windows and door can be made from solid timber of a single species or combinations of different timber species, laminated timber, and other materials.

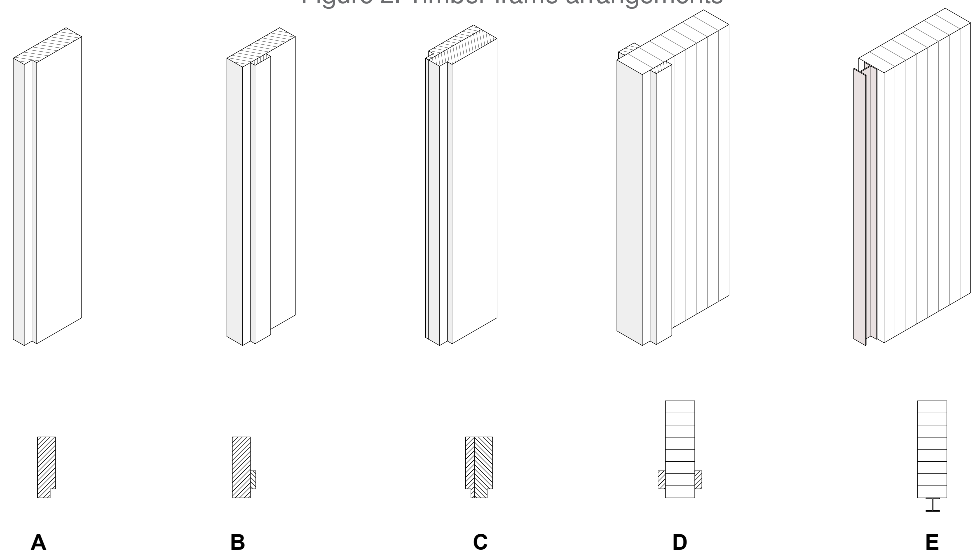
Solid timber

Solid timber elements are available in a wide range of species and sizes. Species can be selected to maximise utility and economy: 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. Due to the limitations on producing a natural material, the size of solid timber sections is restricted and these restrictions vary with species.

Glue laminated timber

Glue laminated timber is pieces of timber assembled with an adhesive to create a large section. They range from single elements of solid timber glued together to large section glue-laminated elements of finger-jointed material, shaped and moulded. Glue lamination uses high quality sections of timber efficiently. There is little waste, as profiles can be assembled to match the required shape. The glue laminated material is often stronger and has more consistent structural properties than solid timber.

Figure 2. Timber frame arrangements



(A) rebated solid timber, (B) solid timber with a stop, (C) rebated laminated timber, (D) glue laminated timber with stop, (E) glue laminated timber with an extruded glazing section

Composite timber and aluminium

Composite elements, as they are known in Australia, have a frame of timber that is faced with a metal profile. This can be simple aluminium or stainless steel sections or specialist extrusions produced to integrate the timber and aluminium materials as effectively as possible. In both cases, the metal sections are incorporated to reduce maintenance. Internationally, aluminium or stainless steel sill covers are common. 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.

Glazing

Windows and doors incorporate glass or other transparent material to admit light and permit views. The type and thickness of glass significantly influences the thermal and acoustic performance, safety and security, and the amount of light admitted. All glass used in windows and doors in Australia needs to comply with Australian Standard (AS) 1288-2006:Glass in buildings - Selection and installation and the standard regulates the size and type of glass according to the required structural capacity of the glass and the safety of occupants.

The most commonly used glass in building is ‘clear’ glass. However, this base material can be modified in a number of ways; to reduce the danger ‘clear’ presents after human impact, increase its aesthetic appeal, provide privacy, alter its thermal performance, or change the amount of sunlight that it allows to enter a space.

For further details, see sections
Design: Safety

Generally, timber window and door units do not carry structural building loads.

They can apply significant loads on the surrounding structure, particularly bi-fold and top-hung sliding units.

Structural adequacy

Timber windows and doors have to safely resist the loads applied to them in service in the building and during assembly and installation. Loads applied can be structural building loads, wind loads and loads applied in operation.

Structural building loads

Generally, timber window and door units do not carry structural building loads but act as non-loading bearing insertions into the load bearing frame of the building. If the joinery units are to carry structural building loads, member sizes and jointing must be determined in accordance with Australian Standard (AS) 1720: Timber structures, and 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, both 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.

Wind loads

Though non-load bearing insertions, windows and door units do 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. For building other than housing, these pressures are provided in AS/NZS 1170.2 -2002:Structural design actions – Wind actions. For housing, the ultimate stength test pressures are:

Table 5. Window rating for housing

WINDOW RATING	SERVICABILITY DESIGN WIND PRESSURE (Pa)	ULTIMATE STRENGTH WIND PRESSURE (Pa)
N1	500	700
N2	700	1000
N3	1000	1500
N4	1500	2300
N5	2200	3300
N6	3300	4500

Source: AS 2047–1999, Table 2.1 & 2.5

Failure conditions are noted. Under the applicable design wind pressures, the maximum allowable deflection of a structural element in the unit is:

Table 6. Allowable deflection under design wind pressure	
BUILDING CLASS	DEFLECTION LIMIT
Class 1 (Residential)	Span/150
Class 2, 3 & 4 (Multi-residential apartments, hotels etc.)	Span/180
Class 5, 6, 7, 8 & 9 (Commercial and public buildings)	Span/250

Source: AS 2047–1999

All glass used in windows and doors in Australia, needs to comply with AS 1288-2006. The standard regulates the size and type of glass according to the required structural capacity of the glass and the safety of occupants. The thickness of glass for structural adequacy depends on the type of glass, the size of the pane and the exposure of the location to wind loads.

The performance of windows and doors strongly influences a space's functionality and architectural quality, and can significantly influence its thermal and acoustic performance.

Environmental control

All buildings seek to moderate and control the ambient environment, keeping their occupants safe, dry and comfortable. Timber windows and doors play vital roles in a building's environmental control: excluding water; providing ventilation; controlling air-infiltration and sound; and contributing to the building's thermal performance. They are an integrated and vital part of the building fabric, especially when included in the external envelope.

As windows and doors admit light and ventilation and doors provide entry, their performance strongly influences a space's functionality and architectural quality. The opening for the window and door unit is a break in the external envelope. The unit's thermal and acoustic performance can significantly influence the performance of adjoining spaces. Finally, the door or window unit is generally the most complex, delicate and expensive part of the external envelope.

Water control: Design for drainage

Excluding water from entering the building is an essential part of window and door design. This includes:

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

Shedding standing water

When designing a window frame, controlling the flow of water on and around the frames is essential. Water needs to be shed off any surface on window and door frames on which it can collect. Any water build up can cause deterioration in the finish, the timber and the joints of the unit. To do this:

- any horizontal, exposed surfaces should have a minimum slope of 1:8. At this slope, water will drain off even with a moderate amount of opposing wind pressure
- the surface under the actual glazing or glazing unit should also be sloped, but as the bottom rail protects it, this slope can be reduced to 1:10
- the top of glazing beads should also be sloped to at least 1:6.

Rounding the corners of the top face of all horizontal or sloping members will also help water to flow off them, as well as improving the durability and adhesion of any finishes. Sills should also include a drip-line of a saw-cut or groove with a nominal 3 mm radius, 10 mm back from its outside edge.

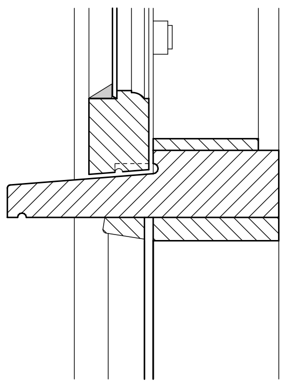


Figure 3. Transom in a window

Water entry into the building

Controlling the flow of water on and through the window or door unit is essential to prevent water seeping into the building. This water can be unsightly, a safety hazard, and lead to the deterioration of the building fabric.

Water can enter through the unit through the gaps between the sashes or doors and the frame by capillary action or by wind pressure. Capillary action is where a liquid appears to defy gravity and move upwards through a narrow gap or channel, dragged along as a result of adhesion and surface tension. Adhesion of water to its surrounding surfaces causes an upward force on the edges of the liquid while surface tension keeps the surface of the water intact. So, instead of just the edges of the water pulling upwards in a thin layer, the whole surface of water is dragged upward. In narrow channels, the water will travel a long way. The weight of water to be supported increases in any wide gaps and the process collapses.

To prevent a film of water being held between the sash and the surface of the sill or frame and drawn into the building, a gap needs to be included in the path of travel that is large to break capillary action. A gap of 6 mm at the front edge is enough to be effective, and this can be reduced to 3mm at the back. The gap must not exceed 16 mm because at this width air pressure has been found to force water into the back of the joint. Alternatively, a groove in the bottom of the sash of a minimum radius of 3 mm can act as a stop for capillary action.

Behind the opening part of a casement window, the sill up-stand acts as a barrier to help prevent water ingress whilst the window is shut.

In the opening awning sash, there should be grooves with a minimum radius of 3 mm running around the sides and bottom of the frame. These grooves stop capillary action and direct water down the sash to the sill. In awning windows, the top rail should be fitted with a compressive seal.

AS 2047–1999 requires that windows for domestic buildings resist water penetration through the assembly to particular design wind pressures and establishes the test method and pressures.

Excluding water from the envelope

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. To break this flow of water, saw cuts or grooves with a minimum radius of 3 mm need to be run on the underside of sills to form a drip line. If the frames of units protrude significantly beyond the external cladding, similar grooves should run down the outside face of each frame.

If water enters the joint, it has to be collected at a flashing and directed to the outside face of the external cladding. Flashing around the openning is a critical part of window installation .

For further detail, see:
TECHNICAL
Technical Sheet A
Installing of timber windows and doors

Water control: Condensation

Condensation is the process of water vapour in the air changing to a liquid. Condensation usually forms on (or in) a window or door when relatively warm moist air comes in contact with a colder surface. It can occur regularly in colder or in hot, humid climates. As timber is a relatively good insulator, timber frames do not heat up or cool down quickly and are not as prone to condensation build up as conductive metal frames.

Condensation in a timber framed unit generally occurs in colder climates when the external temperature drops, the glass cools, and warm internal air meets the cold inside surface of the glass. It occurs first in the coldest areas of the glass, usually in the lower corners. If the glass is cold enough and the inside humidity high enough, sufficient water can condense on the glass for it to bead and run down the glass and pool on the inside of the sill. This can discolour timber with a clear finish, damage other 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 moist outside air.

In colder climates, condensation can be reduced by limiting convective air movement around the glass. Ventilation that reduces humidity in the adjoining spaces will also help to reduce condensation problems. Double glazing creates a warmer internal surface to the glass because the gap between the layers of glass acts as a thermal break. Low-E coatings on the glass also result in higher surface temperatures. Both help avoid condensation.

As insulated glass units (IGUs) age, damage or the breakdown of the edge seal, can compromise the internal air space. Absorbent material in the edge spacers accommodates incidental small amounts of moisture becoming a problem. Continuing moisture can migrate into the air gap and condense on the surface of the exterior pane. In unsealed units, this can be rectified with a small tube, but in sealed units the moisture cannot be removed and the unit should be repaired or replaced.

Condensation can also occur in the air space between the timber and aluminium components of composite windows.

Timber windows are less prone to condensation than metal framed units.

High humidity contributes to condensation.

Ventilation reduces humidity and helps prevent condensation.

Thermal performance

Good design seeks to moderate and control a building's thermal performance to keep occupants comfortable: warm during cold winters, and cool during hot summers.

Many factors contribute to an occupant's thermal comfort: the temperature and relative humidity of the air, radiant heat sources in the space, and ventilation rates and patterns. While there is a range of optimum conditions within which occupants generally feel comfortable, comfort expectations change with climate, lifestyle, income and the cost of energy. If occupants feel that they are too cold or too hot, they act to compensate. This can be in a low energy and natural way, by opening or closing a window, or a high energy way, by operating a heater or air-conditioner.

Buildings that have good natural thermal performance use less energy on average to operate, than buildings with a poor natural thermal performance.

The BCA now regulates the minimum thermal performance of most types of buildings. Heating and cooling buildings consumes significant amounts of energy in Australia and about 38% of the electricity used in a normal home. To moderate this demand and contain the greenhouse gas emissions it generates, the BCA requires the calculated performance of the building, given its site and configuration, comply with set energy targets.

There is no single formula or approach for designing an environmentally responsible building that uses little energy in maintaining a thermally comfortable internal environment. As the climates experienced around Australian are diverse, a well performing solution developed for a site in the hot humid tropics will be very different to that of a well performing house in Tasmania. No single construction approach necessarily provides the correct option for every site.

Designing thermally efficient buildings requires an understanding of the local climate and careful manipulation of the shape, orientation and envelope of the building. As windows and doors form a break in the external envelope, their performance is particularly important. Windows and doors contribute to the thermal performance of a building by:

- Controlling heat gain and losses through the building envelope by resisting heat transfer (insulation) and allowing sunlight to enter (solar gain); and
- Controlling air flow into and out of a building by ventilation or infiltration.

Thermal performance: Insulation and solar gain

Heat can be transferred through the external envelope of a building by radiation, convection and conduction. In a building, high insulation properties are desirable in the external envelope as they help limit fluctuation of the internal temperature in response to outside conditions. Generally, specifying a well insulated external envelope made from materials with a low U-Value means less energy consumed through heating and cooling, lower bills and greater comfort for the end user.

Windows and doors are particularly important in a building's thermal performance as their insulation value as systems is generally much lower than that of the surrounding walls, floors and ceilings. They represent thermal holes or bridges that allow heat in the room to escape or the outside heat to enter. The primary performance requirement of any modern window or door system is protecting the thermal integrity of the building envelope.

The insulating value of a door or window system is a measure of its ability to resist heat transfer expressed as the system's U-value: the lower the U-Value, the more effective the thermal insulating properties of the system. Heat is lost or gained at different rates through a unit's frame and glazing. The unit's total U-value is calculated by combining these rates. Timber is a natural insulator for the frame of the window or door and warm to the touch. As a result, wood windows have slightly lower U-Values on average than PVC and vinyl windows without the environmental concerns of using a by-product of the petroleum industry. Aluminium is a very poor insulator. Timber framed windows and doors will have considerably lower U-Values than similarly sized and glazed aluminium framed ones. Glass is a poor insulator, even though its insulation rate can be moderated with coatings additives, or arranging the glass in an insulated unit.

Table 7. U-Value of window and door materials

MATERIAL	U-VALUE (W/mK)	MATERIAL	U-VALUE (W/mK)
Softwood	0.135	Glass (6 mm clear)	5.8
Hardwood	0.175	Glass (6.38 mm laminated)	5.7
Steel	45.3	Glass (6mm Low-E)	3.8
Aluminium	221	Glass (3/12/3 double glazed)	2.7 (air)

Heat is transferred by radiation, convection and conduction.

The U-value is a measure of the window systems ability to resist the heat transfer.

The lower the U-value, the more effective the thermal insulating properties.

The control of direct or reflected solar radiation, irrespective of differences in temperature is expressed as the window system's Solar Heat Gain Coefficient (SHGC).

Buildings moderate their thermal performance by controlling the direct gain and loss of heat through the building envelope, particular the windows and doors and regulating direct solar gain.

Solar heat gain

Direct or reflected solar radiation (sunlight) entering a window heats up the adjacent space. In an area with a cold climate, this solar gain can be very useful, providing a free heating source to a cold room. However, in summer, late afternoon, and in hot climates, solar gain may create an overheating problem as the additional heat load from the sunlight can make the internal spaces hot and uncomfortable.

A key consideration in the thermal design of any building is managing solar gain by controlling the placement, type and shading of openings such as windows or doors. The ability of a window system to moderate solar gain is expressed as its Solar Heat Gain Coefficient (SHGC). The SHGC is the fraction of total solar radiation admitted through the unit, either directly transmitted or absorbed and subsequently released inward. The lower a window's solar heat-gain coefficient, the less solar heat it transmits, and the greater its shading ability. The major influence on the SHGC is the performance of the glass. With larger sections sizes and lower conductivity timber formed units have a lower SHGC than comparable aluminium framed units.

Table 8. Performance of different window types					
		COOLING	HEATING	Total Window System Values - NFRC	
Glazing ID	Frame	%impr.	%impr.	Uw	SHGCw
GENERIC STANDARD INDUSTRY TYPICAL WINDOW - SINGLE GLAZED					
3Clr	Generic: Aluminium	2%	0%	7.4	0.77
3Clr	Generic: Timber	21%	24%	5.5	0.69
5Toned	Generic: Timber	38%	16%	5.4	0.50
5SToned	Generic: Timber	40%	15%	5.4	0.47
6.38LE	Generic: Timber	52%	33%	3.7	0.41
GENERIC STANDARD INDUSTRY TYPICAL WINDOW - DOUBLE GLAZED					
IGU 3/6/3	Generic: Aluminium	22%	27%	5.3	0.69
IGU 3/6/3	Generic: Timber	38%	47%	3.3	0.61
IGU 3/12/4LE	Generic: Aluminium	32%	38%	4.2	0.64
IGU 3/12/4LE	Generic: Timber	48%	59%	2.1	0.58

Notes: Uw is the whole window U-value and SHGCw is the whole window solar heat gain coefficient.

Key:			
GLAZING ID	GLAZING DESCRIPTION	GLAZING ID	GLAZING DESCRIPTION
3Clr	3mm single clear	3/6/3	3mm clear/6mm air/3mm clear
6.38LE	single solar control pyrolytic low-e	3/12/3	3mm clear/12mm air/4mm low-e
5Toned	5mm toned		
5SToned	5mm Super toned		

Source: WERS 2009 Certified Products Directory - AFRC

Full hinged windows open the full size of the internal frame.

Sliding windows open around half the size of the internal frame.

Cross ventilation is a significant issue in designing for good ventilation.

Thermal performance: Ventilation

Building occupants can moderate the thermal performance of a building by controlling ventilation through the external envelope.

Doors and opening windows can provide natural ventilation to a building, cooling it and refreshing the internal environment, especially if windows placed on opposite sides of the building allow cross ventilation of spaces. Ventilation has always been a major function of windows and doors in residential construction and with the growing interest in passive environmental design strategies, commercial building designers are re-discovering the potential of natural ventilation.

Until recently, air conditioning and mechanical air-handling systems provided the required ventilation in commercial buildings. In this intrinsically high-energy solution, fixed windows simply provided external light and a view of the surroundings. Now, there is a renewed awareness of the need to cater for the building occupants' thermal comfort by providing sufficient air change and energy-efficient climatic control systems. When pursuing a low-energy design solution, only minimal mechanical ventilation is provided and thermal comfort in internal spaces is linked to the occupants' ability to control their own ventilation requirements by opening and closing the windows and doors. Equally important is the relationship of windows to each other within the building. Cross ventilation and use of breezeways and thermal stacks maximize ventilation.

The window and door configuration affects the degree to which the unit opens and the potential ventilation provided. In practice, the level of ventilation safely available from hinged units, such as casement and awning windows is highly dependant on the incorporated hardware, the stays, winders or hooks and safety considerations. The potential ventilation provided by type is listed in Table 9.

Table 9. Ventilation potential for windows

	VENTILATION POTENTIAL*	NOTES
WINDOW TYPE		
Fixed Glass or light	0 %	
Double Hung Windows	~ 45 %	The opening is easily variable. Ventilation is available at both the top and bottom of the opening.
Sliding Windows	~ 45 %	The opening is easily variable. Ventilation is available at one side of the opening only.
Casement Windows	~ 95 %	The opening is variable. Hardware selection affects the extent and safety. Hinged units can be opened to their full size but this is restricted practically by the capacity of winders and other hardware.
Awning Windows	~ 95 %	The opening is variable. Hardware selection affects the extent and safety. Frictions stays can allow full opening. Hinged units can be opened to their full size but this is restricted practically by the capacity of winders and other hardware.
Bi-folding Windows	~ 95 %	The opening is variable but requires the operation of bolts for each unit opened.
DOOR TYPE		
Sliding Doors	~ 45 %	The opening is easily variable. Ventilation is available at one side only.
Hinged Doors	~ 95 %	The opening is variable but is generally restricted to being latched fully open.
Bi-fold Doors	~ 95 %	The opening is variable but requires the operation of bolts for each unit opened.
Pivot doors	~ 95 %	Hardware selection affects the extent and safety. Location control pivot hinges or floor bolts are required if the door is left open.

*Approximate figure based on the percentage of sash or leaf area

Wind-induced pressure can force air through the smallest of cracks.

Infiltration almost always results in a less energy-efficient building.

Design profiles that allow trapped air to escape, rather than be forced into the interior of the building.

Air chambers, or velocity chambers, give the air room to circulate within the frame and escape outwards.

Design profiles that protect the openings around the sash.

Design the window so that the effect of the seals is maximized.

Thermal performance: Infiltration

Infiltration is the leakage of air through gaps around the components of windows or doors, or cracks in the glazed unit itself. In the simplest terms, it is unintended and uncontrolled ventilation, driven by uneven air pressure. Wind causes increased (or positive) air pressure on the windward side of a building and lower (or negative) air pressure on the lee side. This pushes outside air through any gaps in the windows and doors into the building on one side and draw it out on the other side of the building.

Infiltration almost always results in a less comfortable and less energy-efficient building. It can negate any gains made in increasing the thermal capacity of the glazing unit. Cold air being drawn through the building sets up unpleasant drafts. These encourage users to turn the heaters up. In hot climates, air expensively cooled can leak out of the gaps to be replaced by hot outside air. Air leakage can also affect humidity.

Good design and specification aim to reduce infiltration by controlling the shape of the frame, the type of window or door, and the seals in the unit and their maintenance. The shape of the frame can reduce the effects of air pressure, allowing the air to escape back outside rather than force its way into the interior, through the inclusion of air chambers. This also reduces the likelihood of water being forced through cracks and gaps in the assembly.

As shown in Table 10, different types of windows and doors tend to have different infiltration rates. Hinged units, such as casement, awning and hopper windows, close by pulling the sash against a rebate in the frame. Combined with efficient compression seals, this can close any gap effectively. The performance of units that slide, such as double hung and sliding windows, is not as good as hinged units. It is difficult to seal around the unit as the sashes need space around them to slide freely. The seals that can be used are also less effective.

AS 2047–1999 establishes maximum air infiltration rate for particular window or building types. Under the applicable test procedures, the maximum allowable air infiltration rates in the unit are:

Table 10. Comparative infiltration rates	
WINDOW TYPE	COMPARATIVE AIR INFILTRATION LEVELS (l/s m2)
Timber: Awning	0.12
Timber: Casement	0.42
Timber: Double Hung	0.95

Results are averages of 2009 WERS test results for single and double glazed units of each product type from up to 6 companies.

Table 11. Maximum air infiltration rates			
BUILDING OR WINDOW TYPE	PRESSURE DIRECTIONS	MAXIMUM AIR INFILTRATION (l/s m2)	
		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

Acoustic performance can be critical for comfort and privacy, especially in noisy city environments.

A unit's acoustic performance is directly related to the quality of the frame, the properties of the glass, and the sealing of gaps in the frame and between the frame and surrounding elements.

Wood exhibits relatively good acoustic properties.

Windows and doors types that have the most effective air seal will generally have a better acoustic performance than those that are harder to effectively seal.

Acoustic performance can be improved by increasing the density of the materials used.

Acoustic performance

Windows and doors form an integral part of the sound separation layer between the inside of the building and the outside environment. Their performance can be critical to users' sense of comfort and privacy, especially in noisy city environments. Sound travels from its source through the air as a series of radiating pressure pulses. The wavelength of the sound is defined by the distance between each pulse at its maximum. The frequency of sound is the number of pulses that pass a given point in a second. The higher the frequency (and shorter the wavelength), the higher the pitch of the pulse will sound. Amplitude is the sound pressure level or loudness of the pulse.

The external envelope of a building acts to exclude external airborne sound from internal spaces. As sounds hit the envelope, they will partly be reflected back, partly absorbed and partly transmitted through by vibration. The proportion reflected back, absorbed or transmitted varies with the make up of the external envelope and with the frequency of the sound. As the windows and doors are usually the thinnest part of the external envelope, they are often the weakest point in the sound separation layer. The unit's performance and the quality of its installation influence performance. The acoustic performance of the unit is influence by the sealing of any gaps in it, the frame material, and the thickness and the type of the glazing.

Sealing the unit

The acoustic property of window and door systems, their ability to insulate the interior from external noise, is linked to air leakage. Sound travels easily through any air gaps, so measures that reduce air infiltration are also effective in reducing sound transmission. As discussed in the previous section, this starts with selecting windows and door types that close tight against the seals. The use and placement of effective compression seals is then the most effective sound barrier. Two lines of seals are more effective and are effective longer than a single layer of seals, especially if the second layer is not exposed to the weather, as cracked or worn seals allow sound transmission.

The frame and the glazing material

Generally, the higher the frequency and amplitude of the sound, the more the materials will vibrate. However, denser materials tend to vibrate less and different materials vibrate at different natural frequencies. Separating layers of material can also reduce vibration.

Vibration can be reduced by increasing the density of the materials used. Specifying materials with different natural resonances also reduces sound transmission. Wood exhibits good acoustic performance properties as it has the mass and resistance to vibration necessary to reduce the effect of sound waves on its molecules. Combining wood with aluminium cladding reduces sound transmission as the materials resonate at different frequencies.

Table 12. Sound reduction by glass type	
GLASS	DECIBEL LEVEL REDUCTION
3 mm	30 db
6 mm	32 db
IGU (6/16/6)	35 db
6.38 laminated glass	33 db
10.38 mm laminated glass	36 db

Source: Viridian Architectural Glass Specification Guide.

The options for improving the performance of the glass are using thicker glass, laminated glass or double glazing. The greater the thickness of the glass, the better the noise reduction for low frequencies such as traffic noise. However, standard glass has a dip in its acoustic insulation properties when the glass vibrates at the same frequency as the noise source, generally at higher frequencies such as aircraft noise.

Laminated glass is an effective option to reduce noise transmission. The included interlayer is particularly effective at dampening sound when compared to the same thickness of monolithic glass. Further, the dampening effect of laminated glass reduces the dip in its acoustic insulation properties at higher frequencies. Thicker laminated glass with a thicker interlayer is more effective in low frequency noise reduction. Glass laminated from pieces of varying thicknesses is also effective as the layers resonate at different frequencies. Standard insulating glass units (IGUs) do not provide good noise reduction. However, incorporating panels of laminated glass or glass of differing thicknesses in the IGU can produce good results.

Sound insulation data of different glasses is given in Table 12. The sound reduction index, Rw, is the weighted sound reduction in decibels incorporating a correction for the ear's response. Every 10dB step is perceived as twice as loud, so that a 20dB reduction would reduce the noise by four times.

High level performance

For problem sites where the acoustic properties are particularly important, features such as laminated glass, secondary weather strip seals and, if necessary extra wide air gaps between the glass in glazing units may be needed. Triple glazing, double envelope facades and dual sash configurations may be appropriate for challenging situations.

Visual performance

The visible transmittance of glass is becoming more important with the increased interest in improving the quality of life for the occupants of commercial buildings, mostly offices. Windows and doors incorporate glass to admit daylight and allow a view of what lies beyond the room or space. The glass in the frame establishes a safe or filtered connection between the internal and external: framing or revealing views, and admitting or obscuring sunshine and daylight.

The visual performance of window and doors is generally a function of the glass or other translucent material included in the frame. The visible transmittance of glass refers to how much visible daylight it allows through. As seen in Table 13, clear glass allows about 87 % of daylight through. With low-E glass, this reduces by about 5 %. Double-glazing allows approximately 80 % through. The light-to-solar-gain ratio (LSG) expresses the relationship between visible transmittance and the solar heat gain coefficient (VT/SHGC). This is used to ensure that an improved solar heat gain coefficient does not reduce visibility.

Occasionally, a clear view through a door or window is not desirable. Too much light can cause visual discomfort through unwanted glare. In these cases, tinted glasses may be used. If building occupants require privacy or a selected view, the glass can be obscured or coloured. Full details of glass performance is available from glass suppliers.

Table 13. Visibility light transmittance of glass

GLAZING TYPE	VISIBLE LIGHT TRANSMITTANCE
6 mm clear	87 %
6 mm grey tone	42 %
6 mm green tone	76 %
6.38 laminated	86 %
6 mm Low-E	82 %
6.38 laminated Low-E	82 %
3/12/3; Double Glazed; clear/air/clear*	80 %

Source: Viridian Architectural Glass Specification Guide.

Security

In addition to being a weak point in the building's thermal envelope, windows and doors can be a security weak point. Security can be enhanced by the use of screens, the type of frame and accessories and the glass type selected.

Screens

Windows and doors only provide ventilation when they are open, but when open, the privacy, security or protection they normally provide is compromised or lost. To maintain security and privacy, windows and doors can be fitted with security screens or shutters. Screens limit access but can retain ventilation and privacy. Shutters maintain privacy and protection. Not all types of windows and doors can be screened easily. Table 14 lists the potential location of screens.

Frame

The security of the sash or leaf is closely related to the hardware and the rigidity of the frame. Generally, units with concealed hinges will be more secure than units that have exposed hinges or slides. Reflex hinges (or friction stays) appear to be more secure than butt hinges because no part is visible or accessible from the outside when the sash is closed. The number and types of locks also contributes to security.

The frame's rigidity is related to the strength and hardness of the timber species, the size of the frame elements and the quality of the joints. Assuming consistent joint quality, the security of the frame can be increased by selecting a stronger, harder timber for the frame and increasing the member sizes.

Glass type

For security, laminated glass is preferable to toughened, as toughened glass can easily be broken by scoring. It then shatters into small fragments, falling out of the frame and allowing entry. Laminated glass can be cracked, but the inter-liner holds the pieces together. It generally stays in the frame and continues to prevent entry. Additional security can be achieved by increasing the thickness of the interlayer and its strength, as well as using multiple glass interlayer constructions.

Table 14. Potential location for screens

SCREEN LOCATIONS	WINDOW AND DOOR TYPE
Outside screens	WINDOWS: fixed glass or light, double hung, inward opening casement, sliding DOORS: inward opening hinged, sliding
Inside screens only	WINDOWS: outward opening casement, awning and hopper DOORS: outward opening hinged
Difficult to screen	WINDOWS: bi-fold, pivot DOORS: bi-fold, pivot

Clear glass lets over 85% of daylight through

Double glazing allows approximately 80% of daylight through

Low-E glass will reduce visible transmittance by approximately 5%

Light to solar gain Ratio expresses the relationship between visible transmittance and the solar heat gain cooefficient

Safety

Building occupants can be injured or killed if they hit or run into the glass in windows and doors. To reduce this risk, strong regulatory controls limit the types of glass used in areas susceptible to human impact. The requirements are established in AS 1288-2006. Generally, safety glass is to be used where there is a chance of human impact, specifically in:

- glazing in doors and sidelights
- windows capable of being mistaken for an opening, and glazing within 500 mm of the floor generally or within 1000 mm of the floor in schools and childcare buildings
- shopfronts, internal partitions, and windows in bathroom.

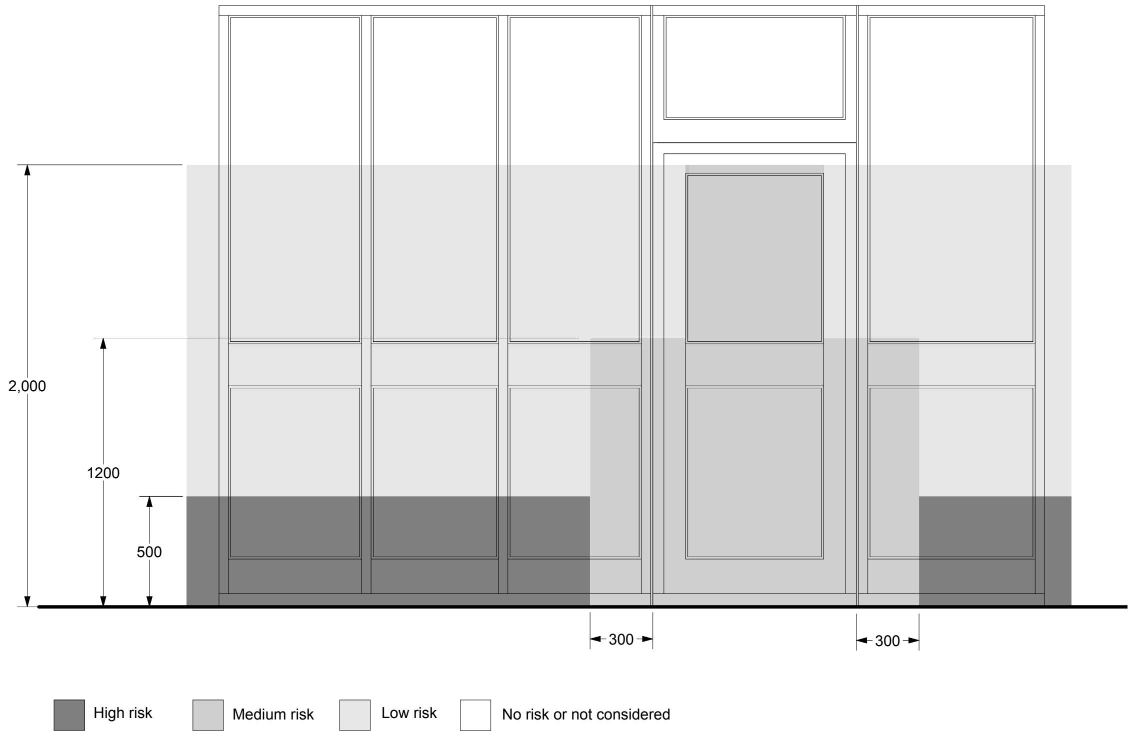


Figure 4. Level of risk of injury from human impact. Source: AS 1288-2006

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.

Laminated glass is two or more sheets of glass joined with adhesive inter-layers of transparent plastic. If broken, the glass sticks to the interlayer and generally stays in the glazed unit. Toughened glass is glass that is heat treated. This increases its strength beyond that of typical glass and determines its behaviour when it breaks. When shattered, it breaks into small, relatively safe pieces. Toughened glass is also called tempered glass.

Mechanical protection can also be provided to the glazing. Also, 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 it visibility.

Safe movement and access

Building occupants can be injured or killed if they fall out of upper storey windows or doors. Also children can drown if they have unsupervised access to swimming pools. Part D.2 of Volume 1 of the BCA and Section 3.9 of Volume 2 impose requirements to ensure safe movement and access. The major provisions affecting door and windows deal with access to pool areas and the extent that upper storey window can open.

Access to a pool area is restricted and must comply with AS 1926 Swimming pool safety. Any access door and window opening to the pool area must be protected with child-resistant door sets and child-resistant openable portions to the window. For windows, this limits the opening of particular sections of the window to 100 mm or protection of openable portions of the windows with bars or suitable mesh.

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 BCA. 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 sashes below 1 m above the floor needs to be constrained to its opening so that 125 mm sphere limit cannot pass through.

Each timber species has its own characteristic performance.

The timber's resistance to decay is directly related to its moisture content in service.

Dry timber can remain serviceable for centuries.

Design for durability

Durability is a key consideration when specifying timber windows and doors, as timber is a natural material and if conditions allow, it biodegrades. Timber windows and doors in good condition remain in service in buildings built a life time ago while timber elements remain in service in buildings hundreds of years old. This success in application comes from recognising two main aspects of using timber: first, particular species are suitable for specific tasks and second, water is a key to timber's biodegradation.

Timber is a natural material. The term 'timber' includes many species and each species has its own characteristics and properties. This natural variability needs to be accommodated during specification and design. Species need to be selected carefully so that they prove to be durable in the design service environment. Water is the key to timber's bio-degradation, as the organisms that break timber down require a threshold of moisture content of above 20% in the wood to survive. Dry timber generally remains serviceable for centuries.

The control of water in an external element is complex and ensuring the durability of a window or door unit extends beyond just selecting the performance of the timber. It includes the unit's ability to resist condensation and air and water infiltration while maintaining its thermal, structural and aesthetic performance over time. 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.

There is no simple rating or guarantee to 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.

Durability and exposure

Every element in a building deteriorates after installation and its rate of deterioration is proportional to its exposure to hazards. The elements on the outside of the building are exposed to the most aggressive conditions: rain, wind, peristent moisture, sunshine, and deteriorate much more quickly than protected elements.

The service life of window and door units in the external envelope will be directly related to their level of exposure. Generally, windows and doors exposed to the rain, wind, sunshine and persistent moisture will deteriorate more quickly than those with less exposure. This 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

Climate affects durability as it influences the level of moisture, humidity, heat and sunlight that the unit has to resist. This affects the performance of the timber, embedded fastenings and any applied finishes. Generally, the timber exposed to a climate that is regularly damp or wet will decay faster than timber in a regularly dry climate. If the climate is moist and warm, it will decay faster again. Hazard zones for the decay of timber above ground are shown in Figure 5.

Hazard zones for embedded corrosion of fasteners are shown in Figure 6 and give broad guidance on the longevity of embedded fixings in exposed timber joinery and probably also for exposed hardware. More detail on this is available in the Timber Service Life Design Guide available at www.timber.org.au.

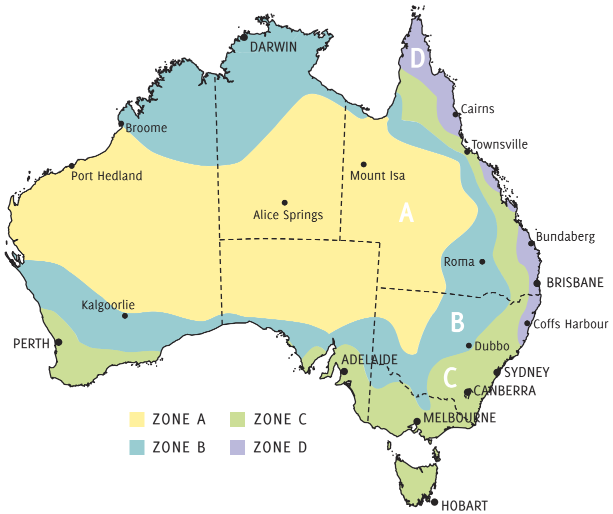


Figure 5. Above ground decay hazard zones. Zone D has the highest decay hazard
Source: FWPA Timber service life design guide

The exposure of window and door units needs to be considered on several scales: climate area, location, building, component and detail.

Figure 6. 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 the slope of the land, the surrounding vegetation and the proximity of lakes or the ocean. These modify the general 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, can influence the performance of hardware considerably.

Similarly, the position of a window and door unit in the building affects its durability. Units on the south side of 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 increased decay. Eave, overhangs and and sunshade dramatically increase the service life of timber windows and doors.

Element and detail scale

For any given climate, location and building, 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 façade or the unit. As well as controlling solar gain, eaves and sunshades reduce the level of sunlight, the force of wind and the amount of rain driven onto or running across the joinery unit. This dramatically increases the service life of facades and windows and doors units in them.

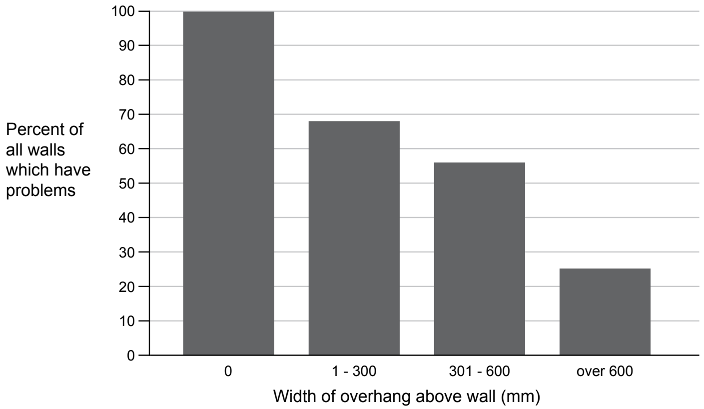


Figure 7. Influence on overhang size on wall problems in low-rise building in Vancouver, B.C. Source: Morrison-Hershfield 1997

Particular parts of external windows and doors regularly endure the most exposure and highest deterioration risk. In windows, this is the window sill and bottom rail of any sash and particularly the joints between the sill and the rest of the frame. In doors, it is the bottom rail of a panel door, the bottom 300 mm of any door. There are several reasons for this. 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. They are also further away from any protection given by the eaves or sun shades. Water runs down onto these surfaces from above while in doors or full height windows, water can be splashed up on them from the surrounding floor or ground. Lastly, dust and water accumulates on these surfaces. Generally flat surfaces, such as sill, are particularly vulnerable - water and dust collecting on the surface and increased heat from the sun can almost double the expected decay risk of nearby elements.

The sill and bottom rails of a unit regularly endure the most exposure and highest deterioration risk.

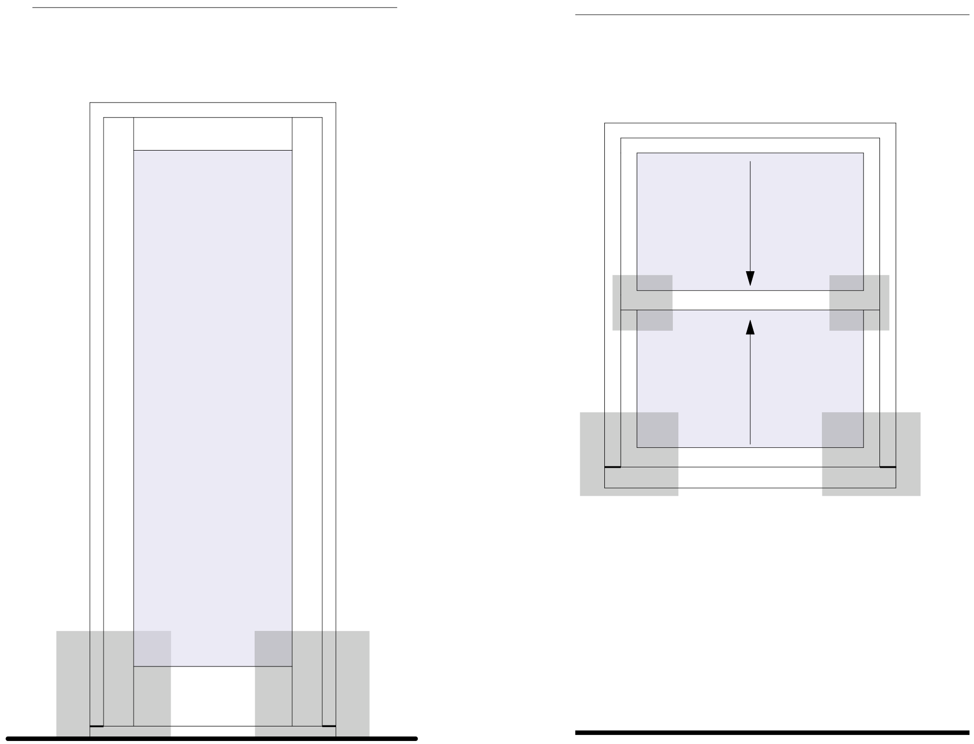
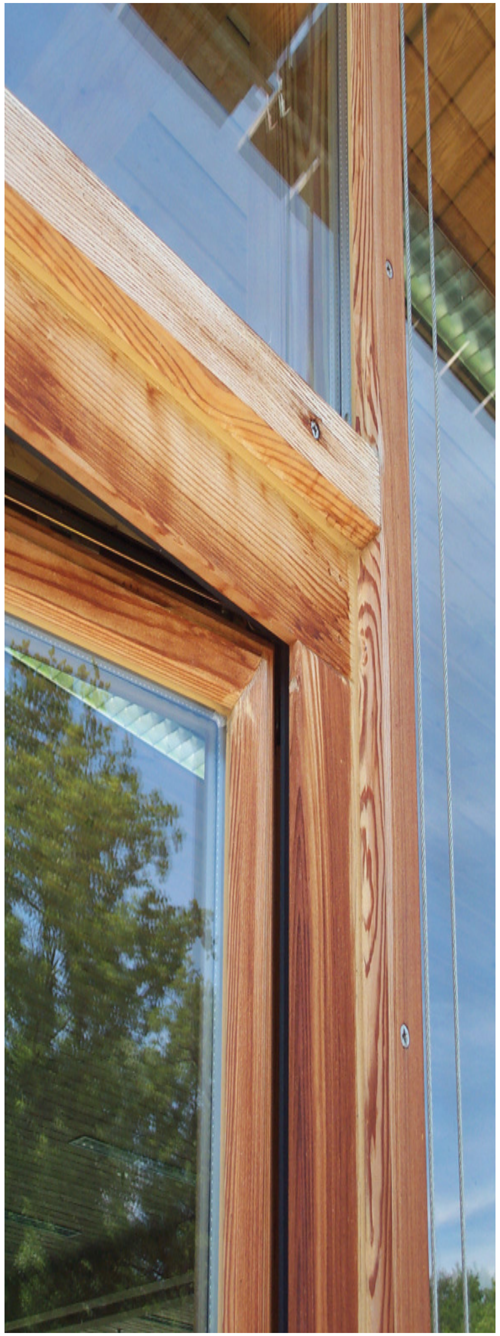


Figure 8. Areas of highest deterioration risk



Durability of the timber frame

The durability of the timber frame is affected by the hazard presented by 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

Timber in window and door joinery is exposed to biological hazards that lead to decay and weathering. The timber can resist these hazards naturally or with the help of preservative chemical treatments.

AS 1604 -1997 - 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 wood by fungi and can occur if the moisture content of the wood is maintained above 20% and the temperature is between about 5° to 60°C. While the temperature on the outside of a building is hard to control, the timber can be kept dry with a moisture content under 20% 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.

Less dramatic than decay, weathering is the greying and minor cracking of a timber surface caused by light, dust or recurrent wetting and drying. Weathering affects appearance, the performances 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.

AS 1604 rates most timber windows and door as being subject to Hazard Class H3, outside above ground.

Decay is the most critical hazard for timber in windows and doors.

The natural durability of timber in windows and doors is most critical in the sills where high durability timber should be used.

The natural durability of a piece of timber is generally a characteristic of its species.

Insects, such as termite and the lyctid borer, 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 acts 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

Timber resists decay and insects naturally or with the assistance of added preservatives. The natural durability of a piece of timber, its resistance to decay, is generally a characteristic of the species. Timber species are rated in one of four durability classes in Australian Standard 5604-2005 - Timber – Natural durability ratings, based on years of comparative tests of timber samples. Two ratings are available for the heartwood of most species: durability in-ground contact and durability exposed out-of-ground contact.

Durability Class 1 timber is rated as highly durable with a probably life expectancy of the heartwood exposed above ground of more than 40 years. By comparison, Durability Class 4 timber is rated as non-durable with a probably life expectancy above ground of less than 7 years.

These rating only refer to the performance of heartwood, with any sapwood either excluded or treated. The sapwood from all species is rated as Durability Class 4.

Table 15. Timber durability life expectancy

	PROBABLE HEARTWOOD LIFE EXPECTANCY (YEARS)	
NATURAL DURABILITY CLASS	HAZARD CLASS 1	HAZARD CLASS 3
	Fully protected from the weather and termites	Above ground exposed to the weather but protected from termites
Class 1 (HIghly durable)	50 +	40 +
Class 2 (Durable)	50 +	15 to 40
Class 3 (Moderately durable)	50 +	7 to 15
Class 4 (Non-durable)	50 +	0 to 7

For further detail, see
TECHNICAL
Technical Sheet C
Durability and timber treatment

Preservative treatment to resist decay, weathering and insects

Timber's natural durability to decay and insects can be enhanced by adding preservative chemicals to the wood. 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 combination of insecticides and fungicides. Applied by dip diffusion or by commercial pressure treatment, the major treatment options are:

- Water borne preservatives applied to unseasoned timber, generally boron-based mixtures.
- 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. Simply, the preservative cannot penetrate into the wood sufficiently or consistently enough to provide the level of chemical retention required in the Standard. These pieces only receive surface coating While water-borne boron treatment is applied to unseasoned timber, surface LOSP treatment is applied to milled material ready for assembly. If cut, the exposed ends should be dipped in preservative to maintain the envelope protection.

Recent research into material treated in this way has shown that this envelope treatment can be effective in reducing decay and increasing the service life of lower durability timbers for windows and doors. After treatment, lower durability eucalypt windows gave performance almost equal to LOSP treated Meranti, and equal or better performance to untreated Western red cedar.

Finishing

Coating timber with a well maintained paint or a high-build translucent finish can reduce decay and increase the service life of the unit. Coatings shed water off the surface of the wood and slow the uptake of moisture, particularly for the relatively porous end-grain of the timber. This limits the availability of moisture necessary for decay.

The expected life of paint or other finishes depends on the quality and type of coating and the care taken in application. Good quality paint systems provide a water resistant and generally long-lasting finish. Stains and water repellents do not last as long and require more frequent re-application than paints. Factory-coated coatings tend to have significantly longer service lives than site applied finished, as factory finishing allows superior coatings to be applied in controlled conditions.

Whether site or factory-finished, particular profile details help prolong the life of any coating. Rounding the corners of the members helps to shed water and reduces the stresses in the finish found at sharp arrises, improving the durability and adhesion of any finishes.

The choice of colour is important. Light coloured paints usually last longer and give greater protection to the timber than dark coloured paints. Dark colours absorb and retain heat from sunlight more readily than light colours. This increases the temperature and stresses in the coating and the underlying wood, and increases the wood's decay rate. 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 leads to further breakdown of the finish, more ingress of water and hastened decay.

Not all timber can be treated to the same degree. Generally, heartwood can only be partially penetrated, while generally the sapwood can be fully treated.

Joints and fixings

The quality of assembly can assist to keep the timber in the joints of the frame dry and protected from decay. The joints between the sill and the rest of the frame needs special attention, and should be preferably completely sealed to exclude water. Additional care also needs to be taken in painting or finishing these areas. Ideally, the joints in the frame should be protected by:

- Treating the cut ends of any treated or low durability material. A minimum 3-minute dip immersion of the end grain in an azole-based LOSP treatment can significantly increase the frames service life.
- Sealing the end grain of the pieces with paint before assembly. This slows water entering the timber.
- Sealing the joint with a flexible, water proof sealant. This fills any gaps that water may enter.
- Shaping joints so that they do not trap water unnecessarily.

Quality fasteners are also important, as corrosion of the metal can split the wood and retain moisture. AS 2047 – 1999, requires that all steel fixings should be hot tip galvanized steel in accordance with service condition No. 2 of Australian Standard 1789-2003: Electroplated zinc (electrogalvanized) coatings on ferrous articles (batch process) or stainless steel. Do not use uncoated steel fixings on any part of the frame.

Arrange in the frame

AS 2047 – 1999, requires that timber windows be constructed of either:

- Durability Class 1 or 2 timber,
- Timber treated in accordance with AS 1604 - 1997, or
- 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 16 lists the preferred species arrangement for commercial and high exposure residential projects.

Composite frames

Composite aluminium-clad timber window and door units have been developed to make the most of the desirable properties of both materials. This type of window has been available for many years in Scandinavia and northern Europe, and is a logical development of the increasing use of beads, clips and integral sills of aluminium used in conjunction with wood frames. The primary advantage of cladding the wood with an external aluminium face is that it eliminates maintenance of the covered wood surface. This is particularly useful on multi-storey buildings where re-painting might require scaffolding, and on sites where an aggressive or polluted atmosphere affects the durability or appearance of coatings. As composite windows have an internal timber frame, they retain the good thermal and acoustic performance, and visual appeal of a fully wood window

Design for wear internally

Windows and doors and their frames tend to wear in areas of regular contact. Finishes wear away where there is regular hand contact, and the finish and timber 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. Realistic, long term thinking about how the product is to be used in service means that design detailing can be used to protect vulnerable points of wear. Replaceable inserts or protective coverings can be applied. Push and kick plates protect the timber from indentation.

Table 16. 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) hardwoods, or VPI boron treated hardwoods
Frame (excluding the sill)	Medium	Normal	Painted	Durability Class 1 or 2 timber, or commercially treated LOSP (azole) hardwoods, or VPI boron treated hardwoods, 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 hardwoods, 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 have specific rquirements that need to be met.

** If any treatment timber is cut, the end-grain needs to be re-treated to maintain the treatment envelope.

Durability of the glass and glazing

Clear glass is a durable and chemical resistant material, and will have a very long service life if protected from impact or heat stress. However, toughed glass and special coatings on glass may be damaged, and integrity of IGUs can deteriorate with time. Toughened glass scratches relatively easily and deep scratches can induce unexpected failure. Also 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 unit (IGUs) is limited. Their expected life is influenced by the quality of their design, their manufacture and installation and their exposure to the elements, especially wind loads and pressure fluctuations. Over time, stresses in the units and between the unit and the surrounding frame can fatigue the seals. Their failure can degrade thermal performance and permit air.

Radiant heat and extreme temperatures affect frames and glazing systems.

Wind drives embers through small cracks around frames.

Fire-resistant timbers are available for many applications.

Design for fire and bushfire

In many parts of Australia, bushfires expose buildings to extreme heat and temperatures, and a storm of wind-blown embers. These conditions affect timber windows and doors. They 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. Also, the timber frames can flare on their inside face.

Areas likely to experience bushfires can be designated bushfire prone areas under state or local planning regimes. This designation requires any new and significantly altered building in these areas to comply with the provisions of Australian Standard 3959 Construction of buildings in bushfire prone areas. After the 2009 Victorian bushfires, all or large areas of several states have been designated bushfire prone.

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. There are described in Table 17. 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. As the assessed threat increases, greater restrictions are placed on the materials used in the construction of the external envelope.

As windows and door can provide a weak point in the fire resistance of the external envelope, limits are placed on their arrangement and construction. The requirements vary with the assessed BAL of the site and whether the window or door is protected by a bushfire shutter or screen. The requirements set restrictions on the species of timber and the glass used in the unit and the clearance between the doors and their frames.

Table 17. Bushfire attack level and levels of exposure

BUSHFIRE ATTACK LEVEL	DESCRIPTION OF PREDICTED BUSHFIRE ATTACK AND LEVELS OF EXPOSURE
BAL - LOW	Insufficient risk to warrant specific construction requirements
BAL - 12.5	Ember attack
BAL - 19	Increasing level of ember attack and burning debris ignited by windborne embers together with increasing heat flux between 12.5 and 19 kWm^2
BAL - 29	Increasing level of ember attack and burning debris ignited by windborne embers together with increasing heat flux between 19 and 29 kWm^2
BAL - 40	Increasing level of ember attack and burning debris ignited by windborne embers together with increasing heat flux between 29 and 40 kWm^2 with the increased likelihood of exposure to flames
BAL - FZ	Direct exposure to flames from fire front in addition to heat flux >40 kWm^2 and ember attack

Table 18. 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	Bushfire shutters or screen and any timber frame or window assembled with bushfire resisting timber or timber species from E2	Non-combustible material, bushfire resisting timber or timber species from E1
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

As set out in Table 19, as the assessed BAL increases, the fire resistance of the timber used in the frame increases. Timber can also be used to make the fire-shutters up to BAL 29. The standard correlates fire resistance to density and timber species are broken into four major groups:

- low density timber species
- timber species with a density of 650kg/m3 or greater, listed in AS 3959-2009, Table E2
- timber species with a density of 750kg/m3 or greater, listed in AS 3959-2009, Table E1, and
- fire resistant timber. Common species in each of these groups are listed in Table 18. The clearance between doors and their frames is also restricted to prevent ember attack. The gap between the door and the sill, head and jamb when closed must not exceed 3 mm.

Table 19. Density and fire resistance of major species	
REQUIREMENT	COMPLIANT SPECIES
'Bushfire resistant' timbers:	Blackbutt, Spotted Gum, Red Ironbark, River Red Gum, Silvertop Ash, Turpentine, Kwila (Merbau)
Timber species* from E1 - density 750kg/m3 or greater include:	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 650kg/m3 or greater include:	All species from E1 (above), also: Alpine Ash, Mountain Ash, White Cypress, Shining Gum, Celery-top Pine, Slash Pine

* a more complete list of species is included in Appendix E of AS 3959-2009 .

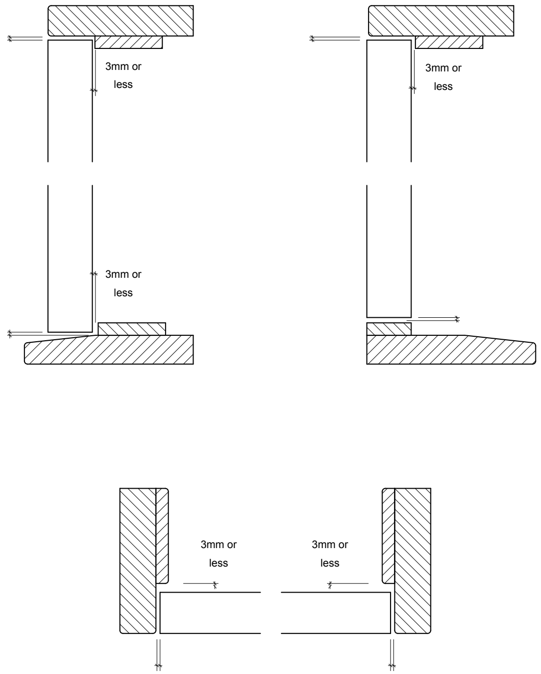


Figure 9: Door and jamb clearances for doors in bushfire prone areas.

Bushfire resisting timbers

Timber species can be regarded as bushfire resistant due to the natural properties of the material, or by coating or impregnation with fire-retardant chemical. Timbers rated as naturally bushfire resistant timbers after testing are included in Table 19. Timber can be impregnated with fire-retardant chemicals or coated with fire-retardant systems to comply with AS 3959, Appendix F. These resist radiation exposures but also must remain in the wood for its service life. Different products are available and their performance should be determined from the manufacturer.

Glass

Specific requirements apply to the glazing, especially glazing within 400 mm of the ground or decks, with toughened or safety glass required in areas liable to flame exposure. Mesh screens are required for the openable section of windows from BAL 12.5 with requirements varying between openings glazed with normal annealed glass and those glazed with toughened or safety glass. Consult the relevant section of AS 3959-2009 for details.

Increasing the life span of the window reduces the impact of the embodied energy from producing a product.

Flexible design allows for changes to be made over time.

Design for disassembly allows for worn parts of the window to be replaced or repaired, and also for the frame to be dismantled and the timber re-used at the end of its service life.

Design for disassembly and replacement

In order to reduce the environmental impact of building materials, it is preferable to spread the embodied energy and other resources used to make them over as long a time as possible. One strategy is to design for and select highly durable materials for the building envelope, ensuring their individual and combined durability performance is high and thus an expected longevity in their service life. However, this is not the only or necessarily the more responsible strategy.

If the human need for change is accepted, then design flexibility should be taken into account and the buildings designed to be flexible enough to change with changing needs, or be designed for easy disassembly so that the materials may be re-configured and used again. Also, if the realities of building exposure are recognised, it becomes evident that some parts of the building have longer effective service lives than others, with the protected internal structural frame likely to significantly outlast most external cladding systems.

Ideally all three of these strategies will be combined – design for longevity, design for flexibility and design for disassembly and replacement can be incorporated.

These approaches have long been used from internal timber elements, with internal doors and similar joinery regularly refreshed in place, removed, renovated or recycled. While changes in performance requirements for windows and glazing have limited the use or reuse of some older external joinery, newer designs incorporate means of replacing the most vulnerable sections, particular the sill, without significant effort or change to the unit. In this, traditional elements such as the front of the sill, or external architraves are evolving beyond a part of the window or door, into a replaceable rainscreen.

materials

Timber

Timber is an ideal material for manufacturing windows and doors. It is a light, strong, natural and renewable material that can be moulded to almost any shape. Timber includes many different species. Only some species and some pieces of timber of those species match the performance requirement of windows and doors, primarily durability, stability and appearance.

Types of trees and timber

Timber is solid wood cut from the trunks of trees. As a natural organic material, the properties of any piece are largely determined by the species and age of the tree and the location in the tree from which the timber is cut.

Tree species commercially harvested for timber are normally classified into two major botanical groups: ‘softwoods’ or Gymnosperms, species of trees bearing seeds in cones, and ‘hardwoods’ or Angiosperms, flowering trees bearing covered seeds. The difference between the timber from softwood and hardwood species, results from differences in their cellular structure and chemical composition. The term hardwood or softwood has no direct relevance to the hardness or softness of the wood.

The trunk of the tree from which most timber is drawn has several zones of wood. Working from the outside of the trunk to its centre, these are the bark; cambium layer; sapwood; heartwood; and the heart or pith. Timber is generally cut from the heartwood and occasionally the sapwood.

In the standing tree, the sapwood is composed of living cells that conduct water and mineral sugars from the roots to the leaves and bark. It is usually lighter in colour than the heartwood and the two layers are generally well defined. However this is not always the case. The sapwood can have considerably different properties to the heartwood. It generally has low durability but can accept preservative treatment. The heartwood is the mature part of the standing tree – an inner zone of dead wood cells. Heartwood is usually darker than sapwood because its contain tannins, phenols and other substances deposited in the cells as they age. These deposits can also inhibit fungal activity and increase durability.

In areas outside the tropics, a tree’s growth rate fluctuates, especially in climates with distinct wet and dry seasons or cold winters. The growth rate is fastest during the wet season or in spring, and virtually ceases during autumn and winter, or in the dry season. These cycles of growth produce rings of wood of different density across the section of a trunk.

Timber is Australia’s major renewable building material. It is light, strong versatile and can be moulded to almost any shape.

Timber is a natural material and the character of the wood changes with the species of the tree, the tree’s age and condition, and the location of the wood in the trunk.

The timber for quality joinery needs straight grained, dry and stable throughout.

It is unnecessarily wasteful to expect all timber to be clear, without feature and an even colour.

Chose the timber species to perform well in the selected application. This may mean several different species are used in one project.

Timber used in joinery needs to be dry. Unseasoned material should not be used.

For further detail, see section Design: Design for durability

Timber quality

Window and door joinery generally requires straight grain timber that is seasoned to a consistent moisture content and stable throughout. If the joinery is to be part of the external envelope, it should also be relatively durable or be treated to be durable

Solid section timber of this type generally comes from relatively large logs of relatively slowly grown trees. Timber from smaller logs of more quickly grown trees tends to be less stable and more variable. It may also be less durable than older, more slowly grown material of the same species. Laminated sections of timber can be suitable for joinery if the sections are stable and the timber is naturally durable, treated to be durable or used internally.

AS 2047 – 1999, applies constraints on the bow, spring and twist of particular elements for windows. The allowable limits are:

Table 20. 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=<2/3w	t>2/3w		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

Moisture content and stability

Windows and doors are fixed into the building envelope and include moving components. Both factors require timber that is stable and likely to remain stable during its full service life. Several service factors affect timber's stability, with moisture content being the most important. Timber is a hygroscopic material: it absorbs and gives up moisture to be in equilibrium with its surrounding environment. As it absorbs moisture, it expands slightly and as it looses moisture, it shrinks slightly. The rate of expansion and contraction varies with the species and direction of the wood fibre. Temperature plays a part in this as it affects the relative humidity of the air and the equilibrium moisture content of the piece.

Generally, timber to be used in a door or window should be fully seasoned with a moisture content complying with Australian Standard 2796 Timber Hardwood - Sawn and milled products or Australian Standard 4785 Timber - Softwood - Sawn and milled products. Both AS 2796 and AS 4785 require a moisture content anywhere in the piece between 9 and 14 %. AS 2047 requires that moisture content of the timber be between 10 and 15 % at the time of fabrication and delivery of the complete assembly.

Ideally, the moisture content should be even throughout the piece. If the inner core is wetter than the outside section, the piece can distort when it is moulded or as it dries out further. Also, the moisture content of all the pieces in the unit should be the same and targeted at the likely moisture content in service. For timber windows and doors built into the external envelope, this is likely to be the range established by AS 2796 and AS 4785. However, if the unit is to be used in an air-conditioned building, the equilibrium moisture content can be as low as 8%. Similarly, units to be used in non-air-conditioned buildings in the tropics may require a higher moisture content.

If the equilibrium moisture content in service is likely to be significantly different to that of the timber during manufacture, the unit should be acclimatised to the final service environment before final assembly and installation. Acclimatisation takes about 3 weeks for unpainted work if the unit is fully exposed to the final service conditions. In service, a door or window where the outside of the unit is continually wetter or dryer than the inside may also tend to bow or distort.

Notwithstanding the moisture content of the timber, the inherent stability of a species of timber is also influenced by a complex combination of the cell structure and grain patterns characteristics. In short, some species are prone to being unstable as surrounding moisture conditions change, even if carefully dried before assembly. There is also evidence that plantation grown material is more prone to movement than more slowly grown native forest material of the same species. Finally, the stability of the timber will be affected by the grain pattern of the piece. Ideally, the grain in the wood should run cleanly along the piece, without major deviations. This is particularly important for moving components, such as sash frames.

The timber has to be stable during its full service life.

The moisture content at assembly is critical to timber stability

For further detail, see
TECHNICAL
Technical Sheet F
Maintaining dry and stable timber

Consistency of species

Timber in different parts of a project will have different performance requirements, with joinery exposed to the exterior requiring greater durability or protection than timber used internally. While timber can be chosen to achieve a particular look or appearance, it is more important that the timber used in the various parts of the project is suitable for its intended function. Issues such as stability, durability, hardness and workability should govern species selection.

Feature and colour

Timber is a natural material that contains features reflecting the life of the tree before it was harvested. Many of these features, such as small tight knots, uneven grain, minor gum vein and colour variation, are part of timber's natural appeal and do not affect the piece's ability to satisfactorily perform its function. Unreasonably excluding this material can increase costs and lead to the irresponsible waste of a valuable resource.

Unless a feature increases instability or decreases durability of a piece, it should be included. Some features, such as hob-nail or small tight gum vein have little or no affect on the performance of the wood and are readily accepted. If the face of appearance of the timber is critical, feature can be confined to concealed surfaces, or areas that are to be filled and painted. Incorporating feature can depend on the intended finish and arrangement of the unit. Units or surfaces that are to be painted can readily include features that do not affect the surface finish or can be filled to not affect the surface. However, some feature can reduce durability and should be excluded. This includes large or loose knots and major gum vein or voids.

AS 2047 – 1999, constrains the feature included in window and the requirements are included in Table 21

Table 21. Feature and characteristics allowed in windows

ELEMENT	ALLOWABLE CHARACTERISTIC
Sashes	Exposed faces and edges are to be free of all knots.
All other timber	Exposed faces and edges are free of loose knot, 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

Natural timber always has some colour variation between or within an individual piece. Again, unreasonable expectation of colour can lead to irresponsible waste of a valuable resource. The colour variation in timber can be moderated by: grouping timber of similar colour together 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.

Properties of major species

The properties of major Australian produced and imported species are included in Table 23 and Table 24

Table 22. Description of timber characteristics

TERM	DESCRIPTION
Name	Common species name
Origin	The region that is the general sources 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.
Density	kg/m^3 of wood seasoned to a moisture content of 12%.
Hardness	Janka hardness to Australian Standard/NZ 1080 Methods of testing timber.
Workability	The stability and general machining characteristics.

For further detail, see
TECHNICAL
Species characteristics

Table 23. Properties of major Australian timbers

NAME	ORIGIN	COLOUR	SUPPLY	FOREST CERTIFICATION	DURABILITY (out of ground contact)	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
Tallowwood	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

For further detail, see
TECHNICAL
Australian Species characteristics

Table 24. Properties of major imported timbers

NAME	ORIGIN	COLOUR	SUPPLY	FOREST CERTIFICATION	DURABILITY (out of ground contact)	DENSITY (Kg/m^3)	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	Canada / USA	Straw to pale brown	Available	Available	4	500	2.7 to 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 a dark blood-red	Available	Occasionally available	2	650	4.7- Moderate	Very good
Silky oak, southern	Pacific	Pinkish brown	Limited availability	Occasionally available		620	3.7	
Surian	SE Asia & Pacific	Light red to red brown	Readily available	Occasionally available	1	480	Very soft	Very good
Western red cedar	Canada / USA	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	Canada / USA	Pale yellow to cream	Available	Available	1	500	2.6 - Soft	Very good

For further detail, see
TECHNICAL
Imported Species characteristics

Timber sizes

Timber is cut from logs and milled into rectangular sections that can be dressed into a finished size or moulded into the desired shape. Generally limited by the size of the logs, the practical maximum size of sawn and milled sections is generally 300 mm wide, 50 mm thick and 4.8 m long. Some pieces to 6 m long are available. Using large sawn section timber requires caution. High quality pieces of large section timber are difficult to get and larger pieces tend to distort. Smaller pieces can be glue laminated into stable large section timber and these are available in widths to 1.8 m, thicknesses to 0.6 m and lengths to 12 m and beyond.

The actual sizes of timber available for window and door components vary with the stage of production and the country of origin of the timber. While timber may be referred to as a particular size (or nominal dimension) when ordering, such as a 100 mm x 50 mm, the piece is generally not exactly that size. The sawn dimension of timber is the size the board is cut to allow it to shrink during production to the nominal dimension. As shrinkage is not always uniform, the board after drying is often marginally larger than the nominal dimension. The machined dimension is the measured size of a piece of timber, once it has been milled to a dressed size.

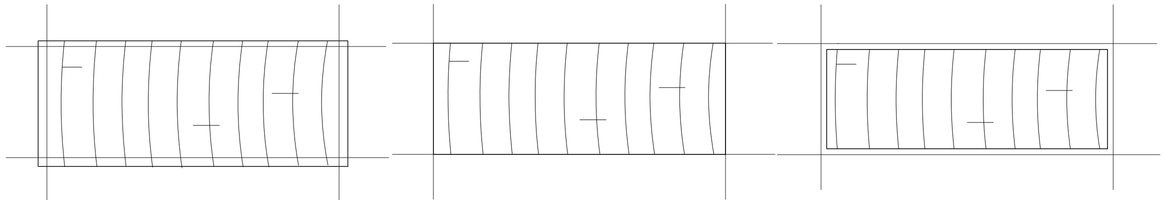


Figure 10. Timber sizing: sawn, nominal, and machined

Standard sizes for Australian produced sawn timber

Timber in Australian is generally milled to metric sizes with nominal thicknesses of 25 mm, 38 mm and 50 mm and nominal widths from 50 mm to 300 mm, generally in increments of 25 mm. Sawn hardwood over 50 mm thick is only sold unseasoned and is unsuitable for window and door construction. Thicker sections of dry Australian hardwoods are glue laminated. The maximum milled component size available from a given nominal thickness and width is shown in the Tables below. Note that the wider the board, the more material may need to be milled off to consistently produce the final machined dimension.

Table 25. Maximum size of timber milled from nominal 38 mm thick Australian timber

NOMINAL THICKNESS	DRESSED
38 mm	31 mm, 32 mm, 33 mm
RANGE OF NOMINAL WIDTH	MAXIMUM COMPONENT SIZE
75 mm	65 mm x 32 mm
125 mm	115 mm x 32 mm
150 mm	135 mm, 136 mm x 31 mm

Table 26. Maximum size of timber milled from nominal 50 mm thick Australian timber

NOMINAL THICKNESS	DRESSED
50 mm	40 mm, 41 mm, 42 mm
RANGE OF NOMINAL WIDTH	MAXIMUM COMPONENT SIZE
100 mm	85 mm x 42 mm
150 mm	135mm, 136 mm x 41 mm
175 mm	165 mm x 40 mm

Standard sizes for North American produced timber.

Timber imported from North American is generally milled to Imperial sizes. The maximum milled component size available from a given nominal thickness and width is shown in the table below.

Table 27. Maximum size of timber milled from standard North American timber sizes	
NOMINAL THICKNESS (mm)	MAX. COMPONENT THICKNESS (mm)
45 mm (1 3/4 ”)	38 mm
50 mm (2 ”)	42 mm
65 mm (2/5 “)	54 mm
75 mm (3 ”)	65 mm
NOMINAL WIDTH	MAXIMUM COMPONENT SIZE
63 mm (2 1/2 “)	54 mm
75 mm (3 “)	65 mm
100 mm (4 ”)	90 mm
125 mm (5 “)	110 mm
150 mm (6 “)	140 mm
200 mm (8 “)	190 mm

Standard size for Australian produced glue laminated timber.

Glue laminated timber is made up of multiple layers of boards milled to exact tolerances. While sizes vary between producers and species, common dressed beam sizes of material are included in the tables below.

Table 28. Common glue laminated beam radiata pine sizes

WIDTH	DEPTH
65 mm	130, 165, 195, 230, 260, 295, 330, 360, 395, 425 mm
85 mm	130, 165, 195, 230, 260, 295, 330, 360, 396, 425, 460+ mm
135 mm	130, 165, 195, 230, 20, 295, 330, 360, 396, 425, 460+ mm

Table 29. Common glue laminated beam hardwood sizes

WIDTH	DEPTH
45 mm	120, 140, 170, 190, 222, 240, 290 mm
65 mm	120, 155, 185, 215, 245, 270, 300, 330, 360, 390, 420, 450, 480 mm
85 mm	120, 155, 185, 215, 245, 270, 300, 330, 360, 390, 420, 450, 480+ mm
135 mm	120, 155, 185, 215, 245, 270, 300, 330, 360, 390, 420, 450, 480+ mm

Sizes will vary with product and process type.

Certification of forest management and timber supply

While timber is recognised for its key environmental qualities as a building material, timber is sourced from forests and the quality of forest management and timber harvesting is a key consideration in determining timber's credentials as a renewable material. One process for assessing the quality and sustainability of forest management is forest certification.

Forest certification assures timber users that the forest practices used to procure the wood meet an agreed standard of operation. It allows companies to differentiate themselves from competitors who may not meet that standard. For companies, certification is fundamentally a commercial marketing choice.

Credible forest certification has two main components: forestry practice is conducted to an agreed and preferably internationally recognised standard; and the practice and the management systems controlling it are accredited as complying with the standard by independent third-party auditors. Certification standards generally include criteria covering: environmental issues, such as water, biodiversity, endangered species, soil quality, storage of CO_2; social and cultural considerations, such as compliance with local laws and recognition of traditional ownership; and economic benefits, such as employment and sustainable supply of timber for society's needs. However, they are not concerned with wood quality and cannot tell us if the wood is fit for any particular purpose.

To be of practical use, forest certification has to be partnered with chain-of-custody certification and the use of exclusive labelling and logos. Chain-of-custody certification provides an auditable trail proving the timber being supplied to a project has come from a certified forest. It is necessary to eliminate the chances of timber from poorly managed forests being substituted for timber from sustainably managed forests. Exclusive labelling also ensures that the timber marketed as certified actually does come from certified forests.

Forest and chain-of-custody certification can also provide 'a significant market competitive advantage in a marketplace which favours materials and products that are sustainable – in their production, application and wider life cycle impacts'. In his report on Australian forest certification, Crawford stated that 'certification for forestry confers significant leadership over other competing industry sectors that impact heavily on our natural environment'.

Forest and chain-of-custody certification are voluntary processes that the forest and wood products industry undertakes in excess of normal legal requirements to assure timber users that the material they are using is responsible sourced. As the processes impose costs on production, they will only be maintained over time if customers demand certified timber and are willing to pay the additional costs.

Certification internationally

Forest certification processes generally operate as international schemes working in particular countries or as national schemes accredited by international organisations. All credible schemes embrace sustainable forest management as a primary goal but there are differences in schemes that can range from the definition of key terms to the approach that underpins the certification process.

The two dominant international certification schemes are the Programme for the Endorsement of Forest Certification Schemes (PEFC) and the Forest Stewardship Council (FSC). Each uses a different approach to certification in individual countries. PEFC operates by examining national certification standards and schemes, and endorsing those that satisfy PEFC requirements and can be marketed under the PEFC logo. By accepted PEFC endorsement, national schemes also agree to recognise other PEFC schemes as reputable certification standards and processes. FSC operates by establishing national organisations that observe FSC processes and principles in framing a local standard. So, while FSC standards and processes tend to align internationally, PEFC endorsed standards tend to reflect the processes and requirement of the country in which they were developed. More information available about these schemes is available at their internet site at: www.pefc.org and www.fsc.org. Other smaller schemes also exist.

Meaningfully comparing international certification schemes can be difficult. Forest certification is a specialist field where apparently large differences in standards or processes may make either very little or significant difference on the ground. Forest certification schemes change regularly as all credible schemes incorporate continuous improvement as a key tenet. A concern about a scheme's processes one year may have been removed the next. Fortunately, the British Government has established a process that assesses international certification schemes against the benchmarks of legality and sustainability. It reports on these assessments through the Central Point of Expertise on Timber Procurement (CPET) at: www.proforest.net/cpet

In June, 2009, the CPET listed both PEFC and FSC as assuring legality and sustainability, where products contain more that 70 % certified or recycled raw material.

Certification in Australia

Both major international forest certification schemes operate in Australia. PEFC has endorsed the Australian Forest Certification Scheme and the Forest Stewardship Council operates in Australia under interim standards from internationally accredited FCS certifying bodies.

The Australian Forest Certification Scheme (AFCS) uses AS 4708 - 2007: Forest Management – Economic, social, environmental and cultural criteria and requirements for wood production (known as The Australian Forestry Standard), as its standard for forest management and AS 4707-2006: Chain of custody for certified wood and forest products, as its standard for chain-of-custody processes. Both standards were developed by Australian Forestry Standard Limited under Standard Association of Australia approved processes. The Forest Stewardship Council in Australia is currently developing a national FSC standard. In the meantime, FSC is certifying forest management in Australia against interim standards developed by the international certification bodies, 'Woodmark' and 'SmartWood'.

Both schemes include the controlled use of labelling and logos that provides consumers with credible information on the origin of forest products and identifies the certified entities involved in their trade. Currently, most productive Australian forests are certified. In June, 2009, the management processes for 9.2 million hectares of Australian forest were certified; 8.7 millions hectares, including most state forestry agencies, under AFSC, and 0.5 million hectares under FSC. 0.25 million hectares had recognition under both schemes. The number of companies with chain-of-custody certification in place is also increasing. Up-to-date information on the certification of forest and production companies under either scheme is available from the AFCS at: www.forestrystandard.org.au, and the FSC at: www.fscaustralia.org.

While there are differences between the two Australian schemes, there are also considerable similarities. Both the FSC and AFS use a similar, three level approach to certifying a forest as sustainably managed. Both use criteria (AFS) or principles (FSC) to establish groups of specific requirements or points of assessment for examination. Both generally require considerable adaptation or improvement to normal commercial processes for compliance. While broadly comparable, the schemes can be quite different. Currently, the AFS scheme takes into account the role of forests in carbon cycles and greenhouse gas emissions. The FSC does not. The FSC precludes the use of genetically modified organisms while the AFS does not. While FSC imposes restriction of specific chemicals, the AFS largely leaves control of chemicals to Australia's national chemical regulator.

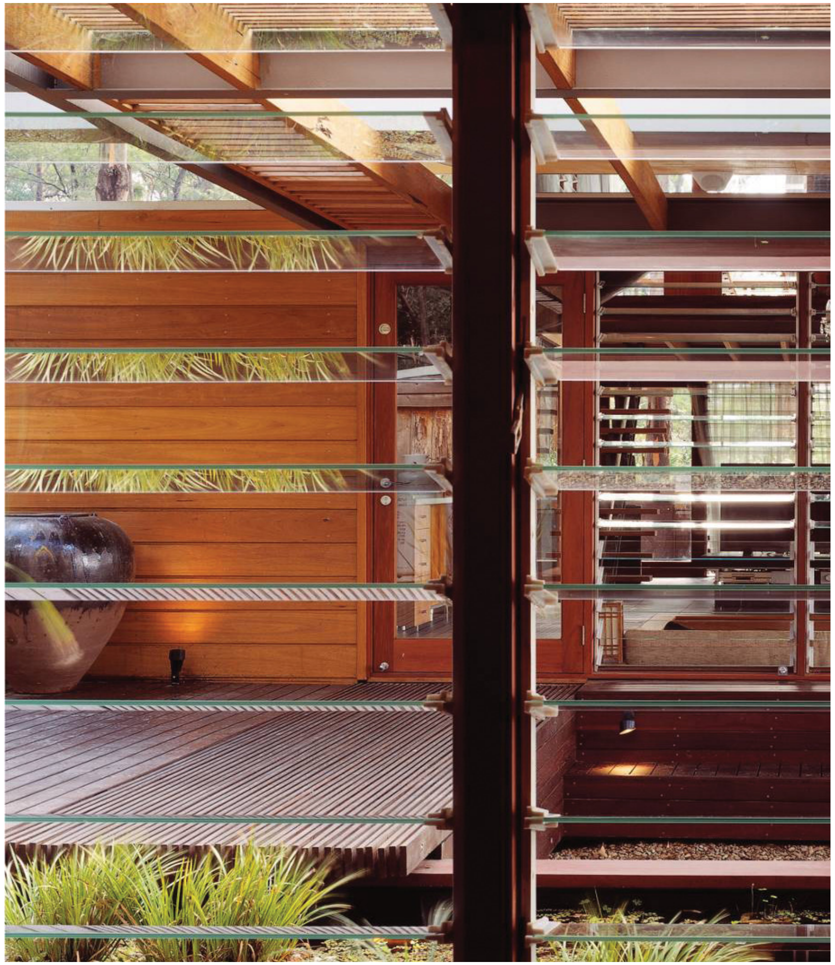
These differences are often highlighted in public discussion but this misses the real point about forest certification. The more fundamental question is if the timber was harvested using forestry practices that comply with a internationally recognised standard or if it wasn't? If the timber is from a certified forest, the specifier can be assured that the environmental impact from its harvest is likely to be less than for timber from an uncertified forest. This is much more important than if the timber is certified by one internationally recognised scheme or another.

information

Glass

Windows and doors incorporate glass to admit light and allow a view of what lies beyond the room or space. The glass in the frame establishes a safe or filtered connection between the internal and external. Glass is an inorganic transparent material generally composed of silica (sand), soda (sodium carbonate), and lime (calcium carbonate) and small amounts of other elements. Unlike timber, glass is a manufactured material and its manufacture can be adjusted to provide particular performance characteristics.

The type and thickness of glass significantly influence the thermal and acoustic performance, safety and security, and the amount of light admitted by the window or door. All glass used in windows and doors in Australia needs to comply with AS 1288-2006. This standard regulates the size and type of glass according to the required structural capacity of the glass and the safety of occupants.



The most commonly used glass in building is 'clear' glass. However, this base material can be modified in a number of ways to reduce the danger clear glass presents after human impact, increase its aesthetic appeal, provide privacy, alter its thermal performance, or change the amount of sunlight that it allows to enter a space.

In Australia, 'clear' glass is usually float glass, formed into sheets by floating the material on a bed of molten metal, and annealed, cooled gradually to reduce residual stress. The resulting glass sheet can be cut and processed easily. Clear glass is commonly available in thickness from 3 to 19 mm.

Safety glass

When it shatters, clear glass can break into dangerous shards. To reduce the risk this can pose to building users, AS 1288-2006, requires that safety glass be used in windows and doors susceptible to human impact. Australian Standard/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 saferty glass.

For further detail, see section Design: Structural adequacy

Laminated glass

Laminated glass usually comprises two or more sheets of glass joined with adhesive inter-layers of transparent plastic. The individual layers of laminated glass break like ordinary glass but do not shatter and disintegrate when broken as they are held together by the inter-layers and generally stays in the glazed unit. In addition to improving safety, the inter-layers can be selected to affect light, solar and especially sound transmission. Normally built up from clear glass, laminated glass can be readily cut and assembled to size locally and can be made up to suit large opening or specific acoustic solutions.

Toughened glass

Toughened glass is material that is re-heated after forming to near melting point, and then suddenly cooled. This sudden surface cooling and shrinkage induces compression and tension layers in the final piece that increases its strength beyond that of typical annealed glass. When shattered, it breaks into small, relatively safe pieces. Fully toughened glass is generally 4 to 5 times stronger than annealed glass of the same thickness. Toughened glass is easier to scratch than normal glass but is generally a lighter option than laminated glass for a given application. Toughening is a specialist process. As the piece cannot be recut after toughening, the pieces have to be fully prepared before treatment.

Labelling

All safety glazing is marked with the appropriate identification to ensure correct, safe installation and permanent traceability.

Obscure and coloured glass

Clear glass is transparent but in applications requiring privacy, light diffusion, or decorative effects, glass can be made obscure by patterning during manufacture, treating the surface or laminating with a translucent inter-layer. Glass can also be coloured.

Patterned glass

Patterned glass is the shaping of the sheet of glass during manufacture so that the one or both sides is impressed or formed to a repetitive pattern. This obscures the transparency of the glass. A wide range of patterned glasses are available.

Surface treatment

Surface treatment is where the surface of the glass is inscribed by sandblasting, acid etching and grinding, or similar process. This reduces clarity through the glass, increases privacy, and can create patterns on the glass surface.

Laminated translucent glass

Laminated translucent glass can be made by laminating clear glass with a translucent core that controls the colour and light characteristic of the finished panel. The design potential of this is really only limited by constraints on the inter-layer.

Coloured glass

Coloured glass is made by including particular ores or pigments into the material during its manufacture. There is a large range of specially coloured glasses available. As the thickness of coloured glass is restricted, they are generally limited to small areas and often included in leadlight panels. To improve safety and security, leadlight panels can be sandwiched between two layers of toughened safety glass.

Thermally improved glass

Clear glass is generally transparent to light - short wave radiation, and opaque to radiated heat – long wave radiation. It is also a poor insulator. As a result, glass can contribute to glare problems inside the building or to buildings overheating during hot days and cooling down too quickly or becoming too cold on cold days. To overcome these problems, the solar access and thermal performance of glass can be modified by applying a coating, colouring the glass, combining sheets of glass into sealed units, or some combination of all three.

Coated glass

Clear glass can be coated with films or membranes that moderate the normal characteristics of the glass. The coating can be made to reflect or transmit light of different wavelengths, altering its visual transmittance, and thermal performance.

Reflective glass is coated to reflect radiation striking the surface of the glass. The reflective coating usually consists of thin metallic layers in various colours (such as silver, gold, bronze). Reflective glass reduces solar radiation through the window, generally blocking more visible light than heat. It reduces the solar heat gain coefficient (SHGC) and greatly reduces visual transmittance and glare inside. SHGC is a measure of how effectively the glass stops solar heat from entering the building.

Low emissivity (Low-E) glass incorporates a special thin coating of metallic oxide that reflects long-wave heat radiation. This can lower the U-factor of the glass and also reduce the SHGC and visual transmittance. The coatings can be positioned to allow short wave solar energy into a building while reflecting heat back into the room, or depending on the climate and site orientation, reflect heat away from the building. A special category of low-e coatings is spectrally selective and is designed to reflect particular wavelengths and be transparent to others. Such coatings are commonly used to reflect heat but admit a high portion of visible light.

Table 30. Performance characteristics of different types of glass.

GLAZING TYPE	VISIBLE LIGHT TRANSMITTANCE	U- VALUE	SHGC
6 mm clear	87 %	5.8	0.81
6.38 laminated	86 %	5.7	0.79
6 mm Low -E	82 %	3.8	0.70
6.38 laminated Low-E	82 %	3.6	0.68
3/12/3; Double Glazed; clear /air/clear	80 %	2.7(air), 2.6(argon)	0.76
4/12/4; Double Glazed; Green tint/air/tint	73 %	2.7(air), 2.5(argon)	0.56
4/12/4; Double Glaze; Clear/air/Low-E clear	74 %	1.9(air), 1.6(argon)	0.69

Source: Viridian Glass

Low maintenance and self-cleaning glass has a micro thin hydrophilic coating of titanium dioxide that encourages water to ‘sheet’ and flow off the surface rather than forming into water spots. In addition, UV rays trigger a reaction in the surface of the glass that destroys any organic material that lands on it. Both reduce maintenance.

Tinted and heat-absorbing glasses

Glass can be coloured with minerals during its manufacture to provide glass with visual and thermal characteristics different to those of clear class. Often, mineral are selected to absorb or reflect specific parts of the light spectrum while having a controlled effect on the transparency of the glass. As they are tinted, the colour extends throughout the thickness of the glass.

Different colour tints produce different effects. Gray and bronze tints tend to reduce the penetration of both visible light and heat into buildings. Blue and green-tinted windows offer greater visible light and heat transmittance.

Insulated glass units

Insulating glass units (or IGUs) are generally two or more sheets of glass separated by sealed air spaces and joined together as a complete unit. The sealed space between the sheets improves the assembly’s resistance to heat transfer and sound transmission.

The size of the spaces between the sheets and the gas used to fill them can also be manipulated to control the unit’s thermal performance, both the heat lost through the window and the energy gained from sunlight. A wider space provides greater insulation than a narrow one and reduces the unit’s U-value. The space can be filled with air, or with inert low-conductance gases such as argon or krypton. These gases have better insulation properties than air and again reduce the unit’s U-value. Also, the glass in the IGU can be coloured or have a low-E coating, further improving its overall performance.

Where safety glazing is required, the IGU can be made from either laminated or toughened glass. While only one side may need to be safety glass, there is a risk of installing the unit the wrong way around. So, safety glass is usually used in both panes. Since safety glass is stronger than annealed glass, it may be possible to use thinner sheets on large windows in order to maintain the maximum cavity width for insulation.

Double glazed units, made from two sheets of glass with an air gap between, were first developed in the late 1960s. Triple glazed units were developed in the 1970s. Both are now common in developed countries, especially in Europe and North America.

Matching older glass

The obscure and coloured glasses commonly found in heritage work are often not available new and if available, the intended applications often do not comply with current safety and performance standards.

Future glass options

Technology with glass is continually improving. Ideally, the glass in windows and doors could be programmable and respond automatically to changes in temperature, humidity and solar heat. Researchers are currently developing ‘smart windows’ that will automatically sense changes and control the amount of heat and light they allow through. Electrochromic glazing is an example that is available in the United States. The concept is an example of biomimicry, where the window has been designed to act as does a biological cell wall, filtering and controlling the flow rate through it. Until these are more widespread, it is necessary to consider each window in its own location on its own merits and accept that windows in different parts of the building will differ in shape, size and specification.

Hardware

To operate efficiently and effectively, timber windows and doors incorporate metal and other hardware. The range of hardware available is diverse but falls into function groups for:

- Moving the joinery, including hinges, friction stays, roller and tracks, and pivots.
- Securing the moving components, including locks, catches, closers, and bolts.
- Handling and restraint, including handles, hooks, knockers, pull and push plates.
- Excluding air and water; including seals and barriers.
- Providing protection and security, including stops, kick-plates, insect screens, and security mesh.

Given the variety of hardware available, this section only deals with the major characteristics of each type.

Hardware is generally differentiated by the capacity of the unit and its quality and sophistication in manufacture and operation. Most load bearing hardware is designed to reliably carry or operate within specific load or capacity limit. If loaded above their limit, the hardware's service life may be significantly reduced or they can fail quickly, especially if the fixing to the wood is overloaded.

Hardware performing similar functions can vary considerably in quality and sophistication. For example, the operating hardware for a sliding window can be extremely simple; the sliding sash can be loosely contained between beads and slide back and forth in a groove in the sill. The handle can be a block of wood, screwed into place. By contrast, the better European sliding window systems include a sliding track and a sealing mechanism that lift the sash partially out of the track and presses it against seals around the frame. They deliver very easy operation with an infiltration performance very similar to a casement window.

Both approaches serve a similar function, allowing a window sash to slide back and forth, but the quality of operation and performance is significantly different. In the end, the architectural intent and the economics of construction drive the selection between these extremes.

For detail on Hardware fixing, see INFORMATION: Installation

Moving the joinery

Hardware is needed to support and locate the moving components of a door or windows unit so that they can operate freely and safely. As these components can be heavy, the ease with which they move is usually directly related to the quality of the hardware used to hang, slide or pivot the unit.

Hinges and other hanging hardware

In many window and door units, such as casement, awning and bi-fold windows and hinged and bi-fold doors, hinges and other hanging hardware supports the weight of the moving components while allowing them to rotate around one edge of the frame. The type and configuration of the hardware controls the path of movement, and the freedom that these elements enjoy in that movement.

Hinges

Hinges are pin joints fixed to the frame and the moving component of a unit, supporting the door or window sash while allowing it to rotate around the fixed edge. As the component pivots around the pin in the hinge, its path of movement and final position can be controlled in part by adjusting the position of the pin relative to the face of the unit. If installed well, hinges allow the moving item to swing freely.

Hinges have to carry the weight of the unit throughout its service life. Their total load-bearing capacity is determined by the capacity of the bearing surfaces of the hinge and the size and number of hinges. The size and number of hinges determines the total area of wood available to take fixings and transfer load reliably into the frame. Timber is a relatively soft material and its capacity to accept point loads without failure is limited. While it can accommodate heavy loads, these have to be spread over a relatively wide area of timber, preferably through a large number of small fixings. Large hinges and thicker sash or door sections assist by providing a larger fixing area and room for an asymmetrical hole layout. This reduces the risk of splitting the wood along a straight line of screw holes.

As the critical load with hinged elements is pull-out load at the top of the unit, extra hinges for large units should be located in this area. For security reasons, hinges on the outside face of exterior joinery should not be loose-pin hinges.

The base material of the hinge determines its durability. Stainless steel is hard compared to other metals, and is highly tarnish and corrosion resistant. Stainless steel hinges can provide long service life, even in exposed location. They are the preferred selection in most high traffic areas, where doors are expected to take a lot of use, and in windows in commercial projects.

Most hinges used in windows and doors are butt or hirline hinges. Butt hinges are simple but highly effective devices with two metal plates (or leaves) that join in the centre around a pin. One leaf of the hinge is rebated and fixed into the frame of the unit while the other is fitted into the edge of the door or window sash. Hirline hinges are similar to a butt hinge but the leaves are shaped so one fits into a cut out in the other, and they sit on the same plane. They do not have the service life or bearing capacity of butt hinges of the same size but they can be surface mounted, and are cheaper to install.

Friction stays

Also known as reflex hinges, friction stays are combinations of metal bars and joints that are fixed between the side of the window sash and the frame and allow the sash to move. The number and location of the bars and joints in the stays determines the path of motion of the sash and the force required to move it. The simplest stays allow the sash to pivot around the top. More complex stays allow the top to slide and move the sash away from the frame, or even allow the sash to completely rotate outside the building.

Friction stays have several advantages over simple hinges. Depending on their operation, they can allow cleaning of the sash and possibly adjacent lights from within the building. The top of the sash often moves down and away from the head of the frame and provides some high-level ventilation. Also, restrictors can be included in the stays to limit the amount the unit can be opened.

Because the stay generally pulls the sash evenly into the frame, consistent compression seals can be located around the rebate of the frame, reducing unwanted infiltration. The friction built into the movement of the stay also means that the sash stays in position without blowing shut or open. However, the capacity of the stay has to match the anticipated weight of the unit.

As friction stays support units part way along the sash frame, they reduce the total load on the unit. They also spread this load more evenly along the styles or rails, rather than concentrating them at hinges. These loads are usually applied across the fixings, rather than as pull out loads, increasing their capacity, reducing the risk of failure due to misuse and protecting the window from forced entry. The hinge is also fully concealed, further protecting it from tampering.

Sliding hardware

Double hung windows slide vertically, while sliding windows and doors slide horizontally. Bi-fold doors, while hinged, can also have a top fixing that slides horizontally along a track.

Double hung windows slide in a frame between timber beads, with the weight of sash taken by either mechanical sash balances or sash weights fixed to the sides of the sash. Built as cylinders with spiral or plain extension arms, mechanical sash balances fit between the sash and the frame in a rebate made in the side of the sash. They fix to the frame near the top of the jamb and to the bottom of the sash and can be tensioned to match the weight of the sash. They operate reliably and are relatively easy to replace.

Sash weights are connected to the sash by cords fixed to each side of the sash and passing over a roller pulley fitted into the side of the frame. The sash weight hangs off the pulley in an enclosure at the side of the window frame. Sash weights are the traditional solution for doublehung windows and they can perform well. However, sash weights have to counterbalance the weight of the sash exactly, or the window will tend to slam shut or sag open. This can create a problem if thicker glass is installed in existing windows. Also, the need to provide an enclosure for the weights reduces the area of glazing and can reduce the thermal performance of the wall overall, as this area can not be easily insulated.

Sliding windows and doors can be hung from a track at the top, or sit on a track at the bottom. Top hung units transfer the weight of the doors or windows through the track onto the lintel over the opening. The track can be fitted immediately above the moving element, such as with a cavity sliding door but is more regularly surface mounted and concealed by a pelmet or other boxing. The bottom of the sliding elements is constrained by guides, leaving the sill and floor plane relatively clear.

Most sliding windows and doors sit on a bottom track. In this type of installation, the bottom of the door or sash is grooved and rollers are rebated into it. These rollers then fit over a track set on the floor or the sill of an external unit. The top of the unit slides along a guide. Predictably, the quality of performance of these units is directly related to the quality of the hardware, and the exposure of the unit. The quality of the bottom track is especially important as it is subject to water, dust and footfall. Weepholes are often included behind the track on external units to drain any water pooling on the sills.

Pivots

Pivot hinges come in two basic arrangements, with or without hydraulic closers. Pivot doors or windows can act like large vertical levering sails that can close with considerable force, especially on the narrower side of the opening. Hydraulic closers in the pivot dampen the movement of the unit and increase its safety.

Securing the items

Windows and doors are only open occasionally. For the remainder of the time, they are closed more or less securely using a combination of locks, latches, catches, and bolts.

There are four major types of locks used in windows and doors.

- Mortice locks are set into a mortice in the cavity of the door. As the operating mechanism is concealed, they are the most discrete type of lock and they come in a wide range of configurations. There are locks for entry and security doors, latch sets for internal doors, and hooked beak locks for securing sliding doors. As they are set into a mortice in the unit, they require skill and time to fit.
- Rim locks are surface mounted locks that are fully exposed on one side of the door. Though economical to buy and easy to fit, they can be intrusive.
- Cylinder locks are a simpler, less expensive form of concealed lock. They fit in a circular hole drilled from one face of the door to the other, and a second hole perpendicular to this from the locking edge.
- Drop bolt locks are fitted to the top or bottom of the door and can be key, unkeyed, or electronically locked. They feature a sliding bolt that extends beyond the door or window into a hole in the frame of surround and secure the unit. They can be morticed, flush mounted or surface mounted. Drop bolts only operate from the inside and are usually used for bifolds, sliders and French doors.

Handling and restraints

Handles, knockers, and pull and push plates provide the most diversity in window and door hardware. As they appear on the face of the unit and are critical to the architectural intent and appreciation of the building, these items provide an avenue for the most imaginative expression. There are few functional constraints on these items, except for the need of the building users to operate the handles. Lever handles are easier to use than round knobs for the elder and young as they require strength to effectively grip and turn.

Excluding air and water

Seals and weatherstripping exclude air and water from entering the building through windows and doors by closing up the gaps between the timber elements. They take a variety of forms but fall into two main groups: weatherstripping and metal strip seals.

Weatherstripping is lengths of foam, rubber, pile or brush filaments that are fixed between the timber component of a door or window to exclude air or water. They can be adhered to the face of the sash, door or frame or set into a groove in the timber. Compressible rubber seals generally provide the best performance but they can only be used effectively when the unit's operations allows one timber element to press against another, such as in a casement window. As these seals grip the surface of the wood when they are compressed, they can't be used with sliding units. Pile and brush striping does not provide the infiltration protection of compressible seals but, as they don't grip the surface, they can be used with sliding units.

Metal strip seals are usually specially designed aluminium extrusion fitted with a flexible sealing insert fitted to the face of the frame, sash or door and stop off the gaps between the timber components as they close. The inserts can be rubber, PVC, polypropylene or other pile, and nylon brush filaments. They are available in a wide variety of arrangement, designed to fit the major window and door types.

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 type and durability of adhesives used varies with the component and its exposure.

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

Timber laminated in the joinery for non-load bearing windows or door frames does not need to meet the same standard and can be glued with adhesives that comply or are at least equivalent in performance with adhesives complying with AS 2754.2: Adhesives for timber and timber products - Polymer emulsion adhesives and achieving 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.

Two glues commonly used in window and door joinery are polyurethanes and PVA emulsions.

- Polyurethanes glues 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 there performance is improving with further research.
- Poly Vinyl Acetate (PVA) is a thermoplastic glue 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.

Finishes

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. There are four major options for finishing timber windows and doors. They can be: left 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 the design intent and flexibility. Windows painted externally can be clear finished internally. Frames can be painted while sashes are left unfinished. Similarly, doors finished with a high-build translucent coating externally may have a softer oil based finish internally.

The selection of an appropriate finish for the location 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.

The expected life of paint or other finishes depends on the quality of the coatings and the care taken in application. The performance of finishes formulations varies between products and brands. For extended durability and service life, only use quality paint or 'high build' stains. The consequences of any breakdown of the finish can be severe.

For further detail, see
Design: Design for durability

For further detail, see
TECHNICAL
Technical Guide 4: Finishes on site

Natural or unfinished

Timber windows and door can be left unfinished, allowing the natural texture and tone of the wood to show through. Unfinished windows and doors may need little maintenance, reducing the environmental impact of coating and subsequent refinishing. However, an unfinished unit will not look continue to look like ‘new’. Over time, the surface of the timber will start to weather, first darkening as moisture mobilises extractives in the wood and then turning grey. This natural, low impact approach has been adopted by architects in Europe, with the joinery and cladding in many award winning contemporary buildings being allowed to grey over time. Architects in Australia have taken a similar approach. Public acceptance of greying timber can be part of the local culture and is gradually being addressed. The main difficulty is the perception that the building no longer looks as it is supposed to. For this reason, in America some recent hardwood clad buildings have been painted with a temporary coat of grey that fades as the wood itself greys.

Care is needed in species selection and detailing for unfinished joinery. Uncoated timber weathers with exposure to sunlight and rain. Turning grey is part of this process. Uneven exposure and wetting can lead to variable staining, bleaching and localised surface mould.

With suitable Durability Class 1 or 2 species in a sheltered or controlled location, unfinished timber can provide an appealing and low maintenance solution, especially for environmentally aware clients. However, poor species selection and detailing or exposing high durability species to aggressive conditions without protection can shorten the service life of the unit and disappoint clients. If the joinery is to be left uncoated, examine a range of timber structures near the project site and note weathering and species performance. Select the species accordingly. Do not use low durability timbers or younger and more unstable species without a coating.

Detail appropriately. As unfinished wood will absorb and lose moisture more readily than finished wood, clearance between opening sashes and the frames can be increased to allow for any moisture induced movement. Where glazing beads are to be left unfinished, glazing seal materials need the capacity to expand into increasing gaps between the glass and bead, or have sufficient flexibility and bond to both the glass and wood. If putty is being used, it needs to be painted. As any incorporated metal will also be more fully exposed to the weather and movement of wood extractives, fixings and hardware should be stainless steel or other corrosion resistant metals.

Joinery units to be left unfinished 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.

Transparent coatings and stains

Transparent coatings and stain mixes protect the timber while allowing the grain and texture of the wood to show through. Coatings suitable for external applications usually combine some or all of preservatives, fungicides, and colorants with an oil that soaks into the wood and a tougher ‘medium’ or high-build’ surface coating. The oil improves appearance and adhesion, which the surface coating protects the timber from occasional wear and tear 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 proper wood treatment.

While these coatings shed water and reduce other impacts, the surface of the wood is still usually exposed to ultraviolet light and can weather over time. The resulting wood breakdown allows the finish to lose adhesion, and crack or peel. Semi-translucent stains which pigment the surface of the wood without necessarily obscuring its natural features can provide better ultra-violet resistance.

Simple oil based coating may contain preservatives and fungicides, but are generally not long lasting in external applications, especially those regularly exposed to sunlight. The oil can also be a ready food source for fungi and cause surface mould. Simple clear varnishes are also 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: 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. While more expensive, they produce less fumes during application and curing.
- Modified oil coatings are clear varnishes, generally made from a mixture of resin and oil. Easy to apply and penetrating, these give a slightly softer look than polyurethanes but are not as hardwearing.
- Oils are penetrating finishes that are generally less hard wearing than the modified oils or polyurethanes. They give a soft, natural appearance but require regular maintenance in high contact areas.

Paint

Paints form an opaque coating over the surface of the wood, generally protecting the timber from water, sunlight and abrasion. Opaque paints are generally applied at higher coating thicknesses than stains and are able to conceal flaws in the surface of wood. As ultra-violet light cannot reach the surface of the timber and break it down, these finishes last much longer than translucent coating.

As the timber slowly expands and contracts with changes in moisture content, the paint needs to be flexible and resist the effects of sunlight that tend to reduce its flexibility over time. When paints become hard and brittle, they can breakdown and flake away from the wood.

Paints are generally applied in a series of coats, usually beginning with a primer that seals the timber and provides a key for further coats. This is followed by possibly an undercoat that builds thickness and then a number of top or finishing coats.

There are two main types of paints generally 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 held to provide a better adhesion to the surface. Older solvent based paints did not have the long-term flexibility of modern systems, and tended to go hard over timber, and crack away from the wood. They also tended to go chalky over time.

Most modern paint coatings for timber are water-based acrylics. Acrylics do not have the chemical emissions commonly associated with solvent-based finished, are easier to apply and clean up, and have a shorter recoat time. Older acrylics were held to form a plastic wrap on the wood, and cause sticking in sashes and doors. They also did not have the durability of contemporary solvent based paints. However, with advances in acrylic technology, acrylics are now the preferred systems for coating external windows and doors. Quality paints, properly applied and maintained, can be long lasting and accommodate moisture induced movement without fissuring or flaking.

Effect of colour

Generally, light coloured paints will last longer and give greater protection to the timber than dark coloured paints. Dark colours absorb and retain heat from sunlight more readily than light colours. This increases the temperature and stresses in the coating and can cause the joinery to warp and shrink. It can also increase the wood's decay rate if moisture is present.

System quality

For extended durability and service life, only quality paints or 'high build' translucent coatings should be used, and then applied strictly to the manufacturer's recommendation. While coating can be of the same type, such as an acrylic primer, their composition and performance can be quite different, and they should not be mixed across brands or systems.

detail and assembly

Timber elements

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

Reflecting this diversity, the detail of the frame and elements can be highly variable. Actual shapes and sizes are determined by a range of influences: the type of unit and their arrangement, aesthetics, the need to contain the glass and durably exclude water, air and sound, and structural requirements, particularly jointing. Approaches to each of these vary from manufacturer to manufacturer but their overall aim will be the same.

Aesthetics

The aesthetics of the window and door reflect the design approach and are expressed through the shape of the unit as a whole, the size of element over structural minimums, the profile of element edges and moulding, the inclusion and form of stops, and the inclusion or profile of architraves. As timber can be moulded to most shapes, the potential for variation is almost endless.

For further detail, see
IN-DETAIL
Window and door types

Containing the glass

Glass in a frame has to be adequately supported and provided with sufficient clearance to allow for movement in the timber frame and expansion or contraction of the timber due to changes in moisture content or of the glass due to changes in temperature. Table 31 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 32 lists the clearance and cover distances required by AS/NZS 4666:2000: Insulating glass units for an IGU.

Note that the required minimum rebate depths do not necessarily allow sufficient depth to install front putty or fix a glazing bead. These are described in the following sections.

Table 31. 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 <0.1m2)	2	2	4	6
3 (panel >0.1m2)	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 32. Clearance cover and rebate depth for IGU			
	FACE AND BACK CLEARANCES (MIN)	EDGE CLEARANCE (MIN)	EDGE COVER (MIN)
Sills	2	6	12
Head and jamb (unit length < 2m)	2	3	12
Head and jamb (unit length > 2m)	2	5	12

Source: AS/NZS 4666:2000

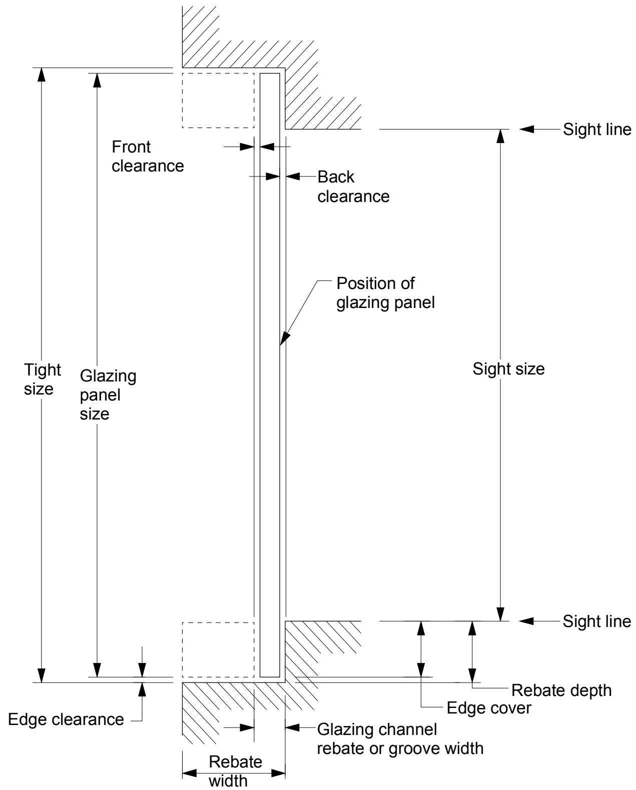
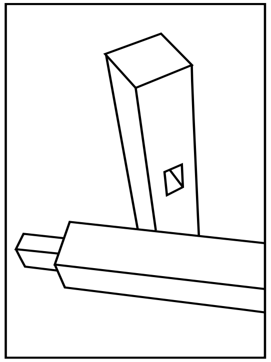


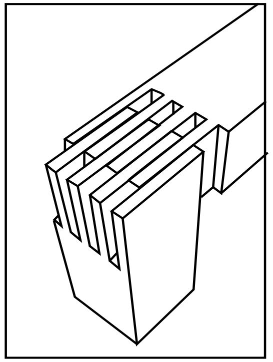
Figure 11. Rebate depth and clearances

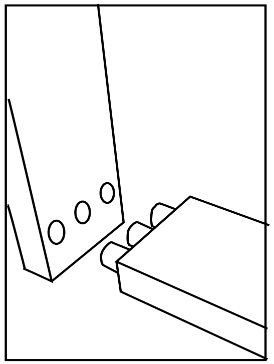
Structural size and jointing

After rebating, the demands of structural adequacy, stability and jointing determine the dimension of the frame and sash elements.

Most manufacturers use a set of standard profiles and element dimensions to build units of particular type and size, developed after long experience with particular species and conditions. Depending on the specialisation and skill levels of the company, many manufacturers will work with architects and specifiers to produce individual frames for specialist projects.







Mortice and tenons

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’ or blind mortice. A ‘through’ mortice goes from one side of the piece to the other, and once assembled, the end of the tenon is visible from the outside face. A ‘blind’ mortice has a enclosed slot that does not go all the way through the piece. To tighten the joint so that the tenon cannot be withdrawn once assembled, wedges can be inserted either around the tenon or the tenon is itself slotted for wedges, and the joint glued.

A variation on the traditional mortice joint is an open slot mortice. This includes at least one slot that goes through the sides and the end of the piece and receives the tenon. In this arrangement, the tenon can pivot when loaded so 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.

Dowels

Dowel joints can also be used to assemble the frame elements. In a dowel joint, matching holes are made in the pieces to be joined and these receive a timber or other dowel. The pieces are then assembled with the dowel glued into place.

Joint selection

Each of these joints has particular advantages and disadvantages. The shoulders on the pieces of the traditional mortice and tenon increase rack 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

Glazing

Glazing is the process of installing glass into the sashes or frame of a window or a leaf of a door. Glass inserted into a timber frame has to be restrained to resist the design load imposed, weatherproof and supported while still allowing for movement, expansion or contraction.

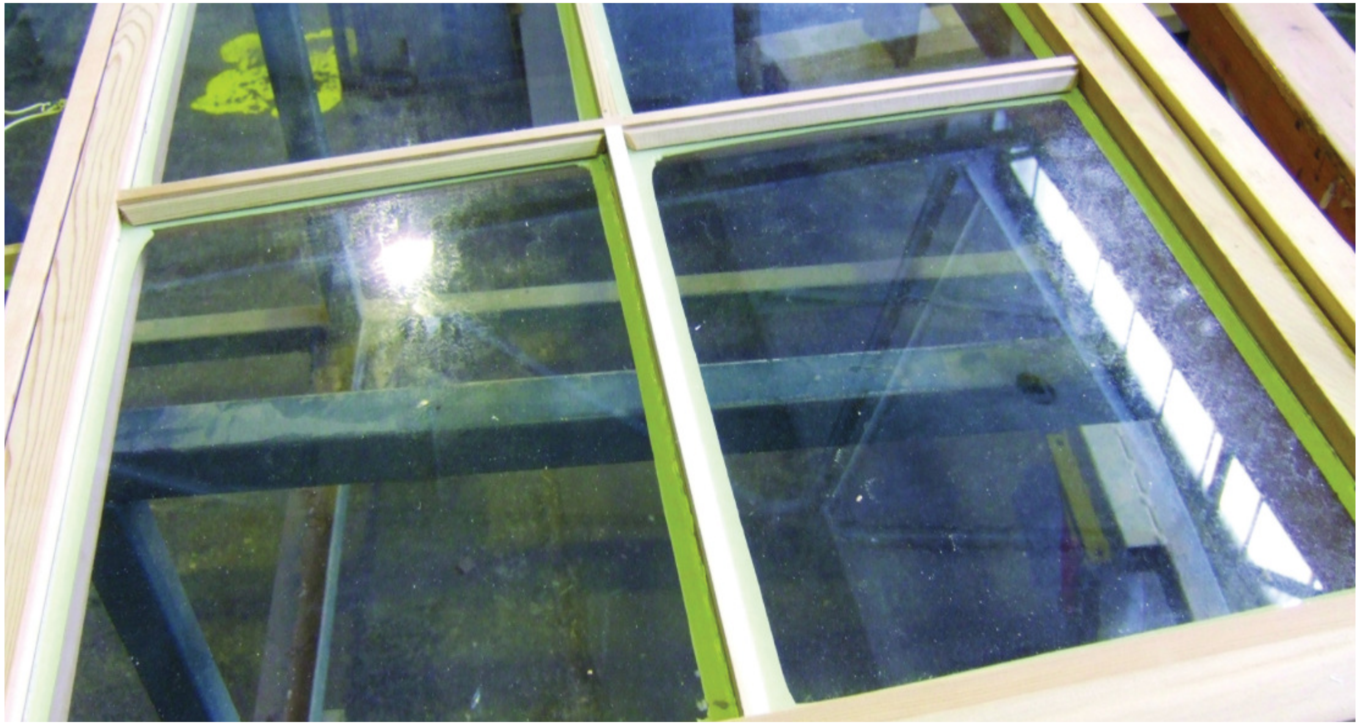
AS 1288-2006 sets out minimum requirement for the installation of single glass into a frame, while AS/NZS 4666:2000 establishes the requirement for IGUs.

Correct installation is critical to the service life of the unit, as incorrect installation can lead to premature failure of the glass, especially 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, covered above, preparing the rebates, installing positioning blocks, and sealing the unit.

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.



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.

Setting blocks are positioned between the bottom of the glass or IGU and the timber frame. These blocks need to be resilient, load-bearing, non-absorbent and rot proof, generally equal to extruded rubber with 80-90 shore-A hardness (AS 1288-2006). Each setting block needs to be a minimum length of 25 mm for each square meter of glass area in the unit, with a minimum length of 50 mm. For single glass installations, the blocks should be positioned at the quarter points of the glass or not less than 150 mm from the corner of the piece. For IGU, the preferred location for the blocks is at the quarter points of the units. The position of the block relative to the glass in shown in Figure 12.

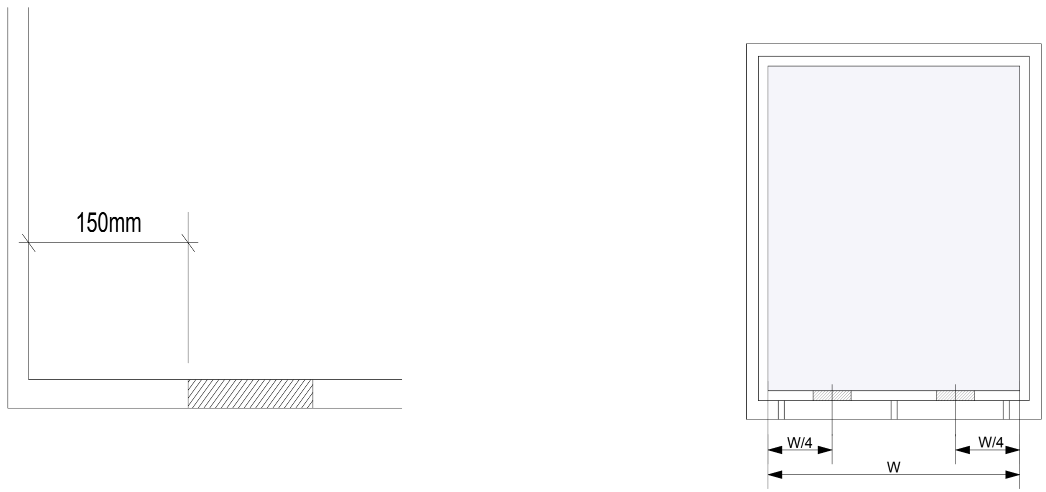


Figure 12. Setting block position

Source: AS 4666, Figure 3.1

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. The position of the blocks for different window and door types is shown in Figure 13.

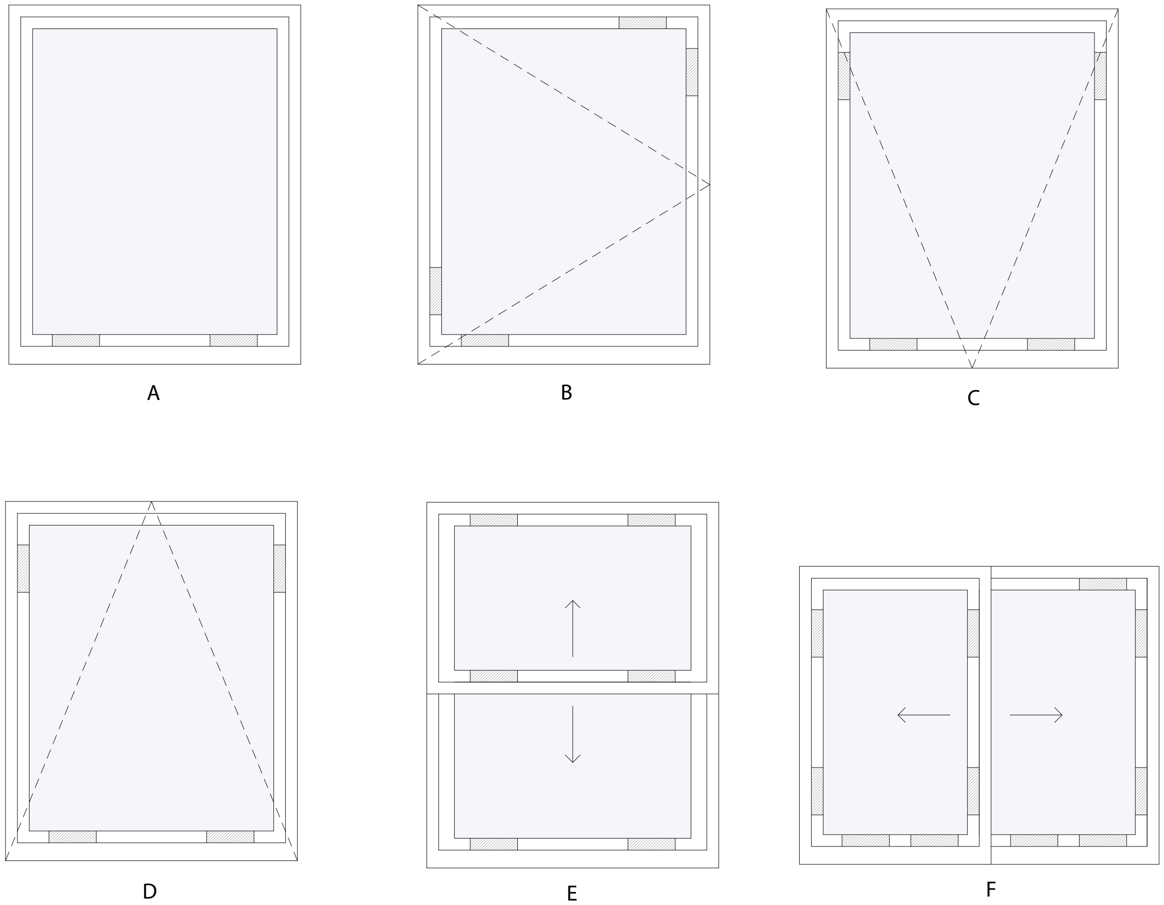


Figure 13. Position of location blocks
(A) Fixed, (B) casement, (C) awning, (D) hopper, (E) double hung, (F) sliding.

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.

Silicon 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 reglazing 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 atleast 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 weepholes.

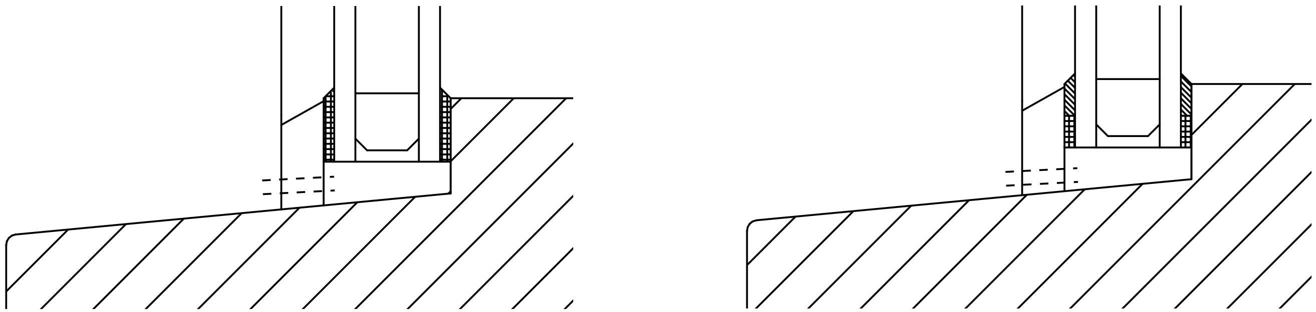


Figure 14. Full silicone (A) and glazing tape (B) methods.

Glass and sash thickness

The thickness of the selected glass or IGU influences the depth of rebates and importantly the thickness of the timber selected from window and door sashes.

Timber window and door sashes can accommodate glass of different thickness and IGUs. There only real limit to this is the thickness of timber that can be glue laminated. Common sash sizes will accommodate standard glass and common IGU sizes: 42 mm thick timber will generally accommodate glass to 16 mm thick; 54 mm accommodate 28 mm glass and 65 mm timber 38 mm glass.

Glazing sealants and tapes

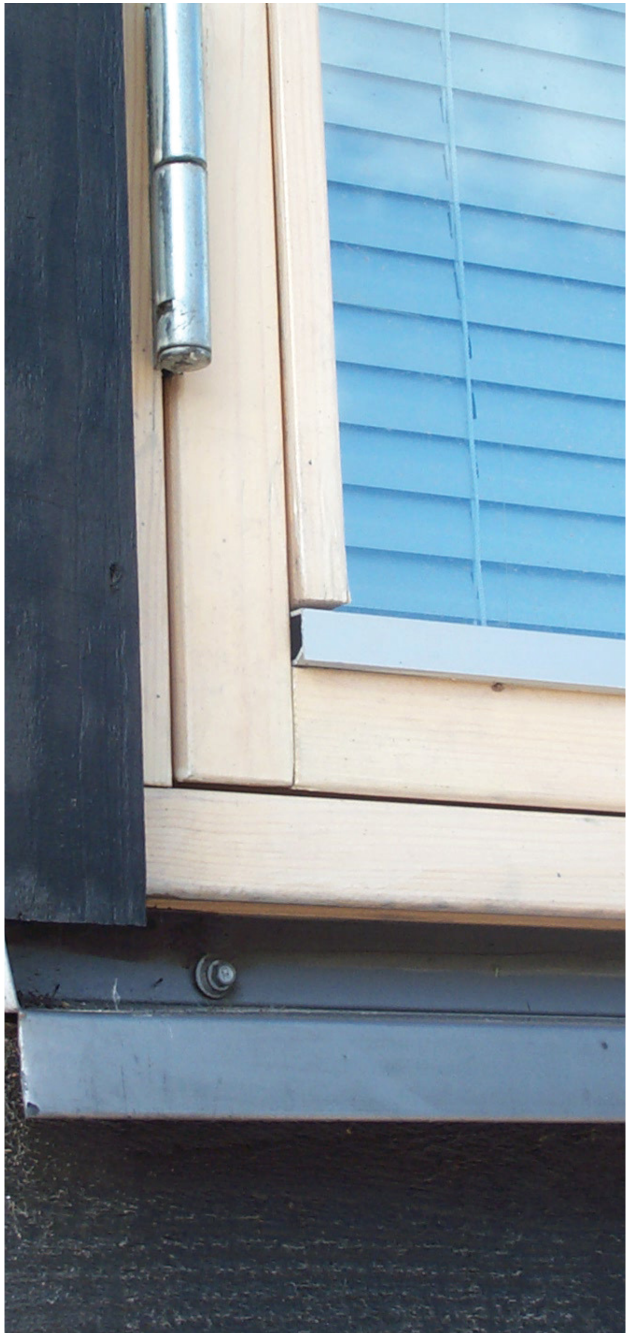
Glazing tapes are compressible, generally butyl adhesive tapes that are applied around the faces of the glass before it is installed in the rebate. Once the backing film is removed, the glass can be fitted into the frame. The tape adheres to the face of the rebate, and to the glazing bead when they are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

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

Glazing putty

Traditionally, linseed oil putty was used for glazing almost all external joinery. Modified oil and synthetic resin putty is also available as an alternative. These putties can be used with or without glazing beads. If used without glazing beads, the glass needs to be retrained 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. Linseed oil is very attractive, while soft, 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 8 weeks. Putty is used as standard for curved work. However, it should not be used with laminated glass as it can attack the inter-layer of laminated glass and lead to delamination. It is not suitable for glazing IGUs. It is not recommended for use with heat absorbing glass, and should be painted in all external applications, so is unsuitable for units with external timber stain or clear finishes.



Where to finish

Coating systems are often designed to be applied on-site or in the factory, or solely in the factory. Like any chemical coating application, painting timber windows and doors requires control of: the preparation of the substrate; the order and application rate of the coatings; the curing time between coating; the temperature of the surrounding environment during curing; and protection of the finished item, at least 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 voiding warranties. Extended delay in applying a top coats can lead to a deterioration of the primer. Temperatures and dust contamination can be hard to control, and the finished unit damaged while the coating is still soft and vulnerable.

Painting 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.

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As individual manufacturers have particular skills, it is important to match the manufacturer's capabilities to your project requirements.

Working with manufacturers from the start of the design process, rather than towards the end, opens up opportunities created by the synergy of skills.

procurement

Working with Australian manufacturers

Manufacturers of timber window frames in Australia work independently, with skills and technology on site that has developed in response to the customer needs in the area, and the availability of expertise. In designing and specifying window and door frames, particularly for innovative commercial work, it is essential to take a concurrent engineering approach and work with the manufacturers from the start of the design process rather than delivering a finalised design to them without thorough formative consultation.

Different timber window manufacturers have different capabilities, so it is important to find the manufacturer that is best suited to be your partner for each particular project. Many manufacturers will work to produce individual frames for specialist projects. Collaboration with the manufacturer at the earliest point in the project is most likely to achieve the design intent and can open up possibilities.

Composite frames, such as aluminium-clad wood provide new options to maximise the properties of different materials within a product, and research into finishes has produced more effective, longer lasting finishes for solid wood and wood composite frames. Window design guidelines have changed with the development of new windows technologies that improve performance, most significantly with glass and glass coatings, but also with improvements in the design of double and triple insulated glazing units. Similarly, the restrictions that used to be placed in the size of timber window frames are being lifted. Frame construction is no longer dependent on the length of timber available and its ability to remain rigid over a long length, but can be made to any length, and also any shape, and still retain its stiffness through the use of engineered wood products. The detail and quality of profiling capability will also vary between manufacturers, with some manufacturers specialising in heritage profiles and have the capability and timber supply to provide large sections of shaped timber. Again, check the capabilities and specialist areas of different manufactures for different jobs.

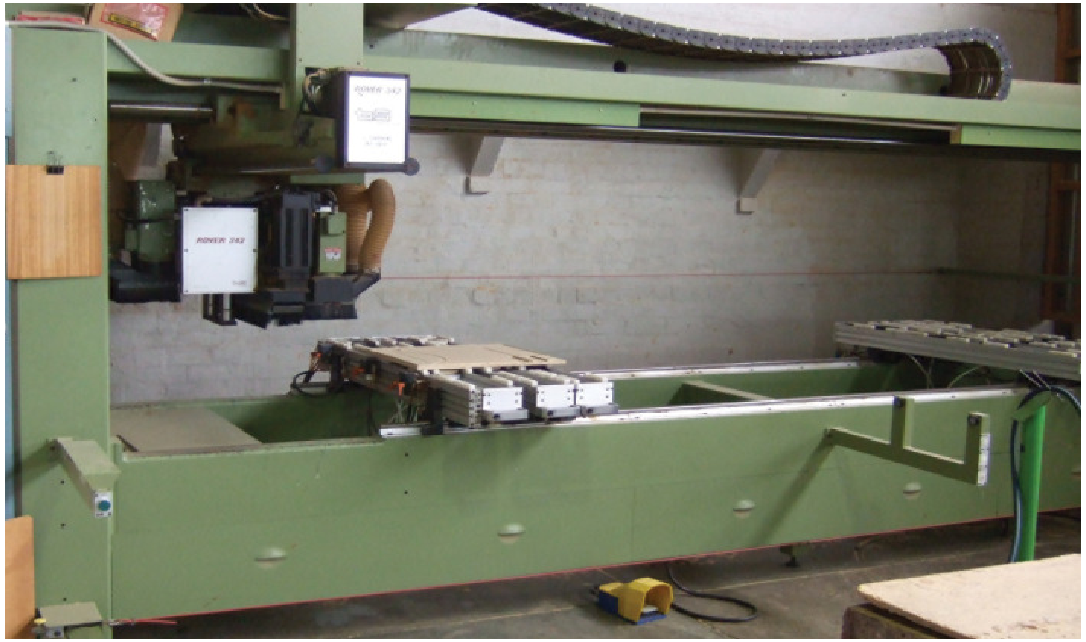
Coping with technical changes

The building industry in Australia is undergoing many changes in construction and built practice. Awareness of energy efficient and thermal performance in the built environment is increasing and regulatory requirements are coming into effect. Timber window and door manufacture will need to adopt new technologies and systems to stay current. Specifications that meet the requirements today will not necessarily meet the performance requirements in the next few years. Design and specification will need to be kept current and informed by changes in policy and technologies.

In the same way, technical innovations from overseas can inform production and use here. New techniques being used in Europe, Scandinavia, the Baltic States, America and Canada that are being applied to timber windows and timber components need to be adapted for use in Australian building construction and practice as they offer up new possibilities of assembly, durability and performance.

The adoption of new regulations and certification practices by the timber industry will see changes to the availability of certain species in Australia. Our current timber supply will change. The imported timber used freely at the moment may not be so readily available, and the Australian timber supply will evolve too. Different plantation timbers will become the predominantly available supply as the changes to access to native forest are implemented. These timber species will have different characteristics to those manufacturers are currently used to, as the trees will tend to be younger and may have to be used in different ways.

In coping with these changes in the wood resource, the wood products industry will be moving towards more use of engineered wood products. Glue laminated and pre-assembled products will become more widespread. The concept that large timber windows and door components will still be made out of single, solid long lengths will become outdated.



Specifications that meet the requirements today will not necessarily meet the performance requirements in the next few years.

Australian timber supplies will become more important as the impact of transportation on environmental credentials becomes an issue.

During transportation the windows will need to be protected from distortion and damage. This may necessitate the design of bespoke storage containers that will keep the panels separate and upright, particularly if the products are travelling overseas.

installation

Delivery and storage

Transportation and delivery are major considerations during the design of windows and doors, especially for large units. Being valuable joinery units, correct delivery and handling is essential but can affect the cost of the windows and doors significantly. Specialised transport for sizes larger than normal needs to be costed and checked for availability. During transportation the windows will need to be protected from distortion and damage. This may require the design of special storage containers that will keep the panels separate and upright, particularly if the products are travelling overseas.

The delivery schedule can affect the choice of finish. To avoid construction delays, windows are generally delivered before they are needed for installation. However, storage on site for any period can lead to the finish on the units being damaged. Frames that are finished in the factory tend to be of a higher quality and should be stored in the factory for delivery only when the installers are ready. If long site storage is likely to be the case, finishing on site may be the most appropriate option. However, finishing on site requires control of the finishing conditions and site trades who understand the importance of the coating to the unit's service life.

To store the frames on site, a well ventilated, dry, secure area must be prepared where the frames are protected from the 'wet' trades working on the building and therefore protected from variation in moisture. On-site security is a further consideration.

For more details, see
TECHNICAL
Technical Guide 1: Transporting windows
Technical Guide 2: Storage on site
Technical Guide 4: Finishes on site

Installation

Timber windows and doors are an integrated part of the building's fabric, especially when included in the external envelope. Architecturally, they form the connection between the internal spaces of the buildings and the surrounding environment, allowing light and air into buildings. Functionally, they play vital roles in a building's environmental control, excluding water, providing ventilation; controlling air-infiltration and sound, and contributing to the building's thermal performance.

Installation practice needs to ensure that the units can perform these functions as designed and the integrity and performance of the building envelope is maintained at the junction between units and the building's envelope. Poor installation practice creates points of vulnerability in terms of thermal performance, infiltration, moisture ingress and security.

The major considerations in any installation program include:

- Ensuring the windows and doors are non-load bearing but transfer applied loads to the supporting frame. In turn, this frame has to be designed to carry the loads without undue deflection.
- Providing a tolerance for movement and settlement in the opening to receive the unit. This needs to be sufficient to allow for deflection, settlement or shrinkage in the surrounding structure without distorting or imposing loads on the frame.
- Maintaining the weather-resistant barrier from the building envelope to the unit. Any water that does enter needs to be able to drain away without entering the 'dry' side of the moisture barrier. This requires: preparation of the sarking layer to receive the joinery unit; flashing between the joinery unit and the sarking and the outside cladding or finish; and sealing between the joinery unit and supporting frame.

To prevent water entering the 'dry' side of the water barrier around the joinery frame, flashings are needed at the head, sill and jambs of the opening. Incorporating storm beads or sealing the external cladding to the unit are inadequate on their own right as they inevitably fail and water will 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.

Fixing should be durable and sufficient to transfer the required load while not distorting the frames. Generally only the sides of the unit are fixed to the frame. Head fixing should be installed so that they provide lateral support but not vertical loads.

To prevent air infiltration and thermal bridging, the gap between the unit and wall frame should be fullly sealed. The outside face of the gap between the unit and the surrounding frame has to be sealed and the space between the joinery and wall frame insulated.

Window and door openings create points of vulnerability for security, infiltration and the building's thermal performance. Installation practice is critical.

Window and door frames are generally not structural elements.

A continuous seal between building envelope and the window frames needs to be established.

For detailed information see
TECHNICAL
Technical Sheet A Installation

maintenance

Timber windows and doors form a vital and expensive part of any building and deserve regular maintenance. This increases their service life and enhances the building's amenity. Maintenance includes cleaning and minor repair, occasional recoating, and timely upgrading of components.

Cleaning

To limit deterioration, cleaning should be factored into the project management plan for the building. The windows, doors and glass should be washed 2 or 3 times a year and any built up dirt and grime removed. In coastal or high pollution area, washing may need to be more frequent. Tracks for sliding windows and doors and any weep holes should be cleaned and any build-up removed. 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.

Regular minor maintenance

Regular minor maintenance is required. The hardware and moving parts should be lubricated regularly, especially in coastal or high pollution areas. Seals should be in place and performing efficiently. Compression seals become less efficient with age and exposure.

The coating or paint finish should be inspected regularly. If it shows sign of failure, plan to maintain it. Also, the timber frame should be inspected regularly. 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. Insulated glass units (IGU) should be inspected regularly for condensations. Expect to replace them if they fail as the seals in insulated glass units have a limited life and cannot be repaired. Poorly performing hardware is a nuisance and can cause further damage to the unit. They can easily be replaced.

Finishes and coatings

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 bare wood is exposed as a poorly maintained paint film can accelerate decay. Expected service life of the major coatings systems are given in Table 33.

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

Glass and glazing

Glasses with special surface coatings may require particular care. Toughened glass scratches easily. Also, insulating, low-e or heat reflective glasses may have special coatings that require specific maintenance. Check with supplier. It may not be possible to replace broken glass. Both silicone sealing and security glazing tapes probably have sufficient adhesion to make removal difficult without damaging the frame. Replacing the sash may be necessary.

Timber elements

Gaps in joints or around the beading can allow water to enter, encouraging corrosion and decay. These gaps need to be carefully cleaned out and repaired. Repair decayed or damaged timber by cutting back the affected timber and patching. Where the timber has deteriorated and joints have decayed, the repair of the timber element could require re-fitting parts of the frame that are beyond a simple handyman task. Discuss replacement with a suitable joiner.

Table 33. 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 (b)	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(c)	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

a) This table is a compilation of data from the observations of many researchers.

b) Using top quality acrylic latex paints.

c) With or without added preservatives. Addition of preservative helps control mildew and mould growth.

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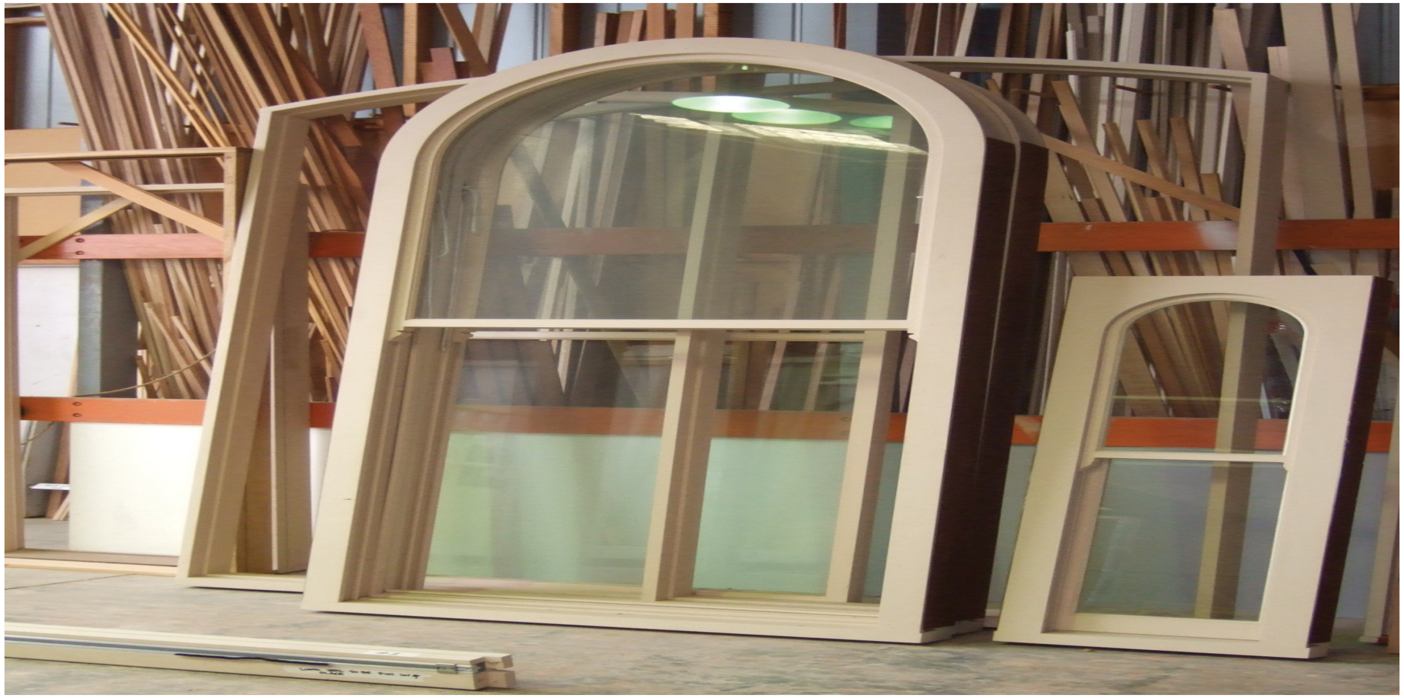
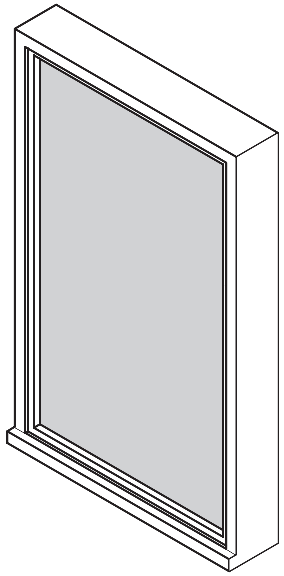
in - detail



- ☑ Provides light and view
- ☑ Economic
- ☑ Weather proof
- ☑ Air tight
- ☑ Secure
- ☑ Suitable for high wind areas

Windows

Fixed glass or light



DESCRIPTION

A fixed pane of glass held in a wood frame. The glass can be set directly into the outside window frame, or into a fixed sash, known as fixed light, in the frame.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial, industrial and high rise.

GLAZING TYPE

Single, laminated and multiple glazed units.

GENERIC PERFORMANCE

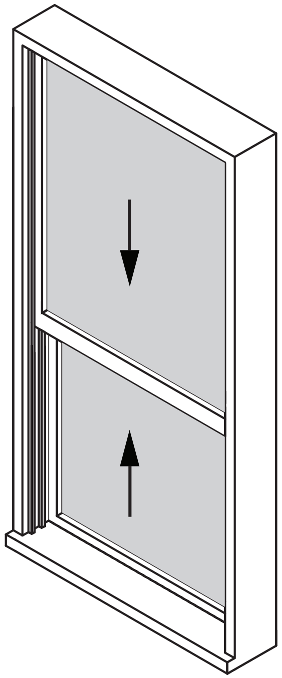
These windows provide no ventilation, have no air-infiltration and are weather-tight. Their thermal performance is determined by the glazing. Cleaning requires access to both sides.

RELATIVE COST

Inexpensive

Nb. Drawings are not to scale and are Indicative only

Double hung windows



DESCRIPTION

Two vertically sliding sashes which slide past each other in a single frame. The weight of the sashes is taken by either mechanical balances or counterweights hung through pullies on either side of each sash pair.

They can also be arranged so that only one sash moves over a fixed sash or glass.

SUITABILITY BY BUILDING TYPE

Residential, apartments, and commercial.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

In addition to sash fasters and lifts, mechanical balances or counterweight are used. The capacity of mechanical balances limits sash size while counterweights can accommodate larger units. Mechanical balances can fail but their replacement is relatively simple.

GENERIC PERFORMANCE

A traditional and heritage window form, quality double hung windows perform well with relative little maintenance. They are watertight, but have high air infiltration as they are hard to make air-tight. They are easy to screen externally and to secure. Sashes generally have to be removed to be repainted and then re-fitted.

They are glazed externally. Only half the window area can be opened and cleaning requires access inside and out.

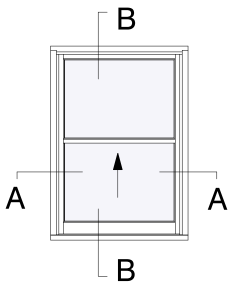
RELATIVE COST

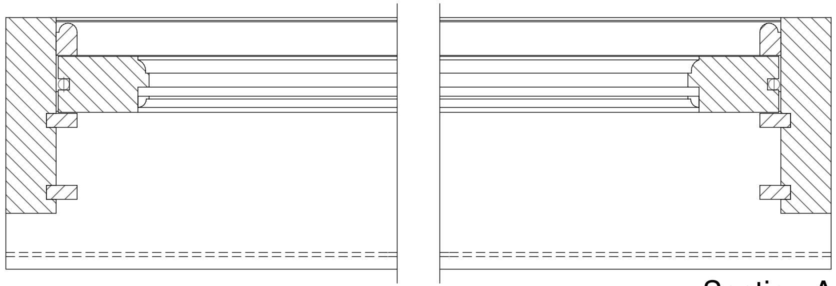
Economical with conventional mechanical balances. Traditional weights and pullies are relatively expensive.

- ☑ Provides light and view
- ☑ Economic with conventional mechanical balances
- ☑ Easy to operate
- ☑ Good ventilation
- ☑ Weather proof
- ☑ Secure

Nb. Drawings are not to scale and are Indicative only

W2. EXAMPLE OF DOUBLE HUNG WINDOW





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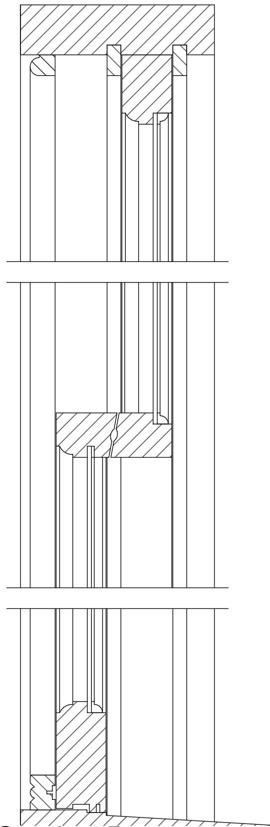

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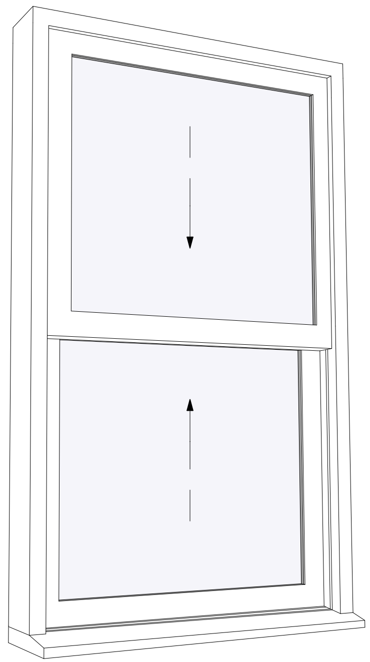

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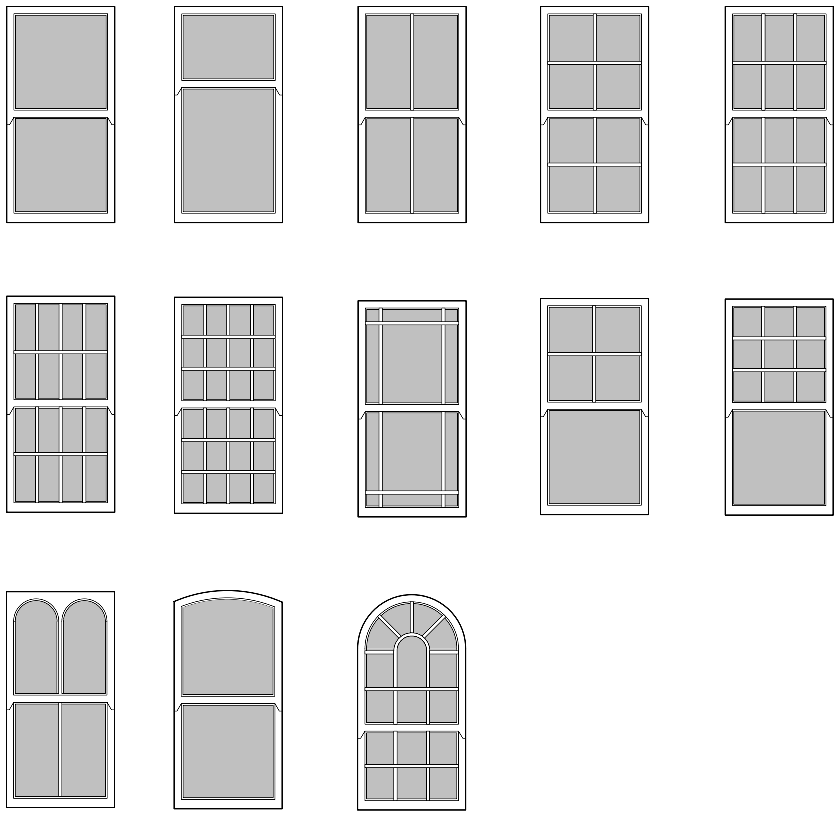
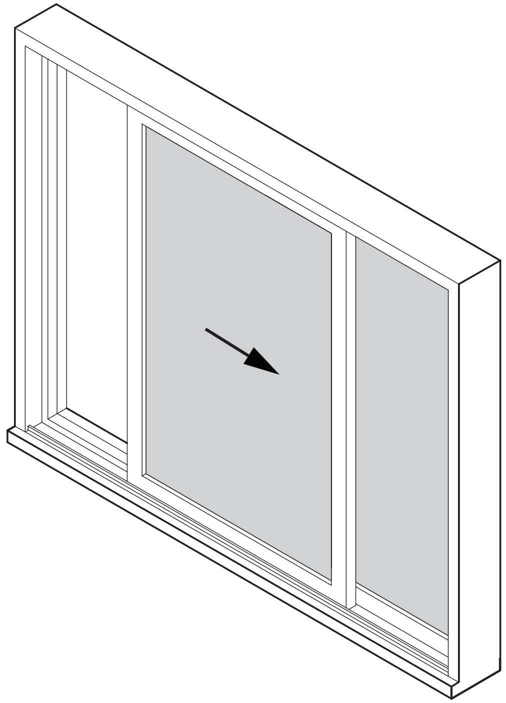
W2. DOUBLE HUNG WINDOWS - STYLE EXAMPLES



Nb. Drawings are not to scale and are Indicative only

- Provides light and view
- Economic
- Easy to operate
- Good ventilation
- Weather proof
- Secure

Sliding windows



DESCRIPTION

Two or more panels which slide past each other horizontally within the frame. Several leaves can also slide past each other to stack to one side of the opening. Bifold windows permit wider obstruction-free openings than sliding and, as their weight can be carried on a bottom roller, do not need heavy lintels. Top-hung sliders are also available.

Sliding windows are easy to open and permit a wide obstruction-free opening. Top-hung sliding windows are also available. Sliding windows are suitable for large openings but if they have multiple sliding sashes, these have to be stacked in the frame, increasing the depth of the frame and reducing the overall opening size. To shed water efficiently, the opening sash should slide outside the fixed sashes.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial and industrial.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

Performance is dependant on the quality of the roller and track system used for bottom roller units. Stainless steel rollers and tracks or brass tracks of the right capacity for the unit generally require little maintenance. Windows can also be hung on an overhead track. As with bi-folds, tracks and lintels need to be designed to carry the required loads. Latches and pulls are also required.

GENERIC PERFORMANCE

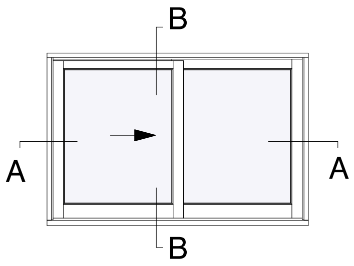
Maintenance requirements are generally low. They are generally less weatherproof than hinged windows, especially under the sashes. Harder to seal between each sash, they allow greater uncontrolled air-infiltration. They are not the preferred option for high wind areas unless high performance hardware is used. Only a portion of the opening is available for ventilation, and cleaning requires access to both sides.

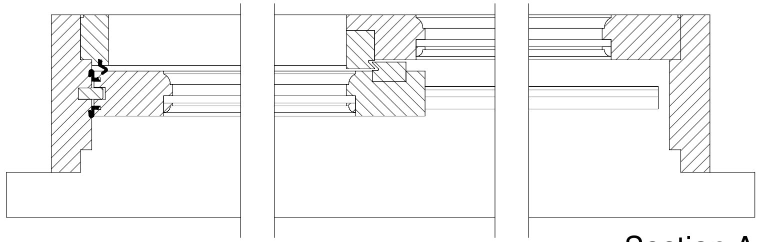
RELATIVE COST

Relatively inexpensive for the size of opening provided, especially bottom roller systems.

Nb. Drawings are not to scale and are Indicative only

W3. EXAMPLE OF SLIDING WINDOW





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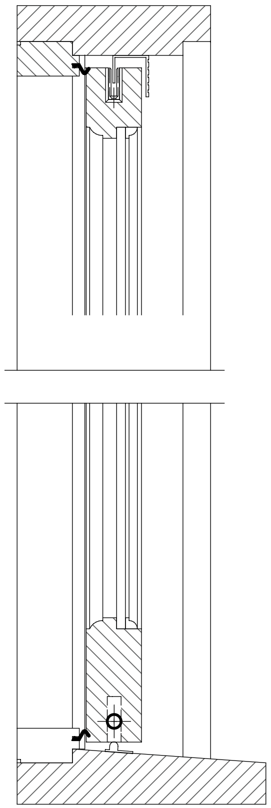

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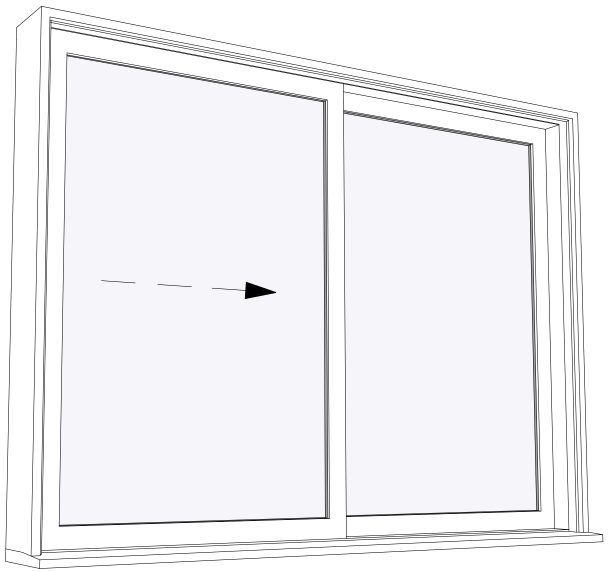

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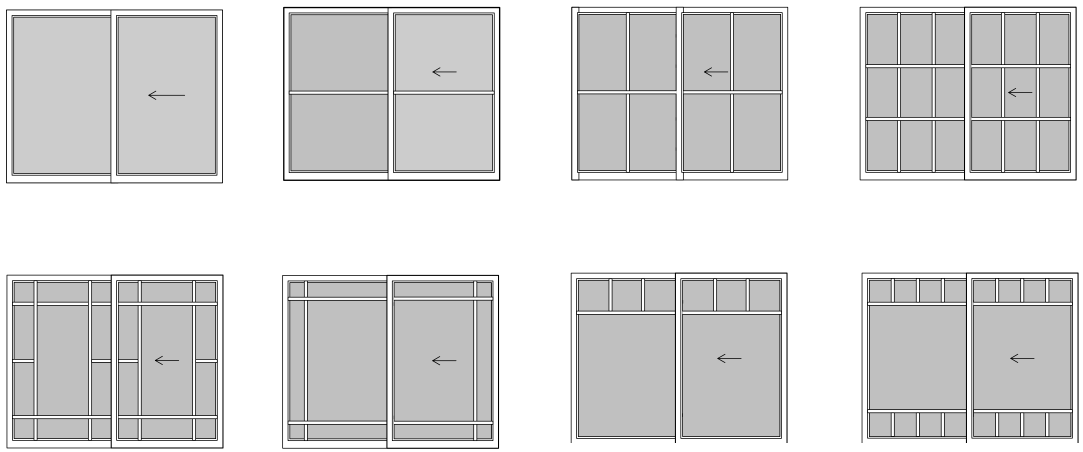
W3. SLIDING WINDOWS - EXAMPLES



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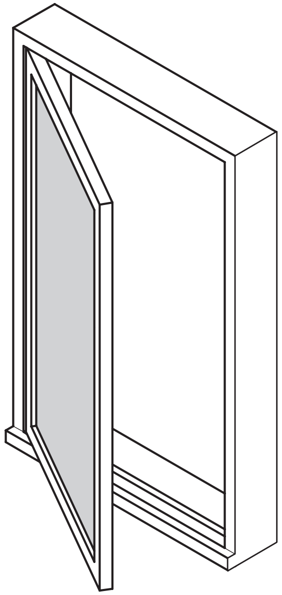
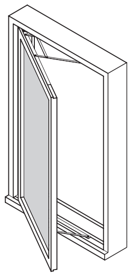
Casement windows





DESCRIPTION

Sashes hung along a vertical edge of a frame with hinges or friction stays. They generally open out but can open in. Screening and security can only be fitted internally.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial, industrial and high rise.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

In addition to friction stays, hinges and latches, casements can also be operated with automatic or manual chain winders, operating arms or lever operators. Compression seals are regularly included between the sashes and the frame.

GENERIC PERFORMANCE

The entire window space can be opened to maximise ventilation and both sides can be cleaned internally. Size is limited by the capacity of hinges and stays.

Casements are completely waterproof and very air-tight when a mullion is fitted between each sash, as the windows can be closed tightly onto compression seals. Central joins, with one sash rebated over the over, reduce weathering capability considerably.

A separate frame is recommended for each sash in high wind areas.

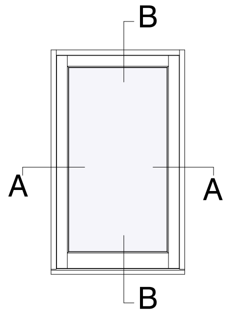
RELATIVE COST

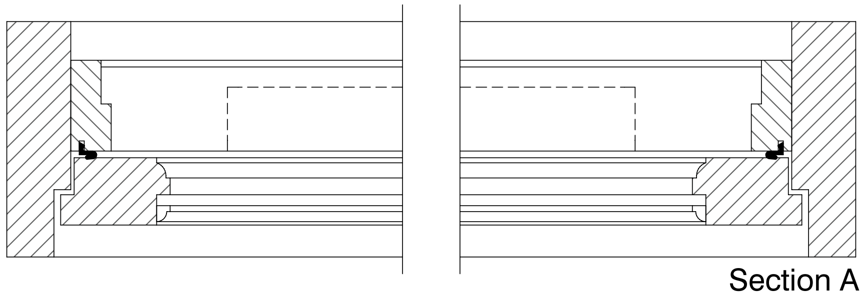
Economical.

- ☑ Provides light and view
- ☑ Economic
- ☑ Easy to operate
- ☑ Easy to clean
- ☑ Good ventilation
- ☑ Weather proof
- ☑ Air tight
- ☑ Secure
- ☑ Suitable for high wind areas

Nb. Drawings are not to scale and are Indicative only

W4. EXAMPLE OF CASEMENT WINDOW





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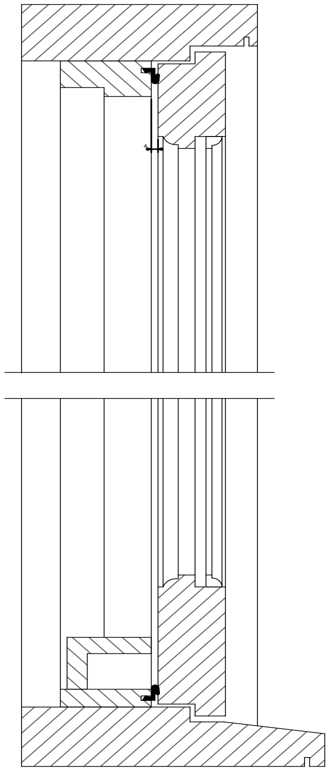

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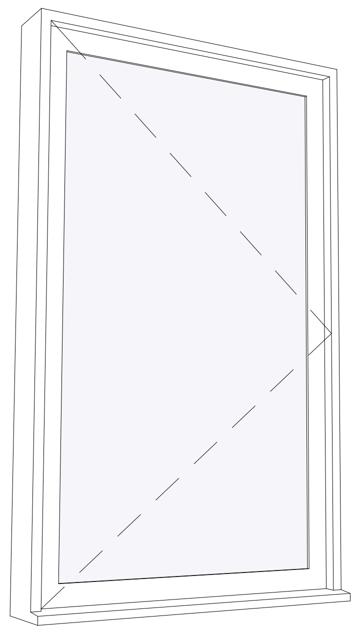

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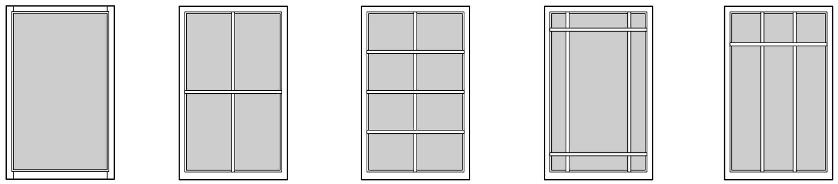
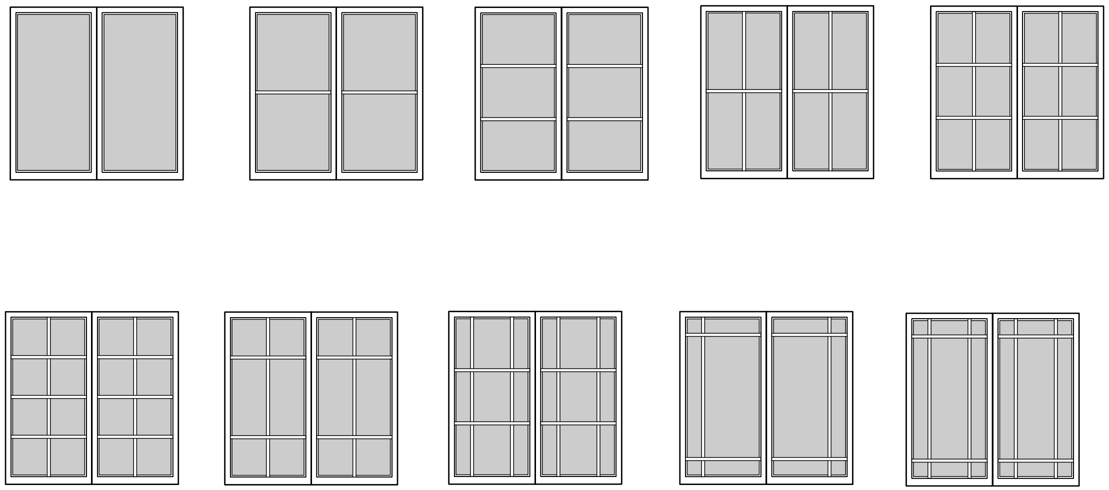
EXAMPLE OF CASEMENT WINDOW - SINGLE



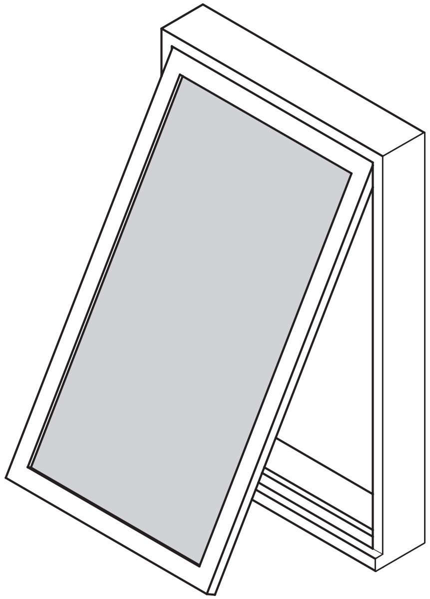
EXAMPLE OF CASEMENT WINDOW - DOUBLE

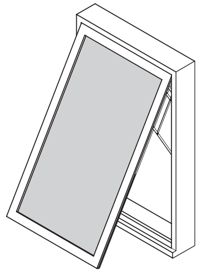


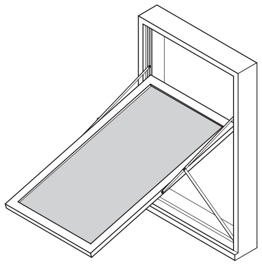
Nb. Drawings are not to scale and are Indicative only

- Provides light and view
- Economic
- Easy to operate
- Easy to clean
- Good ventilation
- Weather proof
- Air tight
- Secure
- Suitable for high wind areas

Awning windows







DESCRIPTION

Sashes hung usually along the top edge of a frame with hinges and struts or along the sides with friction stays. Some stays allow complete reversal of the window. Screening and security can only be fitted internally.

Awnings with hinges or stays at the base of the sash are called hopper windows.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial, industrial and high rise.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

In addition to friction stays, hinges and latches, awnings can also be operated with automatic or manual chain winders, operating arms or lever operators. Compression seals are regularly included between the sashes and the frame.

GENERIC PERFORMANCE

The entire window space can be opened to maximise ventilation and both sides can be cleaned internally. Size is limited by the capacity of hinges and stays.

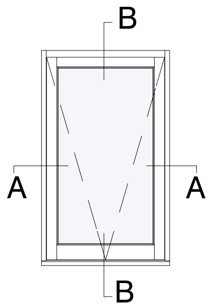
Awnings are completely waterproof and very air-tight with a transom fitted between each sash, as the windows can be closed tightly onto compression seals. Like casements, intermediate joins, with one sash rebated over the over, reduce weathering capability considerably. A separate frame is recommended for each sash in high wind areas.

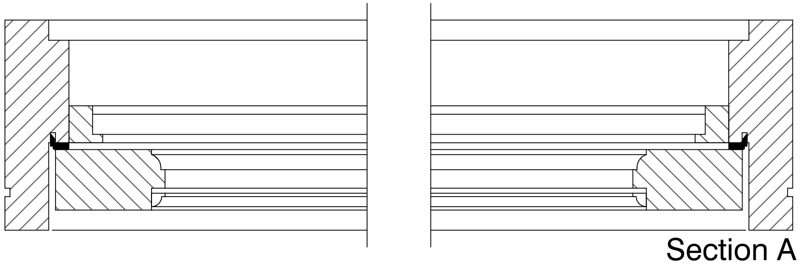
RELATIVE COST

Economical.

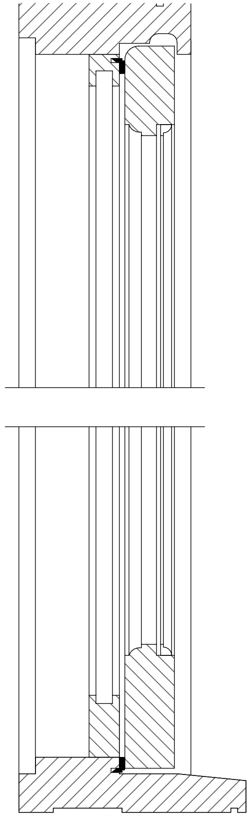
Nb. Drawings are not to scale and are Indicative only

W5. EXAMPLE OF AWNING WINDOW

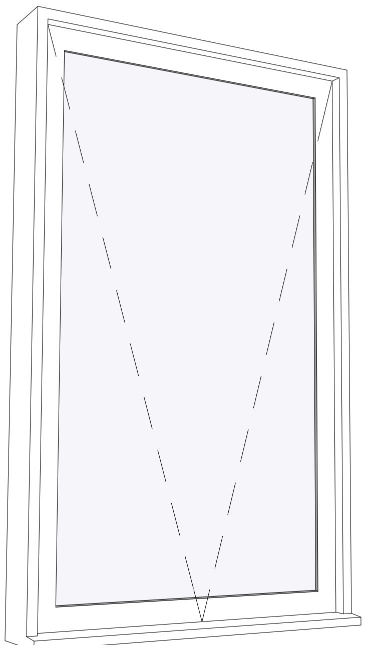




Section A



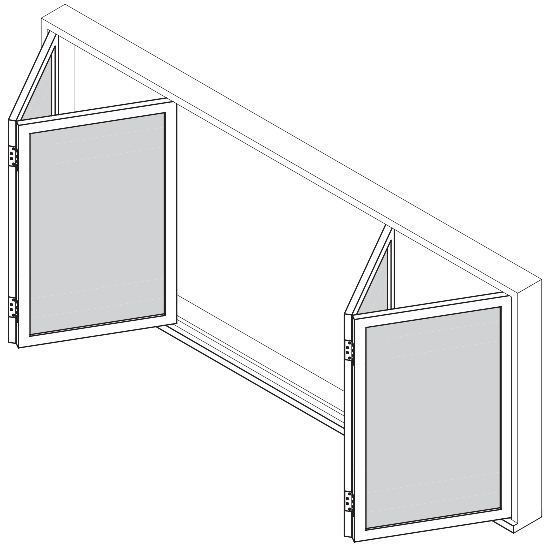
Section B



Nb. Drawings are not to scale and are Indicative only

- ✓ Provides light and view
- ✓ Good ventilation
- ✓ Weather proof
- ✓ Secure

Bi-fold windows



DESCRIPTION

Two or more window sashes 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 sashes per side, hung without a track. While cheaper, trackless installations are less reliable than tracked units as they sag over time. Trackless installations are considered poor practice and not recommended.

SUITABILITY BY BUILDING TYPE

Residential, apartments, and commercial.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

Fully supported overhead track. Quality track units can carry a sash up to 75 kg and 900 mm wide with higher capacity units are available. The need for a lintel to carry the windows can complicate renovation projects.

GENERIC PERFORMANCE

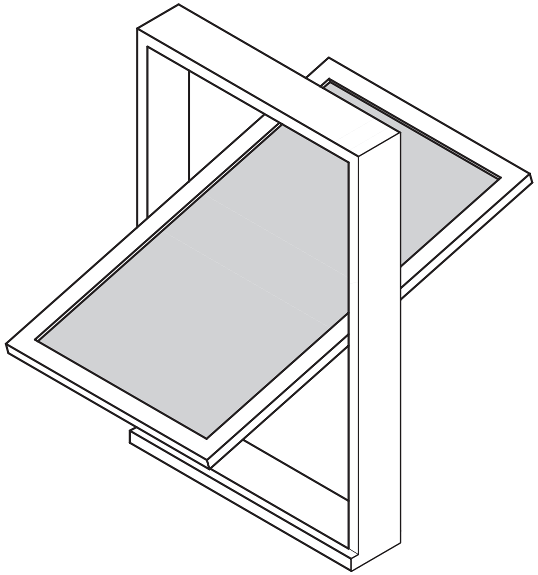
A full width opening though while open in this position, the bi-folds are not weather tight. Access to both sides is needed for cleaning. The operation of multiple bolts is needed to open or close the window fully and the units require regular maintenance. They are difficult to screen in large sizes.

RELATIVE COST

High cost, requiring considerable installation skill on site.

Nb. Drawings are not to scale and are Indicative only

Pivot windows



DESCRIPTION

Pivot windows rotate on pivot hinges in either the horizontal or vertical plane. The pivot line can be central to the sash or can be off-set.

SUITABILITY BY BUILDING TYPE

Residential, apartments, and commercial.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

Pivots are concealed in the base and head of the window or the surrounding structure. Depending on the type of hinge used, pivots can also be operated with automatic or manual chain winders, operating arms or lever operators.

GENERIC PERFORMANCE

The entire window space can be opened to maximise ventilation and both sides can be cleaned internally. Size is limited by the capacity of hinges.

Weather stopping can be difficult as the stripping is broken at the pivot point.

RELATIVE COST

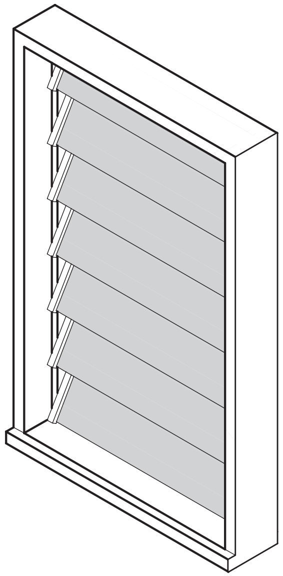
Relatively expensive.

- ☑ Provides light and view
- ☑ Easy to operate
- ☑ Easy to clean
- ☑ Good ventilation
- ☑ Secure

Nb. Drawings are not to scale and are Indicative only

- Provides light and view
- Economic
- Easy to operate
- Easy to clean
- Good ventilation

Louvre windows



DESCRIPTION

A set of glass, timber or aluminium blades arranged horizontally across the frame. Fixed louvres can be housed at each end into the frame. Moveable louvres are fit into mechanical louvre galleries. The blades' angle of inclination is adjustable to allow more or less light or air into the enclosure. The width of louvres is limited by the spanning capacity of the glass.

Louvres are difficult to secure. They can be screened internally or externally but the screen has to be kept clear of the opening blades.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial, and light industrial.

GLAZING TYPE

Single and laminated glass.

HARDWARE REQUIREMENTS

The operable galleries come in multiples of a fixed louvre size, generally 102 mm or 152 mm. They can be fitted with automatically actuators in hard to access locations.

GENERIC PERFORMANCE

The entire window area is open for ventilation and can be cleaned from the inside. They are suitable for light exposure conditions and, difficult to seal, have high air infiltration. Maintenance is generally low.

The width is limited by the capacity of the louvre, usually to 900 mm wide for 152 mm louvres and 750 mm for 102 blades.

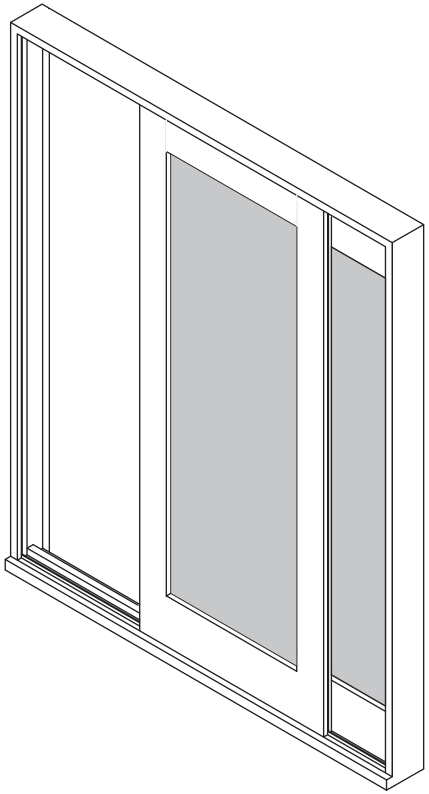
RELATIVE COST

Can be expensive due to the hardware required and separate louvres.

Nb. Drawings are not to scale and are Indicative only

Doors

Sliding doors



DESCRIPTION

Two or more panels which slide past each other horizontally within the frame. Several leaves can also slide past each other to stack to one side of the opening. Sliding doors weight can be carried on the bottom roller, they do not need heavy lintels. Top hung face mounted or cavity sliders are also available.

They are suitable for large openings but the sliding leaves have to be stacked in the door frame, reducing the overall opening size. Also, the more doors 'stacking' to one side, the wider the frame needed. To shed water efficiently, the openings leaves should slide outside the fixed leaves.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial, and industrial.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

Performance can be dependant on the quality of the roller and track system used for bottom roller units. Doors can also be hung on an overhead rail. As with bi-folds, this and the supporting lintel need to be designed to carry the required loads.

GENERIC PERFORMANCE

Maintenance requirements are generally low. They are generally less weatherproof than hinged doors. Harder to seal between each leaf, they allow greater uncontrolled air-infiltration.

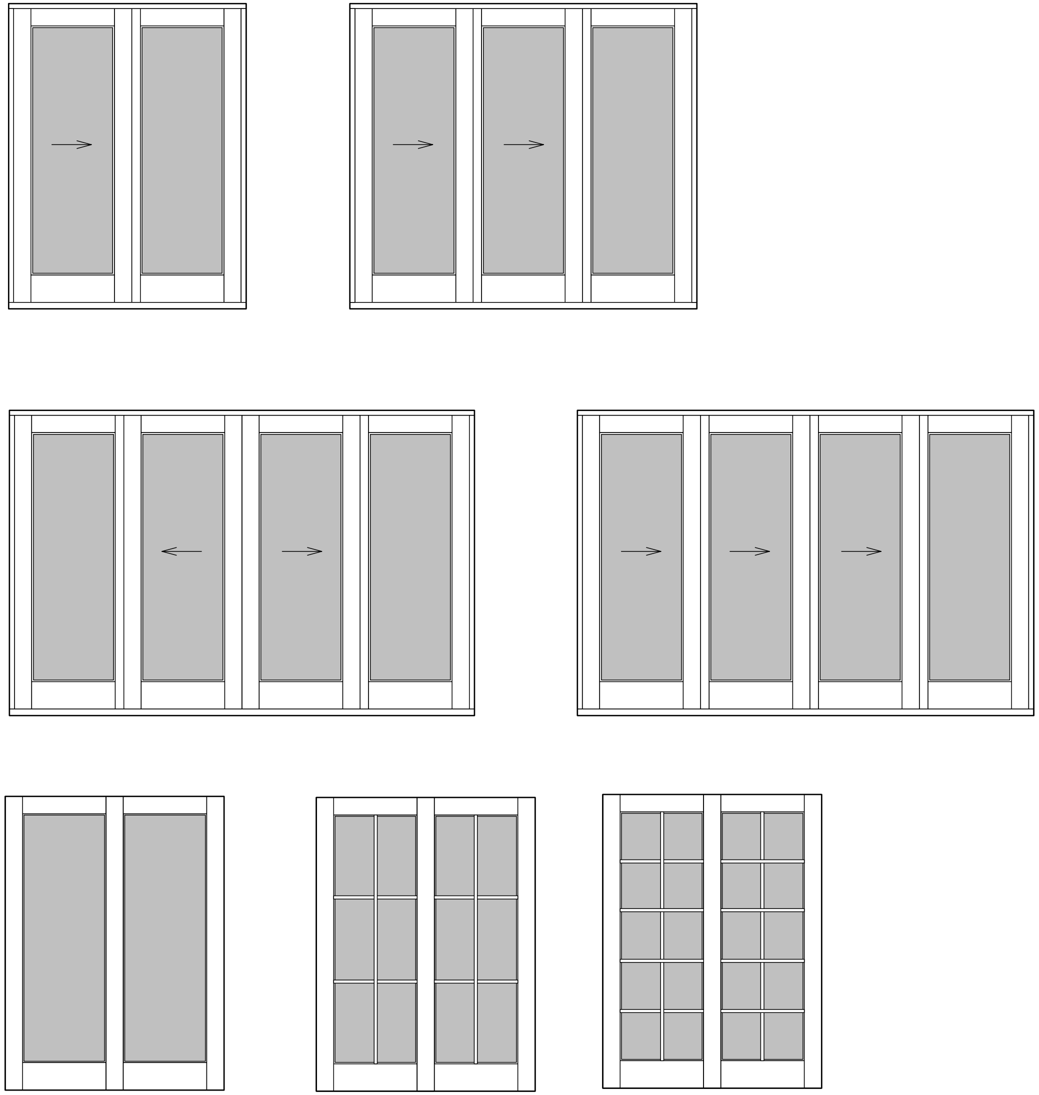
RELATIVE COST

Relatively inexpensive for the size of opening provided, especially bottom roller systems.

- ☑ Provides light and view
- ☑ Economic
- ☑ Easy to operate
- ☑ Easy to clean
- ☑ Good ventilation
- ☑ Weather proof
- ☑ Air tight
- ☑ Secure

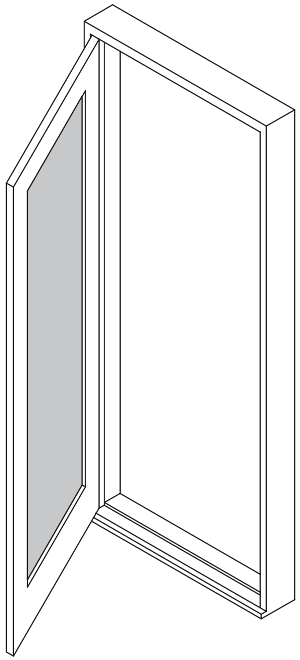
Nb. Drawings are not to scale and are Indicative only

EXAMPLE OF DOORS - SLIDING



Nb. Drawings are not to scale and are Indicative only

Hinged doors



DESCRIPTION

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

Door sizes are generally standardized to a minimum of 2040 mm high, with widths of 620 mm, 720 mm, 770 mm, 820 mm 870mm and 920mm. Other sizes can be made.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial, industrial and high rise.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

Hinges and latching.

GENERIC PERFORMANCE

Doors only provide ventilation when open. They are generally paired with a screen door or doors, which open in the other direction. Security screens can also be fitted. They seal well and can be fully weatherproof if they open out. Inward opening doors require a bottom door seal.

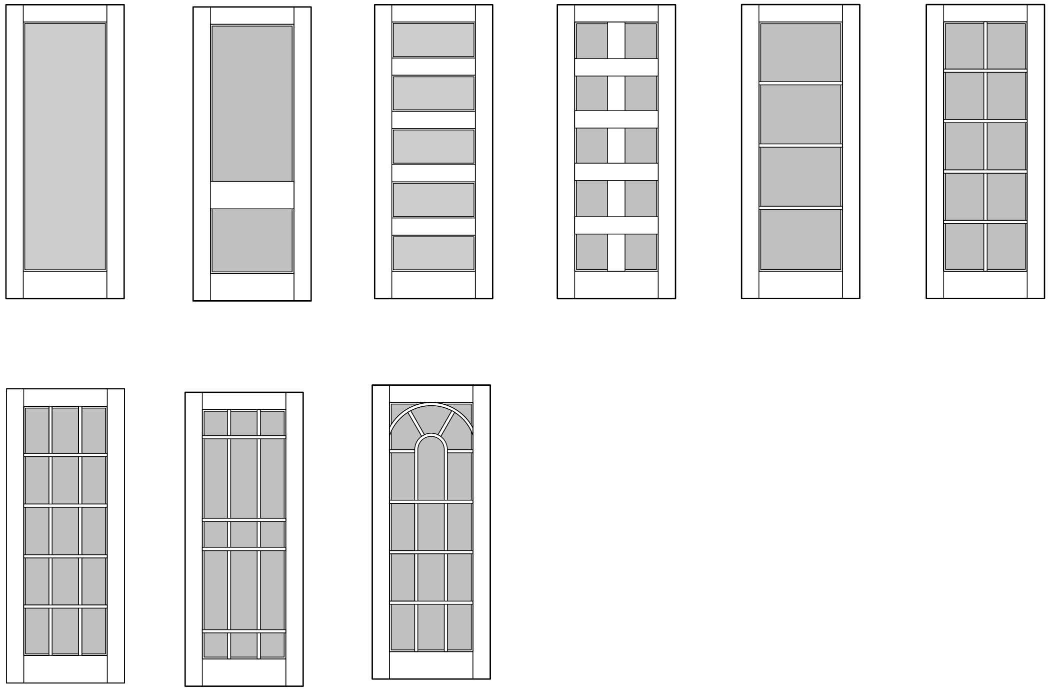
RELATIVE COST

Economical.

- ☑ Provides light and view
- ☑ Economic
- ☑ Easy to operate
- ☑ Easy to clean
- ☑ Good ventilation
- ☑ Weather proof
- ☑ Air tight
- ☑ Secure
- ☑ Suitable for high wind areas

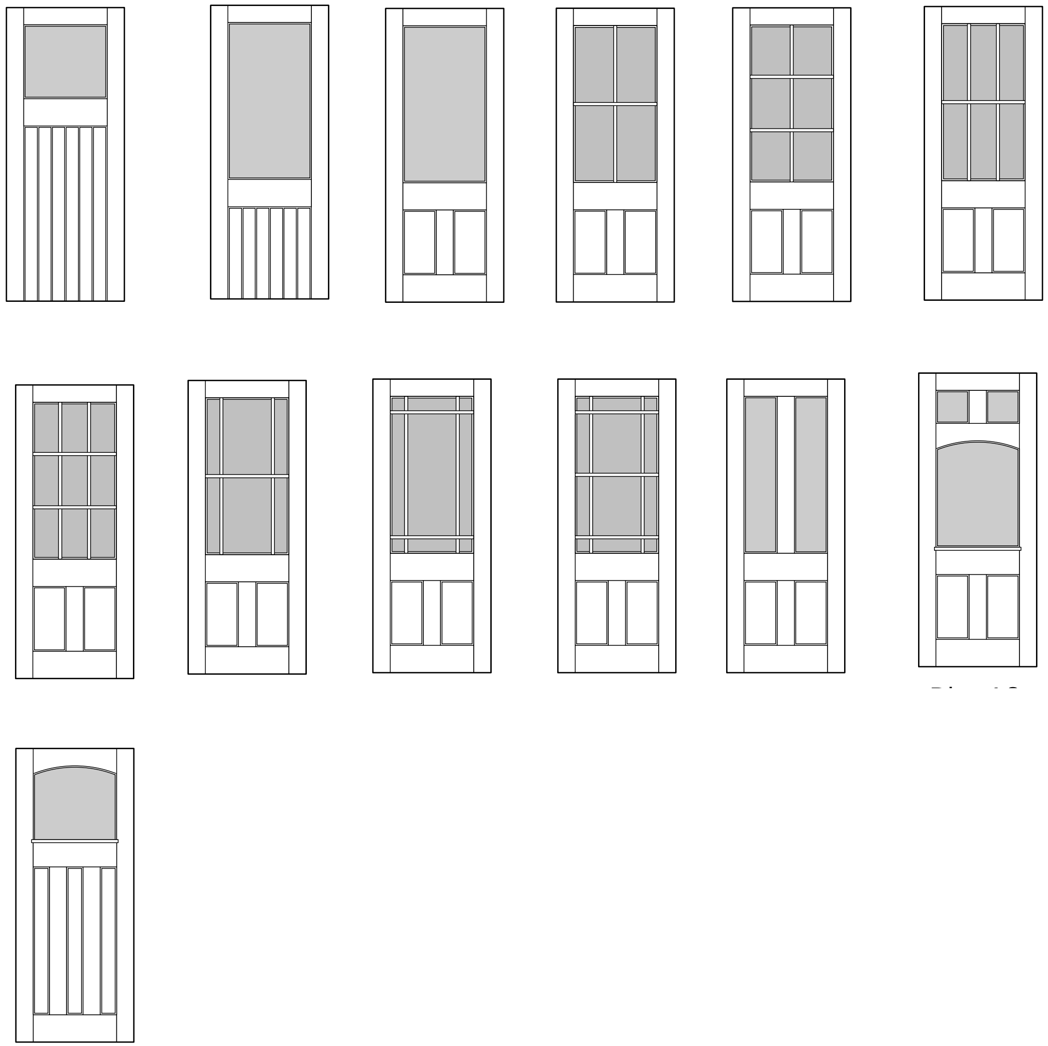
Nb. Drawings are not to scale and are Indicative only

EXAMPLE OF DOOR STYLES - GLAZED



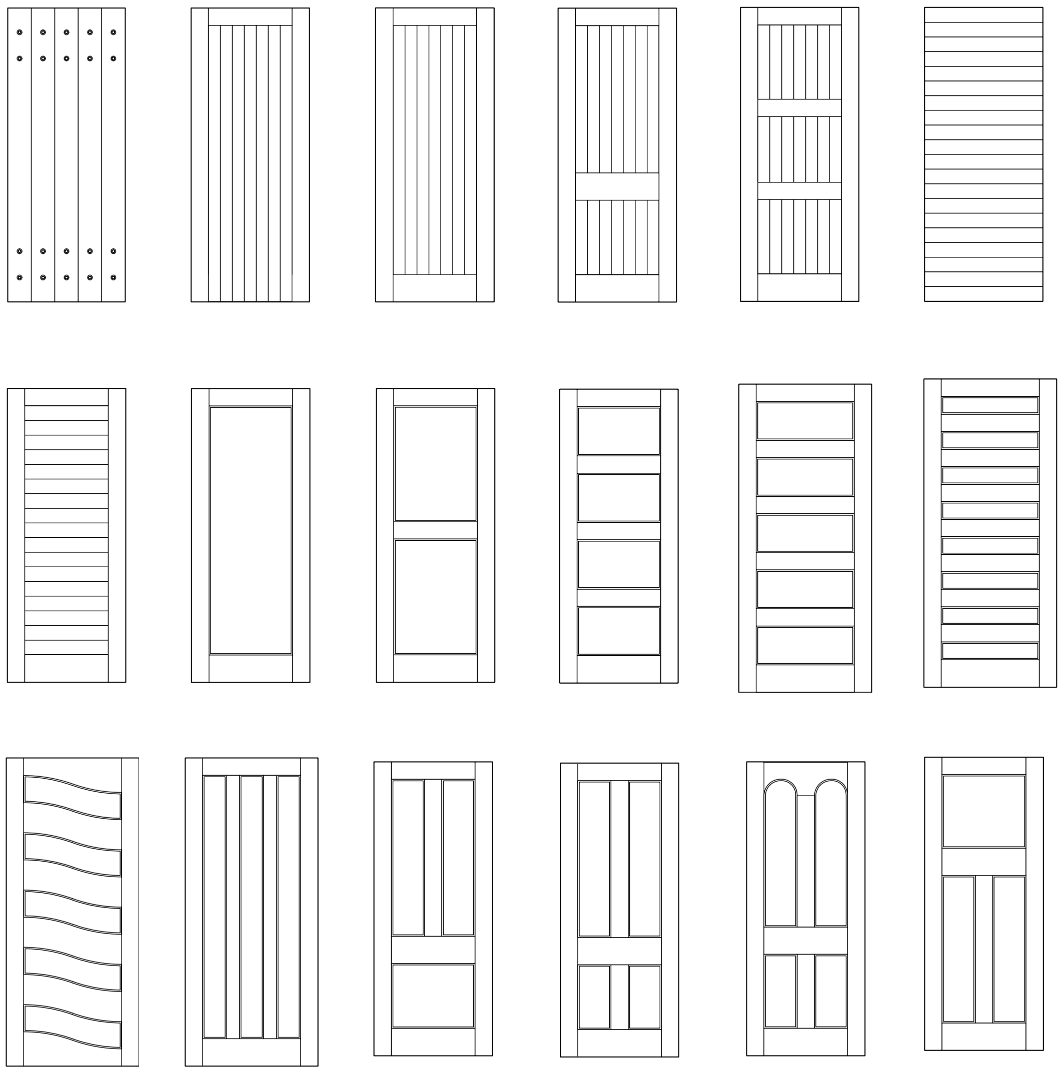
Nb. Drawings are not to scale and are Indicative only

EXAMPLE OF DOOR STYLES - HALF GLAZED



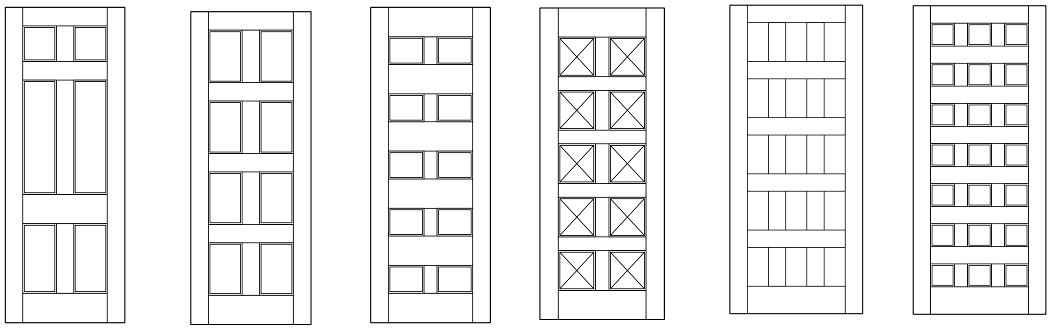
Nb. Drawings are not to scale and are Indicative only

EXAMPLE OF DOOR STYLES - UN GLAZED

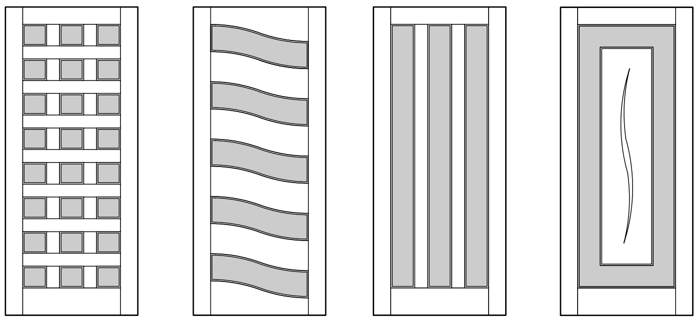


Nb. Drawings are not to scale and are Indicative only

EXAMPLE OF DOOR STYLES - UN GLAZED

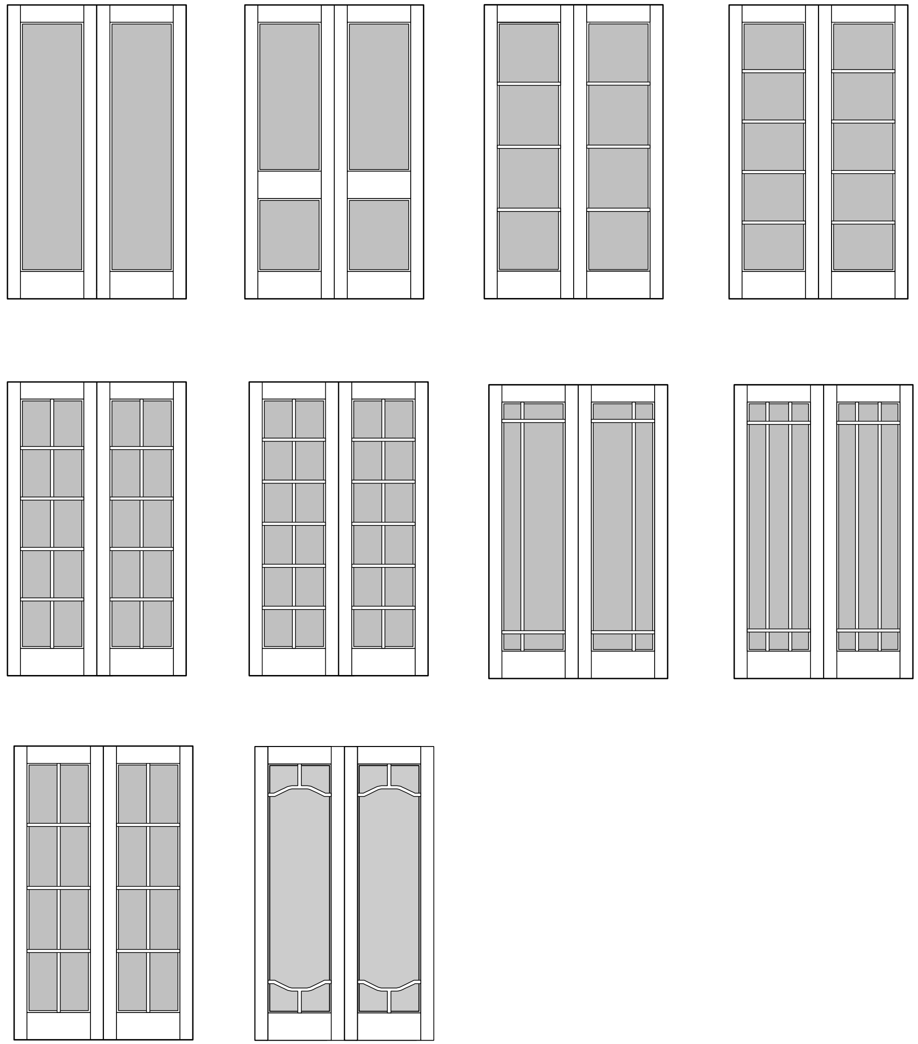


EXAMPLE OF DOOR STYLES - ENTRY



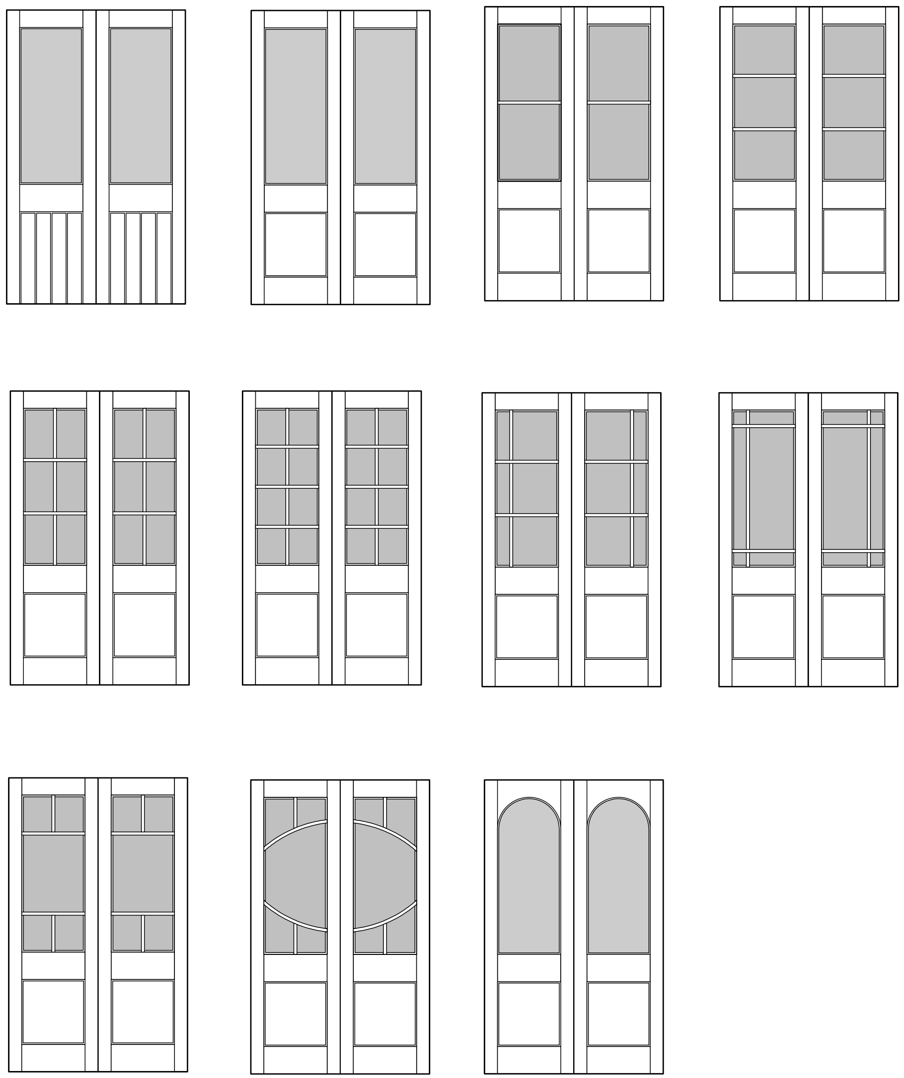
Nb. Drawings are not to scale and are Indicative only

EXAMPLE OF DOOR STYLES - FRENCH GLAZED



Nb. Drawings are not to scale and are Indicative only

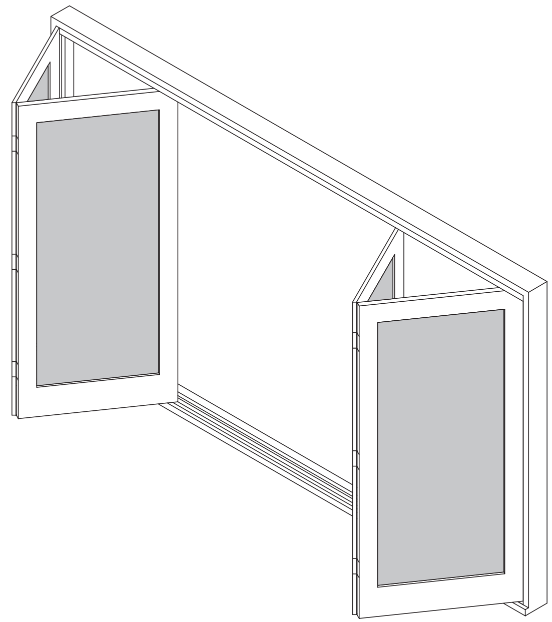
EXAMPLE OF DOOR STYLES - FRENCH - HALF GLAZED



Nb. Drawings are not to scale and are Indicative only

- Provides light and view
- Easy to clean
- Good ventilation
- Weather proof
- Secure

Bi-fold doors



DESCRIPTION

A series of between 2 to 7 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.

Trackless installations tend to sag over time and are less reliable than tracked units. Tracked units over 4.8m can suffer from timber expansion and contraction.

SUITABILITY BY BUILDING TYPE

Residential, apartments, commercial, and industrial.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

A fully supported overhead track is needed. Generally, these can carry a 75kg door 900 wide but higher capacity units are available.

The need for a heavy lintel supporting the doors can complicate renovation projects.

GENERIC PERFORMANCE

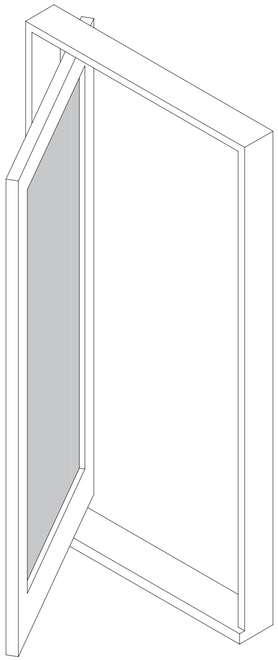
The operation of multiple bolts is needed to open or close the doors fully and the units require regular maintenance. They fully weather seal if the sashes or door open out but are difficult to screen in large sizes, requiring specialist internal screens.

RELATIVE COST

High initial cost, requiring considerable skill on site, and strong support over the opening.

Nb. Drawings are not to scale and are Indicative only

Pivot doors



DESCRIPTION

Pivot doors rotate in the vertical plane with pivots at the top and bottom. They can pivot either one direction or in both directions, giving a wide, generous opening. Doors are generally 45mm thick to allow for the hinging mechanisms. Pivots more than 2400mm high and 1500mm wide are prone to warp.

SUITABILITY BY BUILDING TYPE

Residential, apartments and commercial.

GLAZING TYPE

Single, laminated and multiple glazed units.

HARDWARE REQUIREMENTS

Pivots are concealed in the base and head of the door and the surrounding structure. Hydraulic closers are also available as part of the pivot mechanism.

GENERIC PERFORMANCE

Weatherstopping can be difficult as the stripping is broken at the pivot point. Dual pivoting doors have no weather stops and are not water, draft or insect proof without specialist door seals.

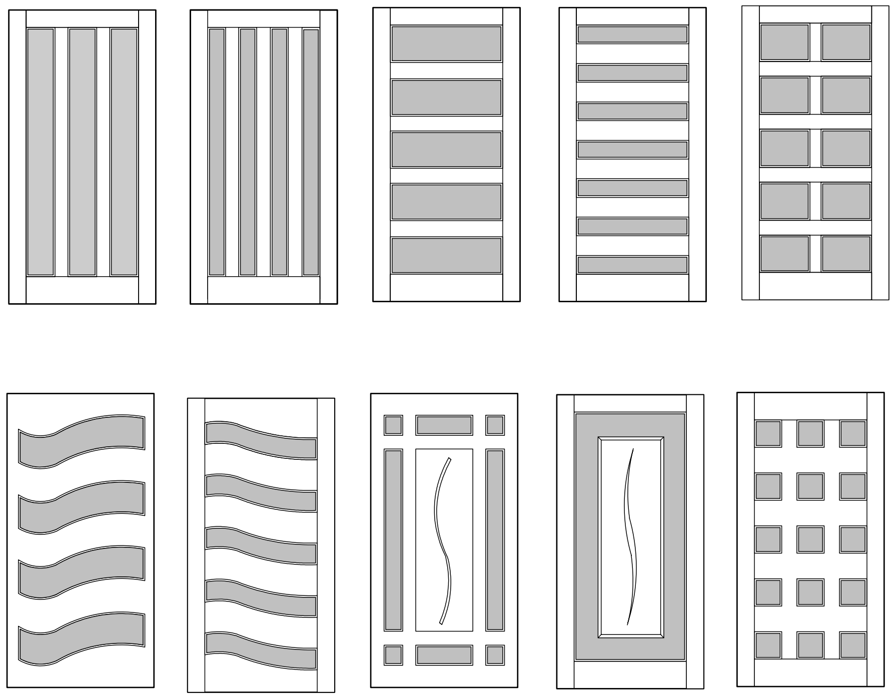
RELATIVE COST

A similar cost to a pair of door but much more expensive than a single hinged door.

- ✓ Provides light and view
- ✓ Easy to operate
- ✓ Easy to cleam
- ✓ Good ventilation
- ✓ Secure
- ✗ Economic
- ✗ Weather proof
- ✗ Air tight
- ✗ Sutiable for high wind areas

Nb. Drawings are not to scale and are Indicative only

EXAMPLE OF DOOR STYLES - PIVOT



Nb. Drawings are not to scale and are Indicative only