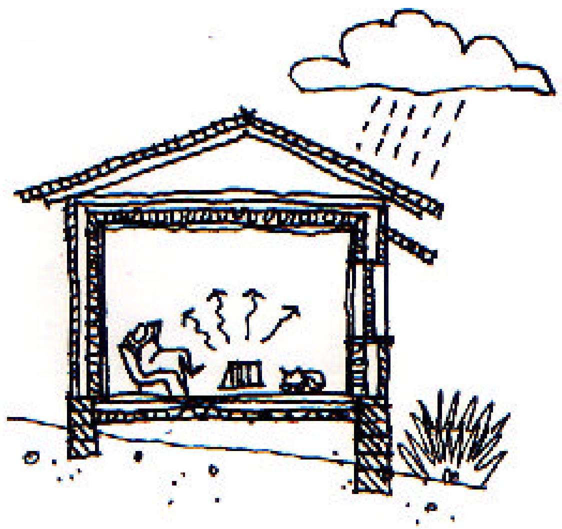
R-values for Timber Framed Building Elements



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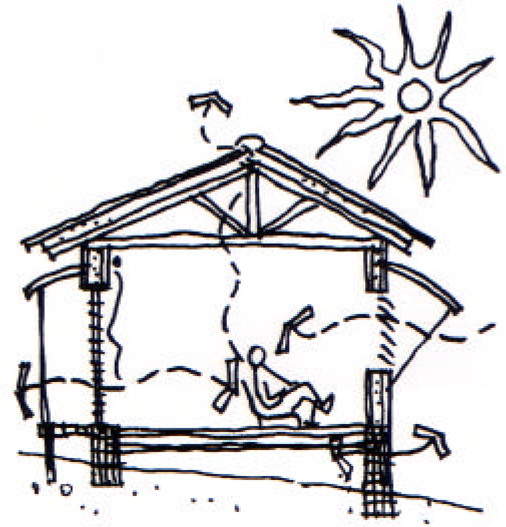

The Breeze House

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R-values for Timber Framed Building Elements

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Sustainable Energy Authority (Victoria) for providing and allowing the reproduction of various building element images.

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New materials and products are constantly being introduced to the building industry. To discuss including new information in this guide, please contact your State timber organisation listed on the back cover.

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INTRODUCTION

This publication provides authoritative estimates of the R-value 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 R-values have been calculated using two computer programs *Rvalues.for* (Walls & Roof/Ceilings) and *FlorsU.for* (Floors). These programs include an iterative calculation of the thermal resistance of all components, including air gaps and spaces, to produce accurate values for the assumed external and internal temperature conditions. The various assumptions inherent in the calculations are explained in this publication. It should be noted that any variation to these variables may result in a different R-value for the element.

NOTES ON THE CALCULATION OF R-VALUES

General

The R-value of a building element is the TOTAL THERMAL RESISTANCE (R_T) including surface thermal resistances between the air on either side of a building element.

The total thermal resistance of a plane building element consisting of layers perpendicular to the heat flow are calculated using the expression:

$$R_T = R_{si} + R_1 + R_2 + \ldots\ldots + R_n + R_{se}$$

Where: R_T is the total resistance

R_{si} is the internal surface resistance;

R_1, R_2, ….R_n are the thermal resistances of each layer, including bridged layers;

R_{se} is the external surface resistance.

Surface resistance values adopted in the calculations are given in ***Table 1***.

The thermal resistance of an element that is not continuous but is bridged by timber frames is determined by the method given in ASHRAE Handbook of Fundamentals (1998) Section F22. The average of the parallel flow and isothermal planes methods is assumed.

The thermal resistance of an air space within a building element depends on the effective emissivity of the space as well as the mean temperature and the difference in temperatures either side of the space. It follows therefore that the calculation of the R-value of a building element containing air spaces depends on the conditions assumed externally and internally. Similarly the conductivity of bulk insulation materials will vary with the temperature of the material. These factors are taken into account when determining the R-values given in this publication. In order to give a range of R-values values corresponding to a range of external and internal conditions, three temperature settings for both "Heat Flow *IN*" and "Heat Flow *OUT*" have been assumed in this publication. These are designated as High, Medium and Low conditions. The external conditions take into account the equivalent increase in the air temperature due to solar radiation on the element. This sol-air increment for walls has been calculated as the average of eight wall orientations and on a horizontal plane for a roof element. For Heat Flow *IN* conditions, this sol-air increment is the average for the location taken over daytime hours for the hottest six months of the year. The boundary condition assumptions used in the calculations are shown in ***Table 2***. An indication of the appropriate temperature setting for a particular location may be determined from ***Figure 1*** for Heat Flow *IN* (Hot weather) and ***Figure 2*** for Heat Flow *OUT* (Cold weather). ***Table 6*** gives the temperature settings for certain locations around Australia.

The R-values given in this publication are intended to give a good indication of the overall performance of an element in Heat Flow *IN* and Heat Flow *OUT* situations. It is important to realise that the boundary conditions (temperature & solar radiation) and other factors used in the calculation of the R-values may differ with assumptions made in other sources of data.

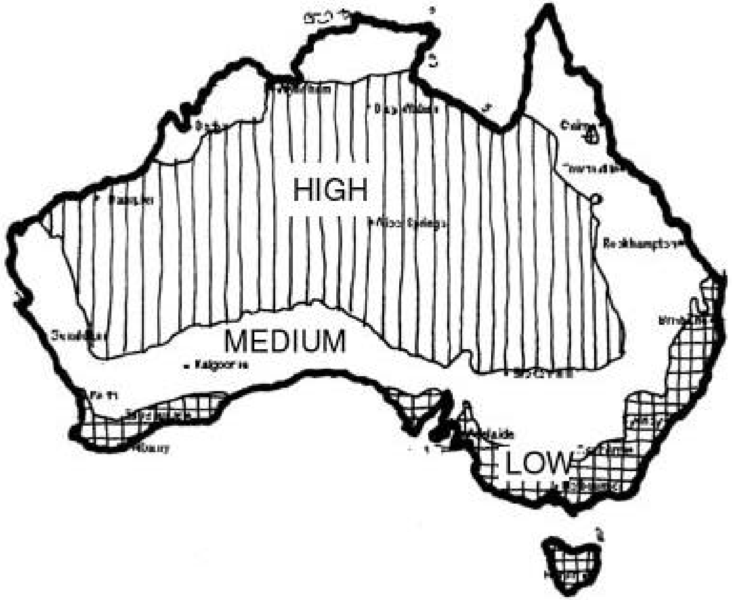


Figure 1: Temperature Zones – Heat Flow *IN*
Wall and Roof/Ceilings

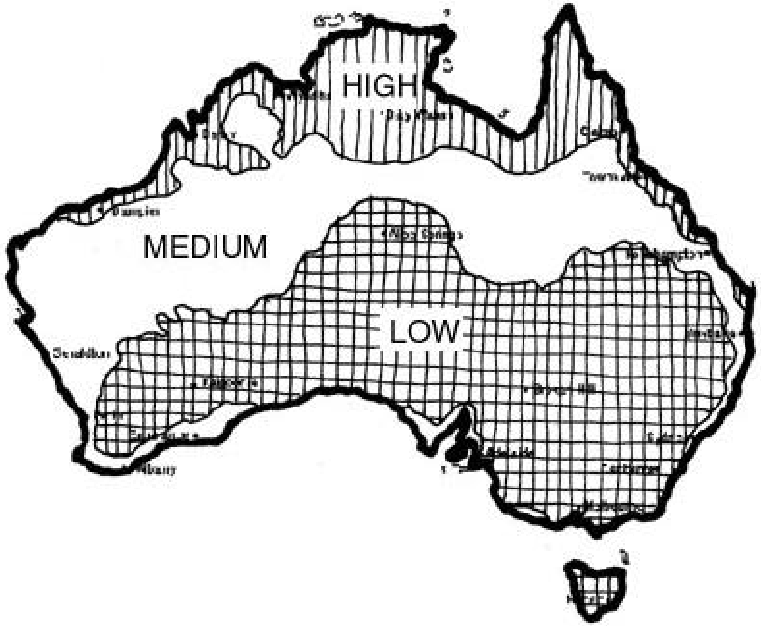


Figure 2: Temperature Zones – Heat Flow *OUT*
Wall and Roof/Ceilings

Thermal Conductivity of Materials

Table 3 gives the thermal conductivity of materials used in the calculations. Unless otherwise noted all values have been taken from the AIRAH Handbook (2000).

Air Space Thermal Resistance

The thermal resistance of air spaces is calculated by the method given in Robinson and Powlitch (1954).

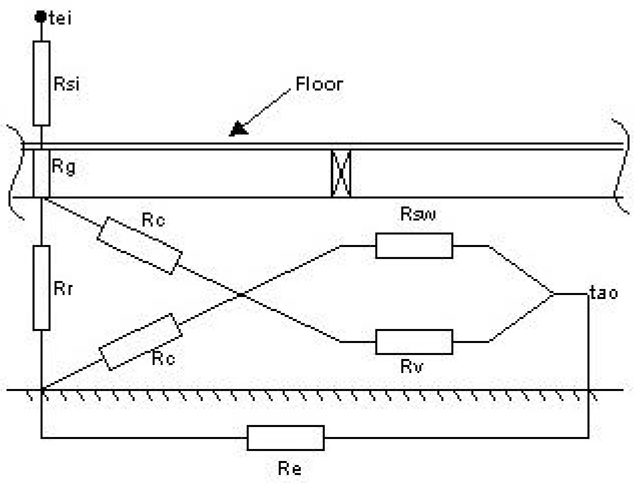
Attic space thermal resistance values are taken from Joy (1958) and the ASHRAE Handbook of Fundamentals (1998).

The emissivities used for several building materials are shown in ***Table 4***.

Floors

The R-value of suspended floors is calculated by a modified CIBSE method (CIBSE Guide, 1986) to allow for the additional effect of the sub-wall (see Figure 3). The calculation of the R-value takes into account the total resistance due to conduction, convection, radiation and ventilation. The computer program, *FlorsU.for* performs the required calculations.

Standard input parameters adopted in the calculations are shown in Table 5.



t_{ei}	inside environmental temperature
R_{si}	inside surface resistance
R_g	thermal resistance of floor
R_r	equivalent thermal resistance due to radiation
R_c	equivalent thermal resistance due to convection
R_v	equivalent thermal resistance due to ventilation
R_e	thermal resistance of the earth
R_{sw}	thermal resistance of the sub-floor wall
t_{ao}	outside air temperature

Figure 3: Thermal Resistance Network Through Suspended Floors Used In Program *FlorsU.for*

Table 1: Surface Resistance Values (m^2.K/W) Moving and Still Air

Position of Surface	Direction of Heat Flow	Surface Emissivity		
		e=0.90 Non-reflective	e=0.2 Partly reflective	e=0.05 Reflective
Still Air				
Horizontal	Down	0.16	0.47	0.80
Sloping 22.5^o	Down	0.15	0.38	0.60
Sloping 45^o	Down	0.13	0.29	0.39
Vertical	Horizontal	0.12	0.24	0.30
Sloping 45^o	Up	0.11	0.20	0.24
Sloping 22.5^o	Up	0.11	0.20	0.24
Horizontal	Up	0.11	0.19	0.23
Moving Air				
Any Orientation				
3.35 m/s	Any	0.044		
6.70 m/s	Any	0.030		
Internal air				
Moving	Any	0.080		

Source: AIRAH Handbook (2000)

Table 2: Boundary Condition Assumptions Walls and Roof Elements

	High	Medium	Low
Heat Flow ***IN***			
Internal Temperature	26^{o}C	24^{o}C	22^{o}C
External Temperature – 90% Maximum for hottest month	<36^{o}C	36^{o}C<t<24^{o}C	<24^{o}C
Sol-air Increment			
Roof	24K	22K	18K
Wall	9K	8K	7K
Heat Flow ***OUT***			
Internal Temperature	24^{o}C	22^{o}C	20^{o}C
External Temperature – 10% Minimum for coldest month	>12^{o}C	12^{o}C>t>6^{o}C	>6^{o}C
Sol-air Increment			
Roof	0K	0K	0K
Wall	0K	0K	0K

Table 3: Thermal Conductivity of Materials

Material	Density (kg/m^3)	Conductivity (W/m.K)
Brickwork – generic extruded 110mm	1580	0.611
Brickwork – generic extruded 90mm	1630	0.600
Carpet underlay		0.040
Cellulose fibre – loose fill (with fire retardant)	29	0.038
Concrete – Aerated blocks 100mm	650	0.13
Concrete blockwork – solid, 90mm	1800	0.750
Concrete blockwork – hollow 390*190*90	1800	0.785
Concrete blockwork – hollow 390*190*140	1410	0.957
Concrete, crushed rock 1:2:4	2400	1.44
Fibre cement sheet	1360	0.250
Glasswool - batts	18	0.036

Material	Density (kg/m^3)	Conductivity (W/m.K)
Plaster – gypsum board	880	0.170
Plaster – cement, sand 1:4	1570	0.530
Plywood	530	0.140
Particle board	640	0.120
Polystyrene – expanded	16	0.035
Polystyrene – extruded	32	0.028
Rockwool – batts	32	0.033
Rockwool – loose fill	64	0.040
Timber/Wood – hardwood	688	0.160
Timber/Wood – softwood	506	0.100
Weatherboards – hardwood	712	0.140
Weatherboards – softwood	506	0.100

Note: Conductivity values given in this table are generally measured at 23^{o}C. The conductivity of bulk insulation materials is varied as a function of the temperature of the material in accordance with AS 4859 Materials for the thermal insulation of buildings, Figure E1.

Table 4: Emissivity of Materials

Material	Emissivity
Common building materials	0.90
Aluminum Reflective Foil	0.03
Aluminum Foil (anti-glare treatment)	0.20

Source: ASHRAE Handbook of Fundamentals

Table 5: Standard Values Assumed in Suspended Floor Calculations

Variable	Assumed Standard Value		
Soil			
Clay density	1300 kg/m3		
moisture content	10%		
Thermal conductivity	*0.55 W/m.k*		
Sand density	1800 kg/m^3		
moisture content	6%		
Thermal conductivity	*1.64 W/m.k*		
Wind speed (10m height)	2.8 m/s		
Sub-floor ventilation	High	Medium	Low
Open sides	100% open	75% open	50% open
Enclosed spaces*			
In accordance with BCA Part 3.4.1 and Table 3.4.1.2 (Adjacent Figure 4 reproduced from BCA)	Zone 3 6000mm^2/m	Zone 2 4000mm^2/m	Zone 1 2000mm^2/m

* Enclosed sub-floor ventilation rates can be reduced if an impervious membrane is used to cover the ground (see BCA, Table 3.4.1.2)

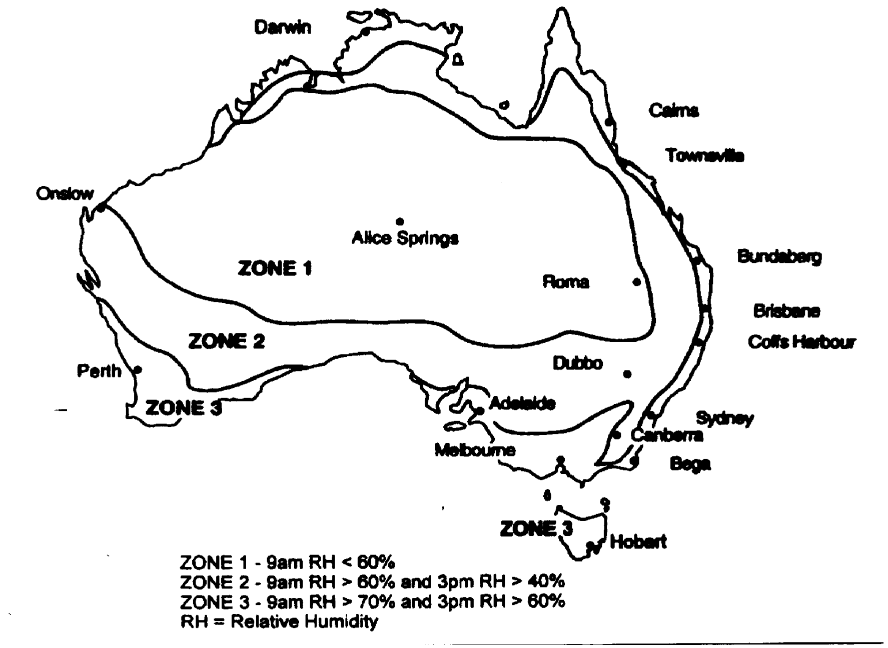


Figure 4: Sub-Floor Ventilation Zones

Table 6: Location Temperature Settings

State	Location	Temperature Setting	
		Heat Flow IN Hot Weather	Heat Flow OUT Cold Weather
NSW/ACT	Bathurst/Orange	***Low***	***Low***
	Broken Hill	***Med***	***Low***
	Canberra	***Low***	***Low***
	Coffs Habour	***Low***	***Med***
	Newcastle	***Low***	***Med***
	Sydney	***Low***	***Med***
	Tamworth	***Med***	***Low***
	Wollongong	***Low***	***Med***
NT	Alice Springs	***High***	***Low***
	Darwin	***Med***	***High***
	Katherine	***High***	***High***
	Tennant Creek	***High***	***Med***
QLD	Brisbane	***Low***	***Med***
	Cairns	***Med***	***High***
	Longreach	***High***	***Med***
	Rockhampton	***Med***	***Med***
	Toowoomba	***Low***	***Low***
	Townsville	***Med***	***High***
SA	Adelaide	***Low***	***Med***
	Adelaide Hills	***Low***	***Low***
	Leigh Creek	***High***	***Low***
	Mount Gambier	***Low***	***Low***
	Port Augusta	***Med***	***Med***

State	Location	Temperature Setting	
		Heat Flow IN Hot Weather	Heat Flow OUT Cold Weather
Tas.	Hobart	***Low***	***Low***
	Launceston	***Low***	***Low***
	Mount Wellington	***Low***	***Low***
Vic.	Alpine regions	***Low***	***Low***
	Bairnsdale	***Low***	***Low***
	Ballarat	***Low***	***Low***
	Geelong	***Low***	***Low***
	Horsham	***Low***	***Low***
	Melbourne	***Low***	***Low***
	Mildura	***Med***	***Low***
	Omeo	***Low***	***Low***
	Portland	***Low***	***Med***
	Warrnambool	***Low***	***Med***
WA	Geraldton	***Med***	***Med***
	Kalgoorlie	***Med***	***Med***
	Perth	***Med***	***Med***
	Port Hedland	***High***	***High***

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ASHRAE. (1998). **Handbook of Fundamentals (SI)**. New York: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

CIBSE Guide (1986) Section A3-Thermal Properties of Building Materials, The Chartered Institution of Building Services Engineers, London.

Joy, F. A. (1958). Improving Attic Space Insulating Values. **ASHRAE Transactions**, **64**, 251-264.

Robinson, H. E., & Powlitch, F. J. (1954). **Housing Research Paper 32. The Thermal Insulating Value of Airspaces**. Washington, DC: Housing and Home Finance Agency.

INDEX OF ELEMENTS

Roof/Ceilings

R1. Pitched roof, flat ceiling, bulk insulation between joists

R2. Pitched roof, reflective foil laminate (RFL), flat ceiling, (without and with) bulk insulation between joists

R3. Pitched roof, flat ceiling, rigid bulk insulation over joists

R4. Pitched roof, flat ceiling, concertina foil between joists

R5. Metal roof, ceilings with exposed rafters, foil-backed blanket

R6. Metal roof, ceilings with exposed rafters, bulk insulation & RFL

R7. Tiled roof, ceilings with exposed rafters, bulk insulation

R8. Tiled roof, ceilings with exposed rafters, extruded polystyrene board insulation

R9. Metal roof, raked ceiling with concealed rafter, bulk insulation

R10. Tile roof, raked ceiling with concealed rafter, bulk insulation

Walls

W1. Timber framed walls, brick or block cladding, reflective foil laminate (RFL)

W2. Timber framed walls, weatherboard or sheet cladding, RFL between studs

W3. Timber framed walls, brick or block cladding, R1.5 bulk insulation between studs

W4. Timber framed walls, brick or block cladding, R2.0 bulk insulation between studs

W5. Timber framed walls, weatherboard, plywood or fibre-cement cladding, R1.5 bulk insulation & RFL

W6. Timber framed walls, weatherboard, plywood or fibre-cement cladding, R2.0 bulk insulation & RFL

W7. Timber framed walls, brick or block cladding 10mm foil-backed insulation boards across studs

W8. Timber framed walls, brick or block cladding, 15mm foil-backed insulation boards across studs

W9. Timber framed walls, weatherboard, plywood or fibre-cement cladding 10mm foil-backed insulation boards across studs

W10. Timber framed walls, weatherboard, plywood or fibre-cement cladding, 15mm foil-backed insulation boards across studs

W11. Timber framed walls, weatherboard, plywood or fibre-cement cladding, RFL

W12. Timber framed walls, brick or block cladding, RFL, R1.5 bulk insulation between studs

W13. Timber framed walls, brick or block cladding, RFL, R2.0 bulk insulation between studs

W14. Timber framed walls, weatherboard or sheet cladding, RFL between studs

W15. MRTFC, FRL 60 mins Class 1, bulk insulation between studs

Walls *Cont.*

W16. MRTFC, FRL 60 mins Class 2, bulk insulation between studs

W17. MRTFC, FRL 90 mins Class 2, bulk insulation between studs

W18. MRTFC, FRL 90 mins Class 2, bulk insulation between studs

W19. MRTFC, FRL 90 mins Class 2, bulk insulation between studs

Floors

F1. Suspended floor, bare timber, no sub-floor walls

F2. Suspended floor, carpeted timber, no sub-floor walls

F3. Suspended floor, tiled timber, no sub-floor walls

F4. Suspended floor, bare timber, sub-floor walls

F5. Suspended floor, carpeted timber, sub-floor walls

F6. Suspended floor, tiled timber, sub-floor walls

F7. Suspended floor, bare timber, no sub-floor walls, RFL between joists

F8. Suspended floor, carpeted timber, no sub-floor walls, RFL between joists

F9. Suspended floor, tiled timber, no sub-floor walls, RFL between joists

F10. Suspended floor, bare timber, sub-floor walls, RFL between joists

F11. Suspended floor, carpeted timber, sub-floor walls, RFL between joists

F12. Suspended floor, tiled timber, sub-floor walls, RFL between joists

F13. Suspended floor, bare timber, no sub-floor walls, R1.0 insulation between joists

F14. Suspended floor, carpeted timber, no sub-floor walls, R1.0 insulation between joists

F15. Suspended floor, tiled timber, no sub-floor walls, R1.0 insulation between joists

F16. Suspended floor, bare timber, sub-floor walls, R1.0 insulation between joists

F17. Suspended floor, carpeted timber, sub-floor walls, R1.0 insulation between joists

F18. Suspended floor, tiled timber, sub-floor walls, R1.0 insulation between joists

F19. Suspended floor, bare timber, no sub-floor walls, plywood under joists

F20. Suspended floor, carpeted timber, no sub-floor walls, plywood under joists

F21. Suspended floor, tiled timber, no sub-floor walls, plywood under joists