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CONTENTS

2.1

Introduction

2.2

Design flexibility

2.2.1

Versatile design options

2.2.2

Provisions for change

2.3

Rational Construction

2.4

Maintenance

2.5

Low energy consumption

2.5.1

Thermal comfort and thermal efficiency

2.5.2

High mass construction

2.5.3

Lightweight construction

2.6

Indoor air quality

Additional resources

References

2.1 Introduction

Timber is one of the oldest known building materials. It has been used in buildings in most parts of the world for thousands of years. Along with masonry, it provided the mainstay of building construction around the world until the 1800s. In the past, timber was often the natural material of choice.

Timber is widely used in a broad range of applications in Australian construction (Figure 2.1). It is long lasting and strong. Australia's oldest timber buildings date back to the first years of European colonisation. The largest timber building in Australia, the dome of the Sydney Olympic Stadium, spans 100 metres. Some buildings and bridges overseas have a much greater span.



Figure 2.1: Melbourne Exhibition Building, 1880

Wood can be used as a product (i.e. timber, panels, building component, furniture), a material in the recycling process (i.e. wood-based panel partially produced from recycled wood), or for energy generation.

Timber is a natural renewable material that is both beautiful and durable. It is easy to work and handle, it is a store for carbon and has a low embodied energy. Trees are home to a variety of flora and fauna. Manufacturing processes create fewer air and water emissions than many of its alternatives; it is totally reusable, recyclable and is 100% biodegradable.

Light, versatile, economical and easy to use, it offers an extensive range of interior and exposed structure and surface uses, including framing, lining, cladding, flooring and roofing in domestic and industrial constructions (Figure 2.2). It can be used in its original shape, rough sawn or hewn to size, dressed to a smooth finish, machined into a variety of shapes or processed into veneer sheets. It can also be transformed into reconstructed products, including glulam, particleboard, plywood and laminated veneer lumber. Each has its own structural and aesthetic properties and qualities in building. Different species possess different basic properties, and therefore timber provides a natural variety of options.



Figure 2.2: Design flexibility. Bus stop, Kings Meadows, Tasmania

The natural qualities of timber can be modified using special treatments that improve its resistance to decay or fire resistance and its dimensional stability.

Environmentally sustainable building

The design of environmentally sustainable building solutions requires consideration of a broad and complex range of issues. The use of any specific material, such as timber, cannot provide the full answer but it may facilitate efficient and effective solutions. The benefits that timber brings to the design and construction process include:

- The use of renewable resources;
- Design flexibility;
- Rational construction;
- Reducing maintenance;
- Low energy consumption; and
- Low internal emissions.

Timber as a renewable and natural building material

Timber is a renewable resource obtained from the wood in the trunks of trees. The process of its production and growth is detailed in Sections 3 and 4.

As a natural material, timber is not homogenous, it is anisotropic. That is, it has different properties in its three different directions. In principle, the cells are like long straws that run up the trunk of the tree.

This cell structure strongly influences the material's load bearing capacity. Like a bundle of straws, timber is strongest in tension and compression when the load is applied parallel to the direction of the cells (along the grain). When loads are applied perpendicular the cells (across the grain), timber is much weaker. The cells tend to be pulled apart or crushed.

Variation of the grain direction across a piece can significantly influence its strength. In essence, each piece is unique. This individuality is accommodated in building by grading the timber into groups of similar structural capability or by reassembling it into more structurally favourable configurations.

Timber in sustainable building design

The natural variability that can complicate timber's structural aspects also creates visual attraction. As each piece is unique, it can bring the surfaces and textures of a design alive.

Once the physical limitations of timber have been accommodated, it is possible to design structures of almost any size with it.

2.2 Design Flexibility

Timber construction can contribute to design flexibility because it allows for:

- Versatile design options; and
- Provision for changing need by ease of alteration.

2.2.1 Versatile design options

Timber provides versatile design options due to the variety of materials and the ease with which it can be handled, jointed and worked.



Figure 2.3: Versatile design options: Olympic Dome, Homebush NSW

Variety of material

There is a broad range of timber products available off the shelf or shaped to suit a particular project. This diversity ensures designs are not unduly constrained by supply or other issues. Timber is available as:

- *Solid appearance timber*: in mouldings, windows, doors, and flooring



Rectangular timber sections



Tongue and groove boards



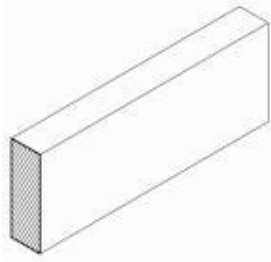
Ornate mouldings



Specialty mouldings

- *Solid structural timber*: in frames, columns, joists and beams

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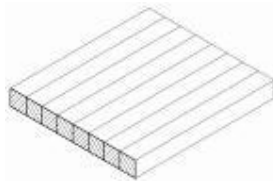


Solid timber

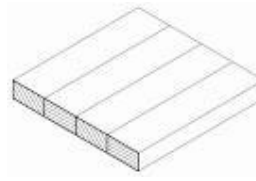
- *Glue laminated timber*: in structural elements or bench tops



Glulam beam



Glulam benchtop



Glulam benchtop

- *Veneer*: in facings to boards in doors, furniture and joinery
- *Plywood and laminated veneer lumber*: in structural bracing, flooring and furniture; in structural elements or joinery

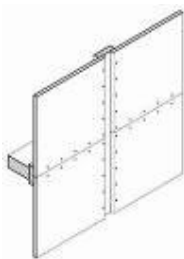


Plywood sheet



LVL beam

- *Sheet material such medium density fibreboard and particle board*: in lining; joinery, and furniture



Ease of working

Timber elements are easy to handle and work. Timber is relatively soft and can be readily worked and shaped with simple hand and power tools. It is easy to join. A young child with little instruction can nail some pieces of wood together to make a frame. While quality and precision come with experience and better

Timber in sustainable building design

tools, the basic principles remain. Timber elements can be joined or prefabricated. Held together with nails, bolts and screws, it is easy to produce a rigid form or a lightweight element.

2.2.2. Provision for change

The use of timber in a building enables changes to be made relatively easily:

- timber elements and surfaces can be reused or recycled; and
- timber walls and frames are easy to cut and re-support and additions can be made without overloading the existing structure.

Recycling and reuse

Timber building, fittings and elements can be recycled and reused. This is considered in more detail in Section 3. Figure 2.5 shows an example of reuse.



Figure 2.5: Timber can be readily reused; see second hand wooden chairs, recycled timber table and doors, recovered solid timber pole and new tongue and groove flooring.

2.3. Rational construction

Timber can contribute to rational construction as its inherent character requires a consistent construction approach while offering lightweight construction alternatives and flexibility of use.

Consistent construction approach

While timber is light and strong, it does not have the homogeneity of man-made material. The fact that timber's strength is highest parallel to the grain places discipline on the design process. While timber provides a considerable flexibility in design, it performs best in design with clearly defined and logical load paths. While this may be seen as a drawback by some, it does limit excess in design and imparts a logical clarity to timber structures, especially those exposed to public view. Because many people have an intuitive understanding of timber's capabilities, these structures have a clarity and assuredness to them that is both attractive and comforting.

High strength to weight ratio

Perhaps the most useful 'environmental opportunity' that a light and versatile building material such as timber opens up is the ability of a structure to touch the ground lightly. This makes building on substandard or delicate sites easier. Timber solutions can be devised and installed to minimise site disturbance, reducing potential impacts to local biodiversity and environments in construction and use. Heavy foundations and considerable site disturbance are not needed.

Similarly, the use of timber in vertical building extensions can mean that the existing structure does not need to be upgraded because the additional dead load does not warrant it.

Timber is also flexible. The flexibility and lightness of timber mean lower foundation costs and a building less susceptible to small site movements than would other, less flexible materials.

As a light material, designs using timber are easier to assemble, move, and vary. This reduces construction and transport impacts.

Site usage

Due to timber's workability, most timber that arrives at site is used. Easy to cut and join, off-cuts can be converted to trims and other necessary blocking. It is often the case that the only waste is in pieces under 300 mm long. Even then, these may be used in a fire for the builders, or to heat the completed building. This reduces wastage.

2.4. Maintenance

Timber is a natural material and is biodegradable. Therefore, its maintenance performance is strongly dependant on its position. Internally, timber is very easy to clean and maintain. Externally, it is easy to maintain if correctly designed.

Internal maintenance

Timber can last in internal applications for centuries if protected from water (Figure 2.6).

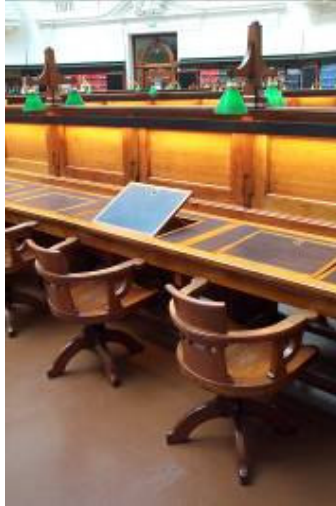


Figure 2.6: State Library of Victoria: these chairs were installed in the early 1920s and have been in continual use

Easy to clean and resurface, properly selected and designed solid timber surfaces and fittings tend to wear in rather than wear out (Figure 2.6). Care is generally needed only to exclude persistent moisture.

External maintenance

Timber will only perform adequately and be durable in external applications if designed correctly.

Design principle for the external use of timber

The fabric of any timber building or structure should shed water and be moisture permeable. Unless the timber is highly durable, it should be kept out of contact with the ground.

Durability can be defined as the capacity of a timber product, component, system, building or structure to perform its function for a specified period of time. Crucial factors in achieving durability include: appropriate design, detailing and specification. As an organic building material, timber elements have to be protected from biological damage (insect attack such as borers and termites, and fungal damage). This can be readily achieved using considered detailing and appropriate timber for the job.

Considered detailing

The general rules for detailing timber for durability are:

- Keep the timber dry wherever possible. This can be achieved by:
 - Providing eaves, flashings and other protective barriers.
- Exclude & shed water:
 - Ensure good design, workmanship and finishing;

Timber in sustainable building design

- Avoid moisture traps, particularly where connections and joints are exposed to the weather. The presence of regular moisture encourages fungi. Do not enclose the timber in sockets or "shoes" if exposed to the weather;
- Horizontal contact areas between members should be minimised and all joints should be free draining where possible. If necessary, drainage holes should be included in the joint detail;
- Bevel exposed surfaces to shed water away from the building.
- Let the timber breathe so it can dry out if it gets wet:
 - Provide natural ventilation to as many surfaces of the timber as possible (Figure 2.7);
 - Avoid inaccessible places in a building so as to avoid the possibility of condensation;
 - Allow for shrinkage or differential movement in the joints.
- Design joints for serviceability.
 - To avoid splitting of timber, use correct fasteners and installation techniques;
 - Allow for the timber to be easily replaced if necessary.
- Detail to exclude insects (especially termites) or see them easily.
 - The probability of insect attack, for example attack by borers, termites, beetles, or marine borers, will affect timber serviceability.

Source: NAFI (1989)



Figure 2.7: Spaced and ventilated timber cladding

Appropriate timbers

Timber's natural durability can be enhanced with preservative treatment if necessary. This should be used with discretion and care.

The hazard levels for timber are set out in Table 2.1 and vary from the lowest hazard, H1, inside above ground to H6, exposed in marine waters.

Timber in sustainable building design

Timber's natural durability levels are set out in Table 2.2. These are based on field trials of untreated heartwood in the ground and indicate the resistance of the heartwood of the species to fungal and insect (termite) attack.

In good design, timber used externally has to be matched to the hazard class, treated to that hazard class, or be protected by coatings or shelters.

Hazard class	Exposure	Service Conditions	Biological hazard
H1	Inside above ground	Fully protected, well ventilated	Borers only
H2	Inside above ground	Protected from wetting, nil leaching	Borers and termites
H3	Outside above ground	Moderate wetting and leaching	Decay, borers and termites
H4	Outside in ground	Severe wetting and leaching	Severe decay, borers and termites
H5	Ground contact	Extreme wetting, leaching and/or critical use	Very severe decay, borers and termites
H6	Marine waters Nth and Sth	Prolonged immersion in sea water	Marine wood borers and decay
H6SW	Marine waters Sth only	Prolonged immersion in sea water	Marine wood borers and decay

Table 2.1: Timber durability hazards. Source: AS1604.1

Class	Characteristics
<i>Class 1</i>	Timbers of the highest natural durability. Can be expected to resist both decay and termite attack for at least 50 years in a structure and up to 25 years in the ground (AS5604:2003 specifies 'greater than 40 years' and 'greater than 25 years' respectively) .
<i>Class 2</i>	Timbers of high natural durability which may be expected to have a life of about 15 to 25 years in the ground. AS5604:2003 specifies that these timbers should also last 15 to 40 years above ground.
<i>Class 3</i>	Timbers of only moderate durability which may be expected to have a life of about 8 to 15 years in the ground. AS5604:2003 specifies life expectancies of 5-15 years in the ground and 7-15 years above ground.

Timber in sustainable building design

<i>Class 4</i>	Timbers of low durability which may last from about 1 to 8 years in the ground. These timbers have about the same durability as untreated sapwood, which is generally regarded as Class 4, irrespective of species. AS5604 specifies life expectancies of 0-5 years in the ground and 0-7 years above the ground.
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Table 2.2: Durability classes for timber. Source: AS1604.1 and AS5604:2003

2.5. Low energy consumption

Timber can contribute to a building with low energy consumption:

- Timber has a low embodied energy so less energy is required to make the building initially. This is explained in detail in Section 3.
- With correct detailing, timber buildings can be thermally efficient and maintain a comfortable internal environment without major energy inputs.

2.5.1. Thermal comfort and thermal efficiency

According to the RAIA Environment policy, it is an unethical architectural practice to not make the most efficient use of energy in any form of building.

One of the major functions of any building is to keep its inhabitants thermally comfortable, either warm or cool, as conditions outside the building become uncomfortable. The factors that contribute to thermal comfort include temperature, relative humidity, and ventilation rate. There are no general and universal benchmarks for acceptability. Living standards and comfort expectations change with lifestyle, income and the cost of energy.

An important aspect of acceptability relates to the concept of 'design times'. These are the time of year and times of day causing the main thermal performance concerns. As part of a research project, people in four capital cities were asked to choose from a list of possible times they considered important in designing a house. Although all times were registered as important, slightly more weight was given to 'Hot summer nights in bed' and 'Hot summer evenings'. This indicates special importance should be attached to comfortable conditions at these times (National Timber Design Council 2001).

Designing thermally efficient buildings requires an understanding of the local climate. It also requires careful manipulation of the shape, orientation and fabric of the building. People can be kept comfortable by:

- Use of solar energy
- Controlling air flow into and out of a building
- Controlling heat gain and losses (insulation)

Solar gain

The main factors influencing gain of energy from the sun are:

- Building shape and orientation: minimise east and west façades, maximise north and south façades, maximise floor area exposed to good lighting,

maximise ratio of wall surface to floor area after considering internal lighting.

- Glazing area, type and shading: window-wall area should be about 40-50% in north and south façades, minimise windows size in east and west façades, provide good insulation levels in windows and frames, maximise light transmission of windows.

Control of air flow into and out of a building

Although air exchange is vital for a healthy indoor environment, uncontrolled air leakage into and out of a building can be a source of significant heat loss and gain. In addition to increasing heating and cooling loads, it can create draughts and cause localised discomfort for occupants. The design principles for air-tightness are:

- Specify windows and doors with good air seals. Use draught excluders and weather-stripping wherever possible.
- Detail wall, floor and ceiling joints so that air leakage is minimised.

Control of heat loss and gain

High thermal performance of a building is a key to sustainable construction.

However, as the climates experienced around Australian are diverse, an environmentally friendly house in the hot humid tropics will require a different solution to that of a house in Tasmania. No single construction option necessarily provides the correct approach for every site.

In Australia, the main construction approaches are:

- High mass construction;
- Lightweight construction;
- Composite construction;

2.5.2. High mass construction

High mass construction involves making use of thermal mass, generally in passive solar designs, although some buildings may make use of solar energy through active systems.

A passive solar home or building naturally collects the sun's heat through large, equator-facing windows (Figure 2.8). Heavyweight building materials provide the thermal mass to store the heat and insulation in the ceiling and walls, enabling it to be gradually released to create comfortable indoor living conditions. In periods of hot weather the massive building materials can absorb heat to reduce the internal temperature swings.

The high mass solar-efficient house model can be very successful in reducing the operational heating and cooling requirements when the location is suitable, the allotment is oriented and sized adequately, and when used appropriately. In order to operate properly, it requires:

- Good exposure to the sun on north facing windows for living rooms.

Timber in sustainable building design

- A site suitable for a long rectangular building on the East-West axis.
- Householders prepared to leave living room (and other) windows 'unscreened' during winter days to allow sunlight penetration.
- A construction method allowing for wall and ceiling insulation.
- Correct orientation, correct design of windows to allow entry of the winter sun.

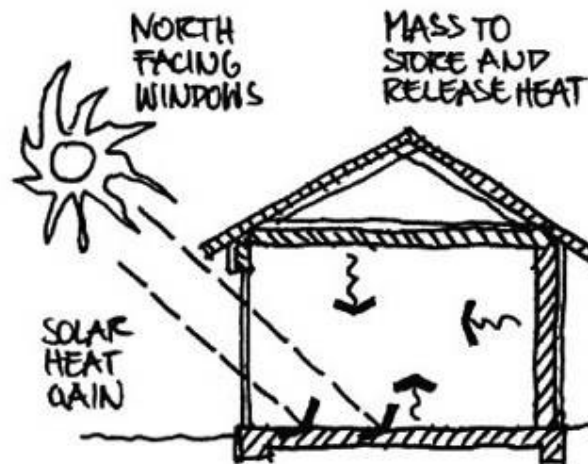


Figure 2.8: High thermal mass construction. Source: National Timber Development Council (2001)

It has been suggested a minimum daily temperature variation of 10°C is needed for heavyweight construction to be useful, while others believe daily variations of as little as 6-8°C are satisfactory. Regardless of the actual figure, the greatest benefits are derived when there is a fairly wide daily temperature variation.

It was previously thought that increasing thermal mass was the only way to improve the thermal performance of most buildings. However, small changes in orientation, window design and sun shading can cause large changes in its effectiveness.

Thermal mass and passive solar heating is generally less important in commercial buildings than in residential buildings as there is often a significant amount of heat already being generated inside by lights, people and equipment. Even on the coldest day in winter, the centre of a deep plan office building often requires cooling. With minimal occupancy at night, heat storage is not normally required. Also, direct sunlight is not desirable for people working in offices as it can cause unnecessary glare.

The heavyweight construction required for a solar-efficient house generally uses materials with high embodied energy.

2.5.2. Lightweight construction

The lightweight timber house concept offers a flexible alternative to high mass construction and can provide excellent environmental performance. Timber frame housing is a popular construction mode in many different climates from the cool

Timber in sustainable building design

to temperate regions of Europe and the Americas, to the very cold climates of Scandinavia and Canada, and the very hot tropical climates of South East Asia. Timber frame houses can be found throughout Australia from Tasmania to the tropical north.

The lightweight timber model is generally more cost effective and more flexible in design than the high mass construction, and is the most common house construction type in Australia.

There are two general approaches to effective thermal performance with a lightweight construction:

- A **Snug House** is well insulated and sealed (Figure 2.9). This design concept is suitable for cool climates, such as Canberra, Hobart, and Melbourne, and for temperate areas such as Sydney, Perth, and Adelaide.
- A **Breeze House** is open, light and naturally ventilated (Figure 2.10). This kind of house is ideally suited to hotter humid climates. This design concept can apply to places such as Brisbane, central and northern Queensland, northern Western Australia and Darwin (National Timber Development Council 2001). See Figure 2.11.

Snug House



Figure 2.9: The Snug House. Source: National Timber Development Council

The approach with the Snug House is to minimise unwanted heat gain or loss through the fabric of the building by:

- insulating all surfaces effectively. Insulation makes the building envelope more resistant to the flow of heat, thus reducing summer heat gains and winter heat losses.

Timber in sustainable building design

- limiting the amount of glazed area, particularly unshaded glazing to the east and west. Glazing and shading to the north and south may be optimized to allow good solar gain in winter, or the morning; and
- sealing the building from unwanted draughts or ventilation.

Fine temperature control depends on prevailing conditions. Solar radiation can be used to heat and ventilation to cool where available and appropriate.

Timber is a natural insulator. Due to air pockets within its cellular structure, it does not form a thermal bridge. The thermal conductivity of steel is approximately 400 times that of timber; concrete 10, brick and glass 6; and mineral wool has 1/3 of the conductivity of timber. This enables timber components to achieve more complete and effective insulation, especially around windows.

As most timber buildings are 'stick' built, the spaces between noggings and joists can accept bulk insulation readily.

The Breeze House



Figure 2.10: The Breeze House. Source: National Timber Development Council (2001)

The approach with the Breeze House is to moderate heat gain or loss through the fabric of the building by:

- reducing direct solar gain by shading walls and windows and either insulating or ventilating the roof space.
- opening up the building to breezes and natural ventilation; and

Timber in sustainable building design

- restricting thermal mass to limit undesirable heat retention.

These two general approaches can be modified to meet various design challenges including difficult sites, environmentally sensitive sites, small budgets, or to optimise the performance of particular appliances. In addition, either can be achieved in a cost effective manner and within the price range of standard design solutions.

Benefits of lightweight timber construction include:

- A house with reduced life-cycle energy consumption (or lower embodied energy) and lower greenhouse gas emissions compared to concrete, masonry or steel.
- Less sensitivity to orientation and solar access, and therefore greater site flexibility than the massive solution.
- It is actually quite difficult to make the thermal mass model 'work', e.g. in many parts of Australia, daily temperature variation is inadequate for thermal mass to do its job of evening out the peaks and troughs in outdoor temperature.
- Greater flexibility in design, layout and zoning, because a northern orientation is not critical.
- Reduced capital and life-cycle costs compared with an equivalent massive (solar) house.
- Quick thermal response of a lightweight insulated structure to intermittent heating and cooling.
- It is easily constructed – no cut and fill on sloping blocks, easy installation of insulation in walls and ceiling due to framing details.

Contrary to much current design advice, timber floors may be used in these dwellings with good results. An uninsulated timber floor in the Breeze House has the big advantage of being able to contribute to thermal comfort during hot summer nights because it will cool down rapidly during this uncomfortable period, perhaps reducing the need to air condition bedrooms. However, it is important to insulate the building envelope, including the floor, in the Snug House. This way, more constant comfortable indoor conditions in cooler and climates can be achieved. Recent research (Llewellyn 1999) has found a suspended timber floor out-performs a slab when intermittent heating during the day is used. The concrete floor requires a much greater energy input and slowed the response time of the space to heating.

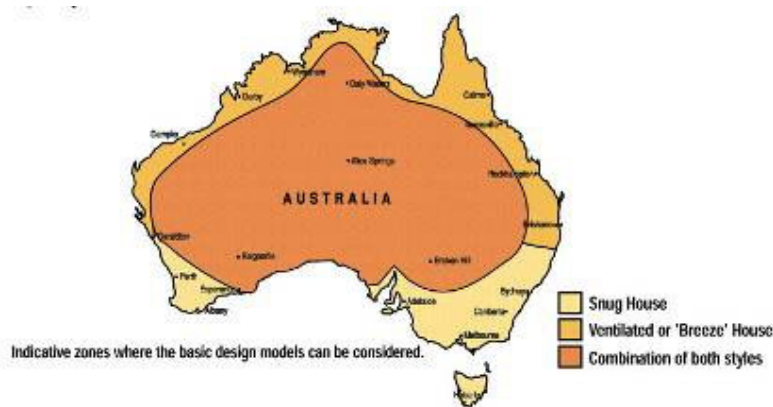


Figure 2.11: Indicative zones where the basic design models can be considered

Composite construction

It is possible to combine aspects of the massive and the lightweight house. For example, if the site allows real access to some northern sun, mass can be used in particular places to make use of that solar heat. Housing construction 'hybrids' are commonly used. The use of a concrete slab-on-ground (instead of an elevated timber floor) combined with lightweight walls, is a very widely used concept. In addition, in the hot-arid zone of central Australia, where the summer climate consists of predominantly hot days and cool nights, it would be useful to build heavyweight living quarters and lightweight sleeping quarters.

The relative benefits of different building techniques will depend on factors such as geographical location, climate, site orientation and so on. There will be no one 'best' solution suitable for all possibilities.

2.6. Indoor air quality

Solid timber is a natural product and does not off-gas toxic chemicals. However, glues used to reassemble small dimension timber into products such as glulam and LVL, the binders in many particle and fibreboards, and the varnishes and coatings used to finish the timber can all off-gas.

Medium density fibre board is a versatile and widely used product in furniture, lining and joinery. It is an efficient use of by-products, made of wood fibres which are bound together by an adhesive, usually urea formaldehyde. MDF can off-gas formaldehyde and low levels of volatile organic compounds (VOCs) such as terpenes and aldehydes, during its use in a building.

Emissions from new building materials, such as MDF and carpets, occupants and their activities, and insufficient ventilation can contribute to concentrations of harmful pollutants in a building. People suffering from allergies or with chemical sensitivities can suffer a range of health effects.

There are a number of ways to minimise these health effects:

- Use low emission materials
- Ensure a building is well ventilated
- Separate uncovered surfaces from working surfaces

Timber in sustainable building design

- Absorb what is off-gassed by including plants in the design

Emissions from products such as MDF have decreased significantly over the past 15 years. MDF is now manufactured to meet the voluntary AS/NZS E1 standard. Formaldehyde emissions from wood panels also decrease with time and for particleboard there is a loss of up to 40% in emissions in the first 30 days.

Adequate ventilation is essential for a healthy indoor environment as it removes pollutants by direct replacing the air. Where thermal performance is critical, ventilation should be maintained and heat exchangers incorporated in the air intakes and exhausts. A complementary solution is to specify the use of indoor plants.

Additional Resources

The publication, *R-Values for timber elements*, provides estimates of R-values of common building construction elements incorporating timber framed construction. These may be required to satisfy minimum thermal performance design standards introduced by state and local government building regulatory authorities throughout Australia. The achievement of a high thermal performance in the building's external envelope is a key to sustainable construction.

Prepared by Dr Terry Williamson of the School of Architecture, Landscape Architecture and Urban Design at the University of Adelaide, the brochure is easy to follow and highly graphical.

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General recognition goes to the School of Architecture at Cardiff University, Wales, for their excellent site at: <http://www.squ1.com/index.php>