

PART B

Chapter 9

Thermal Performance

This chapter provides design guidance for maximising the thermal efficiency of buildings using concrete masonry superstructures.

It considers masonry's resistance to the passage of heat (thermal insulation) and the resistance to gain or loss of heat (thermal mass).

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- 9.1 BASIS OF DESIGN**
- 9.2 DESIGN REQUIREMENTS**
- 9.3 STANDARD DESIGNS**
- 9.4 WORKED EXAMPLE**

9.1.1 INTRODUCTION

Increasing community awareness of the need to conserve energy and reduce greenhouse gas emissions has resulted in the provision of thermally efficient buildings becoming the focus of community and regulatory attention. Large quantities of energy are used for climate control of buildings and many of which are designed with little or no thought for minimising cooling and heating loads. Significant reduction in the capital cost of heating and air-conditioning equipment, the space it occupies and its energy consumption and operating costs, are possible. Well-insulated walls and intelligent facade treatment reduce summer heat gains and winter heat losses over the life of a building. Savings in running costs can be considerable and can more than offset any additional capital costs.

9.1.2 ENERGY, COST AND GREENHOUSE GAS EMISSIONS

It is important to understand that not all building systems will necessarily achieve simultaneously what may be perceived to be desirable goals. The designer must balance the potentially conflicting goals of:

- Minimising energy use, including heating and cooling energy as well as the energy used to produce the building materials
- Minimising cost, including heating and cooling cost as well as the cost associated with particular building-construction practices
- Minimising greenhouse gas emissions.

9.1.3 CRITERIA FOR COMPARING ENERGY USE AND COST

When considering cost, it is also necessary to distinguish between the initial building cost (borne by the initial property owner) and the long-term heating and cooling costs (borne by subsequent property users). The problem is further complicated by government policies and international commitments to particular levels of greenhouse gas emissions. When analysing energy use and costs, the following criteria should be considered:

Total Energy Savings (without considering cost)

This criterion relies on the insulation properties of the roof and wall structures, together with some allowance for thermal mass, to minimise total energy use. This philosophy forms the basis of the Home Energy Rating Schemes (HERS) which are in use in various parts of Australia. Such an approach is attractive to those who are principally concerned with conserving energy over a long period with little concern for the short-term cost. Lightweight concrete masonry is a good insulating material and appropriate for this approach. Similarly, the use of insulation in conjunction with concrete masonry is suitable.

Peak Energy Savings (without considering cost)

This criterion is similar to the previous one, but with an emphasis on reducing the peak daily energy use. Such an approach is attractive to power-generating authorities

because the low peak demand can be more easily achieved using existing generating equipment. Greater reliance on the thermal mass properties of concrete masonry will help achieve this end.

Community Cost Savings (considers life-cycle cost discounted to present worth)

This criterion minimises the “life cycle cost” of the building capital cost, heating and cooling equipment capital cost and energy cost. While an important factor in this approach is the minimising of energy use, it is not the only consideration. This approach should be attractive to consumer groups concerned with economic benefit to the population. It will favour those low-cost building materials that also have reasonable insulation properties, such as concrete masonry.

First Home Buyer Savings (considers a relatively short life-cycle cost discounted to present worth)

As for the previous one, this criterion minimises the “life cycle cost” of the building capital cost, heating and cooling equipment capital cost and energy cost, but over a shorter period corresponding to the period of ownership of the “first-home buyer”. It will also favour those low-cost building materials that also have reasonable insulation properties, such as concrete masonry.

9.1.4 DETAILING BUILDINGS

In all cases, sensible architectural design and detailing are significant factors in achieving the criteria. In southern Australia, prominent north-facing shaded windows with large eaves overhangs will permit the entry of winter sun and restrict that of summer sun. In northern Australia, large eaves around the building and well-designed ventilation will help keep the building cool. Well-designed, properly-sealed doors and windows will allow cross-ventilation in summer and restrict air and heat leakage in winter.

9.1.5 HEAT TRANSFER

Heat is transferred through the building envelope from spaces of higher temperature to those of lower temperature. Thus, in summer, the heat flow is into the building, while in winter it is usually in the reverse direction. Heat is transferred in a combination of three modes – conduction, convection and radiation, defined below.

Conduction is the principal heat transfer mechanism through opaque airtight barriers such as external walls.

Radiation is significant where, for example, glass is not shaded from direct sunlight. Glass transmits heat both by conduction and by radiation. Its comparatively poor thermal insulation properties make large windows undesirable.



Convection becomes a problem only when poor detailing or construction practice leave openings which allow transfer of heat by air leakage.

Much of the thermal advantage of using walls of high thermal resistance will be lost if radiation and convection are not controlled by avoiding excessive use of glass, shading them from summer sun and designing and building to eliminate air leakage.

9.1.6 INSULATION

The primary method of restricting heat flow is by providing insulating materials in the roof and walls. Such materials have a high thermal resistance or ‘R’ rating.

A wall is typically made up of a number of components, each of which has a different ability to insulate against heat flow. Dense concrete (as used in most concrete masonry units) is not a particularly good insulator but lightweight concrete masonry is. Metal cavity ties are poor insulators.

Thermal bridging is the phenomenon whereby heat flows through concrete webs, cavity ties or other bridges to enter or leave the building. When considering the flow of heat across a wall, it is necessary to consider the thermal bridging as heat travels through materials with lower R values rather than through those with high ones.

9.1.7 THERMAL MASS

Thermal mass (also known as thermal inertia or thermal capacitance) is the ability of a material to retain heat when subjected to a temperature differential. Dense-weight concrete has high thermal mass. If a building with high thermal mass is subject to a heating and cooling cycle that crosses the comfort zone, the material with high thermal mass will maintain its heat energy for an extended period. In practical terms, in summer a building with dense concrete floors and walls will remain relatively cool during the day time, while in winter the same building will remain relatively warm.

9.1.8 PROPERTIES OF CONCRETE MASONRY

Concrete masonry has moderate thermal insulation properties (controlling the passage of applied heat out of the building in winter or atmospheric heat into the building in summer). It has good thermal mass (slowly releasing stored heat in winter and slowly absorbing atmospheric heat in summer) It is a relatively inexpensive building material, providing attractive life-cycle costings, particularly when the building life is relatively short. The amount of energy used to produce concrete masonry is relatively low when compared to most other building materials.

Generally, materials that are good thermal insulators are incapable of supporting heavy loads. Conversely, most good load-supporting materials are poor insulators. Concrete masonry is a notable exception to these general rules.

Its good insulating qualities are derived primarily from the minute voids in the concrete of the units. In general, it will be found that masonry units of lower density concrete will have higher thermal resistance because of their greater voids content. Thermal resistance is generally improved by substituting lightweight aggregates for dense aggregates in the masonry concrete. It may be further improved by filling the cores of walls of hollow blocks with lightweight insulating materials. Where cores are filled in this way, measures must be taken to prevent entry of moisture to the wall cores and the core-filling material. Such precautions include the use of cavity wall construction, moisture-resistant external coatings and the preventing of water entry by good flashing and weathering practice.

9.1.9 DESIGN OPTIONS

The main options open to the users of masonry are given in **Table 9.1**.

Note:
For various Thermal Terms, see the **Glossary**.

Table 9.1 *Design Options for use with Masonry Wall Systems*

Wall system	Insulation		Batts	Pumped
	None	Foil		
Masonry veneer	Most common	Common	Must be water-resistant	Masonry must be sealed
Cavity masonry	Common	Common	Must be water-resistant	Masonry must be sealed
Single-leaf masonry	Common	Possible with internal plasterboard	Possible only with customised inserts	Masonry must be sealed

9.2.1 BACKGROUND

The following sequence, traces the development of energy standards and regulations in Australia.

- In the early 1980's, Standards Australia published AS 2627.1, recommending insulation in the ceilings of some dwellings.
- In the 1980's, the Victorian Government required ceilings to have R 2.2 and walls to have R 1.3 (if the ground floor has R 1.0) or R 1.7 (if the ground floor has R 0.7). Masonry of thickness 180 mm on a concrete slab was exempted.
- In the 1980's, the South Australian Government required wall insulation of R 0.8.
- In 1992, the ACT Government required insulation of Class 1, 2 and 3 residential buildings (and permitted the same exemptions as Victoria) with a value of R 1.5, except for masonry of 180 mm thickness on a concrete slab.
- In 1993, Standards Australia published the revised version of AS 2627.1, recommending insulation in the ceilings and walls of some dwellings.
- During the 1990's, Standards Australia unsuccessfully attempted to write a Commercial Building Energy Code and to standardise the protocols for Home Energy Rating software.
- During the period 2003 to 2012, amendments to BCA Volumes 1 and 2 were published, introducing energy efficiency and greenhouse gas reduction provision into the BCA. For Class 1 buildings (houses, row houses, villa units and the like) covered by BCA Volume 2, the stringency of these provisions has been gradually increased for to "6 star" stringency, as defined by the ABCB Protocol for House Energy Rating Software. For some houses in Climate Zones 1 and 2 with outdoor living areas, there is a concession to "5.5 or 5.0 stars". For other buildings (Class 2 to 9 buildings) covered by BCA Volume 1, the stringency has also been increased, although the precise level of stringency is not so clearly defined. There are also some structures (e.g. open deck car parks) that do not have requirements.
- State variations were included in within the BCA to account for some fundamental deviations by some states. In essence the principal deviations from 2006 to 2009 were as follows. For exact details, the designer must consult the BCA Volumes 1 and 2, and the state building regulations .

BCA Volume 1 - DLCC

In most states Class 3, 5, 6, 8, 9a, 9b, 9c energy efficiency may be determined by using simulation software or DTS provisions. For Class 2, 3 & 4 buildings in NSW, BASIX applies. DTS services, and comparing to Table JV2.

BCA Volume 2:

NSW - BASIX applies

VIC Provided additional requirements for rainwater tank and solar hot water are met, the DTS provisions of Section 3.12 may apply. Otherwise 5-Star performance using the software protocol applies. OTHER STATES – BCA 2005 or 2006 applies.

- In 2011 major revisions were made to the BCA, The Building Code of Australia Volume 1 Class 2 to 9 Building is now referenced as the National Construction Code – Series Volume One – Building Code of Australia. In it the stringency is significantly increased to 6 stars (for residential buildings) and the equivalent for non-residential buildings.

9.2.2 APPLICATION OF THE NCC/BCA ENERGY PROVISIONS IN EACH STATE

Each state government has the right and responsibility to adopt those parts of the BCA that are deemed to be in the best interests of the particular state. The situation in respect of these provisions as at 2010 is shown in **Tables 9.2 and 9.3.**

The state provisions are subject to change as further amendments are published by the ABCB or as State Government Administrations change their policies in respect of the adoption of the various parts of the BCA. It is the responsibility of designers to obtain the latest requirements applicable for each state.



Table 9.2 *NCC–BCA Volume One – Class 2 to 9 Buildings, Situation as at 2012*

State	Comment
NSW	For Class 2 & 4 buildings, NSW BASIX applies – BCA Volume One general provisions do not apply. For Class 3 and 5 to 9 buildings, NSW BASIX does not apply – BCA Volume One general provisions apply with minor variations.
VIC	All of NCC–BCA Volume One applies except for J7.2.
ACT	NCC–BCA Volume One applies, together with additional territory legislation covering sustainability.
WA	NCC–BCA Volume One applies.
SA	NCC–BCA Volume One applies, together with additional state provisions covering hot water supply systems.
QLD	For Class 2 buildings, BCA 2009 Volume One applies. For Class 3, 4 and 5 to 9 buildings, NCC–BCA 2012 Volume One applies.
TAS	BCA 2009 Volume One applies.
NT	For Class 2 & 4 buildings, BCA 2009 Volume One applies. For Class 3 and 5 to 9 buildings, the BCA does not apply.

Table 9.3 *NCC–BCA Volume Two – Housing Provisions Class 1 and 10a Buildings, Situation as at 2012*

State	Comment
NSW	NCC–BCA Volume Two <i>Part 2.6 and 3.12 as varied by the NSW Appendix</i> are designed to complement the requirements for class 1 and 10 buildings subject to BASIX.
VIC	NCC–BCA Volume Two common provisions apply.
ACT	NCC–BCA Volume Two common provisions apply.
WA	BCA Volume Two common provisions apply but varied by WA Appendix relating to hot water systems and water use.
SA	NCC–BCA Volume Two common provisions apply.
QLD	NCC–BCA Volume Two common provisions apply.
TAS	NCC–BCA Volume Two common provisions apply.
NT	NCC–BCA Volume Two common provisions apply.

Notes:

1 BCA Vol 1 2006 refers to the ABCB Protocol for House Energy Rating Software, which is currently based on NatHERS, and permitting the use of AccuRATE, First Rate and BERS.

9.3.1 GENERAL**Design and detailing**

All design and detailing shall comply with the requirements of AS 3700 and state building regulations.

Masonry properties

The worked examples in this chapter are based on masonry properties complying with the General Specification set out in **Part C:Chapter 2** of this manual, modified as noted below.

Hollow concrete blocks

Width 90 mm, 110 mm, 140 mm and 190 mm

Height 190 mm

Length 390 mm

Face-shell bedded

Average face-shell thickness,

$t_{s,av} = 28$ mm for 90 mm, 110 mm
and 140 mm units

$t_{s,av} = 33$ mm for 190 mm units

Material density is noted in the tables.

Mortar joints

Mortar type M3 (or M4)

Joint thickness 10 mm

9.3.2 CALCULATION OF R VALUES

The consideration of R values in this manual is based on the following:

H.A. Trethowen

R Values that are made-to-measure
Building Research Association of
New Zealand (Reprinted from ASHRAE
Transactions Volume 91 Part 2 1986).

9.3.3 INDEX TO DESIGN CHARTS

The following Thermal Resistance Charts are included:

Concrete Masonry Units

90 mm Concrete Masonry Walls

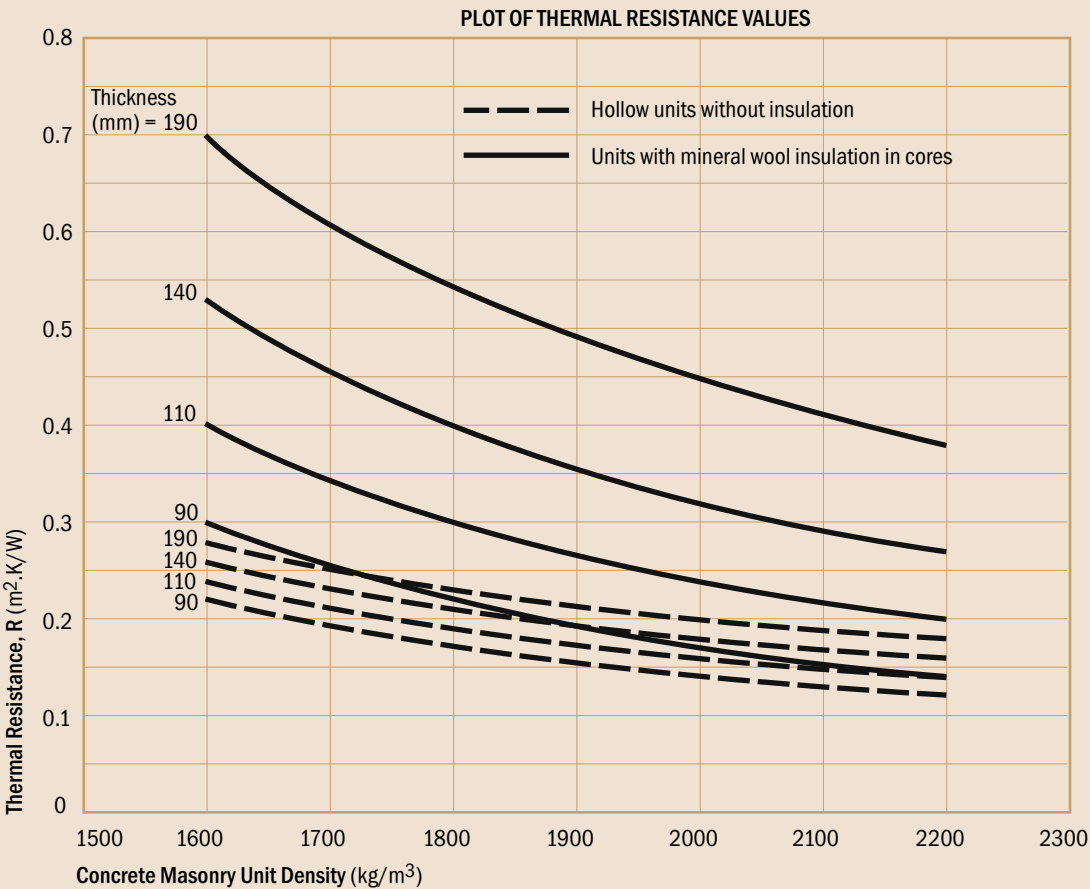
110 mm Concrete Masonry Walls

140 and 190 mm Concrete Masonry Walls

THERMAL RESISTANCE OF CONCRETE MASONRY UNITS

Masonry Unit Thickness (mm)	THERMAL RESISTANCE, R (m ² .K/W)							
	Hollow Units without Insulation.				Units with Mineral Wool Insulation in Cores.			
	Density (kg/m ³)				Density (kg/m ³)			
	1600	1800	2000	2200	1600	1800	2000	2200
90	0.22	0.17	0.14	0.12	0.30	0.22	0.17	0.14
110	0.24	0.19	0.16	0.14	0.40	0.30	0.24	0.20
140	0.26	0.21	0.18	0.16	0.53	0.40	0.32	0.27
190	0.28	0.23	0.20	0.18	0.70	0.54	0.45	0.38

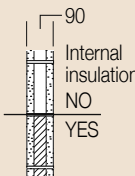
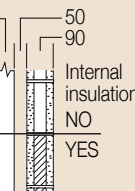
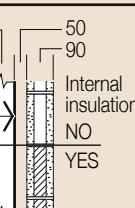
NOTE: The R values include allowance for thermal bridging across the concrete webs.
 These theoretical values are yet to be verified by test
 These values do not include any contribution by air films.

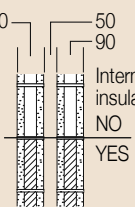
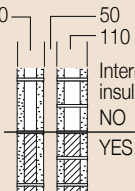


THERMAL RESISTANCE OF CONCRETE MASONRY WALLS

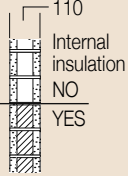
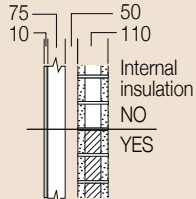
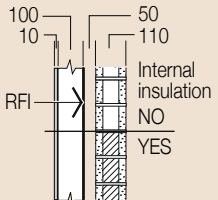
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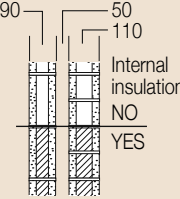
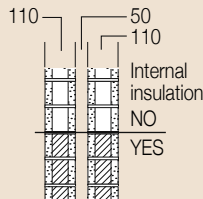
90-mm wall combinations

		Internal insulation in masonry units:		NO		YES	
		Net density of masonry units (kg/m ³)		>2100	≤1800	>2100	≤1800
Wall detail (Not to scale)	Component	Specification	Thermal resistance (m ² .K/W)				
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	90-mm hollow block	0.12	0.17	0.14	0.22	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m ² .K/W)		0.28	0.33	0.30	0.38	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	90-mm hollow block	0.12	0.17	0.14	0.22	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Plasterboard	10-mm gypsum	0.06	0.06	0.06	0.06	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m ² .K/W)		0.48	0.53	0.50	0.58	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	90-mm hollow block	0.12	0.17	0.14	0.22	
	Reflective airspace	50-mm ventilated	0.55	0.55	0.55	0.55	
	Reflective airspace	100-mm with RFI	0.61	0.61	0.61	0.61	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m ² .K/W)		1.50	1.55	1.52	1.60	

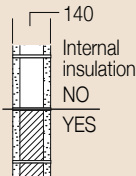
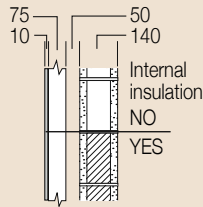
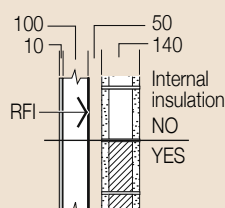
		Internal insulation in masonry units:		NO		YES	
		Net density of masonry units (kg/m ³)		>2100	≤1800	>2100	≤1800
Wall detail (Not to scale)	Component	Specification	Thermal resistance (m ² .K/W)				
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	90-mm hollow block	0.12	0.17	0.14	0.22	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Internal masonry leaf	90-mm hollow block	0.12	0.17	0.14	0.22	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m ² .K/W)		0.54	0.64	0.58	0.74	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	110-mm hollow block	0.14	0.19	0.20	0.30	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Internal masonry leaf	90-mm hollow block	0.12	0.17	0.14	0.22	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m ² .K/W)		0.56	0.66	0.64	0.82	

110-mm wall combinations

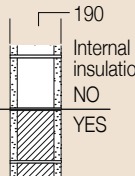
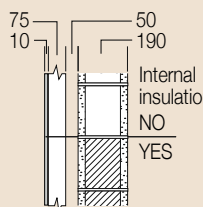
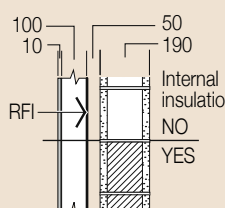
		Internal insulation in masonry units:		NO		YES	
		Net density of masonry units (kg/m ³)		>2100	≤1800	>2100	≤1800
Wall detail (Not to scale)	Component	Specification	Thermal resistance (m ² .K/W)				
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	110-mm hollow block	0.14	0.19	0.20	0.30	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		0.30	0.35	0.36	0.46	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	110-mm hollow block	0.14	0.19	0.20	0.30	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Plasterboard	10-mm gypsum	0.06	0.06	0.06	0.06	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		0.50	0.55	0.56	0.66	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	110-mm hollow block	0.14	0.19	0.20	0.30	
	Reflective airspace	50-mm ventilated	0.55	0.55	0.55	0.55	
	Reflective airspace	100-mm with RFI	0.61	0.61	0.61	0.61	
	Plasterboard	10-mm gypsum	0.06	0.06	0.06	0.06	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		1.52	1.57	1.58	1.68	

		Internal insulation in masonry units:		NO		YES	
		Net density of masonry units (kg/m ³)		>2100	≤1800	>2100	≤1800
Wall detail (Not to scale)	Component	Specification	Thermal resistance (m ² .K/W)				
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	110-mm hollow block	0.14	0.19	0.20	0.30	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Internal masonry leaf	90-mm hollow block	0.12	0.17	0.14	0.22	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		0.56	0.66	0.64	0.82	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	110-mm hollow block	0.14	0.19	0.20	0.30	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Internal masonry leaf	110-mm hollow block	0.14	0.19	0.20	0.30	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		0.58	0.68	0.70	0.90	

140-mm wall combinations

		Internal insulation in masonry units:		NO		YES	
		Net density of masonry units (kg/m ³)		>2100	≤1800	>2100	≤1800
Wall detail (Not to scale)	Component	Specification	Thermal resistance (m ² .K/W)				
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	140-mm hollow block	0.16	0.21	0.27	0.40	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		0.32	0.37	0.43	0.56	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	140-mm hollow block	0.16	0.21	0.27	0.40	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Plasterboard	10-mm gypsum	0.06	0.06	0.06	0.06	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		1.82	1.57	1.63	1.76	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	140-mm hollow block	0.16	0.21	0.27	0.40	
	Reflective airspace	50-mm ventilated	0.55	0.55	0.55	0.55	
	Reflective airspace	100-mm with RFI	0.61	0.61	0.61	0.61	
	Plasterboard	10-mm gypsum	0.06	0.06	0.06	0.06	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		1.54	1.59	1.65	1.78	

190-mm wall combinations

		Internal insulation in masonry units:		NO		YES	
		Net density of masonry units (kg/m ³)		>2100	≤1800	>2100	≤1800
Wall detail (Not to scale)	Component	Specification	Thermal resistance (m ² .K/W)				
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	190-mm hollow block	0.18	0.23	0.38	0.54	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		0.34	0.39	0.54	0.70	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	190-mm hollow block	0.18	0.23	0.38	0.54	
	Airspace	50-mm ventilated	0.14	0.14	0.14	0.14	
	Plasterboard	10-mm gypsum	0.06	0.06	0.06	0.06	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		0.54	0.59	0.74	0.90	
	Outdoor air film		0.04	0.04	0.04	0.04	
	External masonry leaf	190-mm hollow block	0.18	0.23	0.38	0.54	
	Reflective airspace	50-mm ventilated	0.55	0.55	0.55	0.55	
	Reflective airspace	100-mm with RFI	0.61	0.61	0.61	0.61	
	Plasterboard	10-mm gypsum	0.06	0.06	0.06	0.06	
	Indoor air film		0.12	0.12	0.12	0.12	
	TOTAL THERMAL RESISTANCE, R (m².K/W)		1.56	1.61	1.76	1.92	

9.4

WORKED EXAMPLE

Purpose of the worked example

The purpose of the following worked example is to demonstrate the steps to be followed when performing manual calculations or when preparing computer software for the analysis and design of masonry. The worked example also serve the purpose of demonstrating the origin of the Standard Designs which are based on similar masonry capacity considerations. The worked example is not intended to analyze or design all parts of the particular structure; it deals only with enough to demonstrate the design method.

Set out in the worked example are calculations demonstrating the derivation of R values for hollow concrete masonry, with or without added insulation and making allowance for thermal bridging.

Design and detailing

All design and detailing shall comply with the requirements of AS 3700 and the state building regulations.

Masonry properties

The worked examples in this chapter are based on masonry properties complying with the General Specification set out in **Part C:Chapter 2**, modified as noted in the calculations and as noted below.

Hollow concrete blocks

Width 90 mm, 110 mm, 140 mm and 190 mm

Height 190 mm

Length 390 mm

Face-shell bedded

Average face-shell thickness,

$$t_{s,av} = 28 \text{ mm for } 90 \text{ mm, } 110 \text{ mm and } 140 \text{ mm units}$$

$$t_{s,av} = 33 \text{ mm for } 190 \text{ mm units}$$

Material density as noted in the example.

Mortar joints

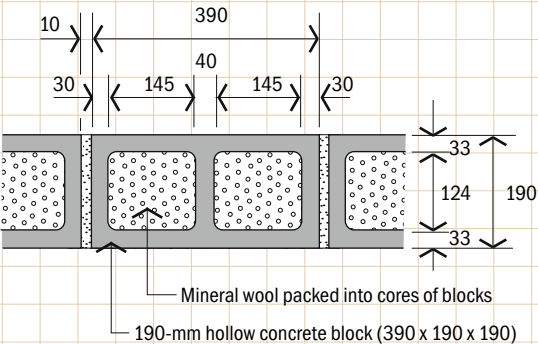
Mortar type M3 (or M4)

Joint thickness 10 mm

GO TO WORKED EXAMPLE →

DESIGN BRIEF

For 190-mm hollow concrete blocks of density 2000 kg/m³ with internal mineral wool insulation, calculate the thermal resistance (R).



SECTION OF INSULATED CONCRETE MASONRY BLOCK

Note on Basis of Calculations

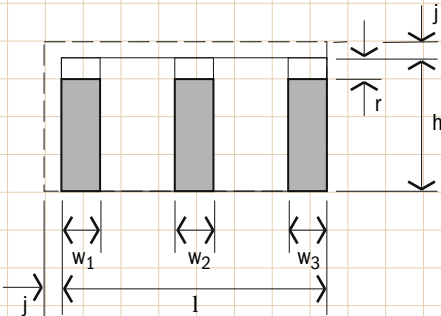
The following calculations are based on the recommendations of the paper by H.A. Trethowen *R Values that are made-to-measure* Building Research Association of New Zealand (Reprinted from ASHRAE Transactions Vol. 91 Part 2 1986), with or without added insulation and making allowance for thermal bridging.

DIMENSIONS

Block length	Block height
$l = 390 \text{ mm}$	$h = 190 \text{ mm}$
Block thickness	Face-shell thickness
$t = 190 \text{ mm}$	$s_1 = 33 \text{ mm}$
	$s_2 = 33 \text{ mm}$
Web rebate	Web thickness (average)
$r = 0 \text{ mm}$	$w_1 = 30 \text{ mm}$
	$w_2 = 40 \text{ mm}$
Joint thickness	$w_3 = 30 \text{ mm}$
$j = 10 \text{ mm}$	

AREA RATIOS AT WEBS AND CORES

Assume face-shell bedding of hollow blocks. There will be an air space above and at the end of each block.



Web area ratio

$$\frac{A_w}{A_t} = \frac{(w_1 + w_2 + w_3) (h - r)}{(l + j) (h + j)}$$

$$= \frac{(30 + 40 + 30) (190 - 0)}{(390 + 10) (190 + 10)}$$

$$= 0.238$$

Core area ratio

$$\frac{A_c}{A_t} = \frac{(l - w_1 - w_2 - w_3) (h - r)}{(l + j) (h + j)}$$

$$= \frac{(390 - 30 - 40 - 30) (190 - 0)}{(390 + 10) (190 + 10)}$$

$$= 0.689$$

Web rebate ratio

$$\frac{A_r}{A_t} = \frac{(w_1 + w_2 + w_3) r}{(l + j) (h + j)}$$

$$= \frac{(30 + 40 + 30) 0}{(390 + 10) (190 + 10)}$$

$$= 0$$

Joint air space ratio

$$\frac{A_j}{A_t} = \frac{(l + h + j) j}{(l + j) (h + j)}$$

$$= \frac{(390 + 190 + 10) 10}{(390 + 10) (190 + 10)}$$

$$= 0.074$$

THERMAL CONDUCTIVITY

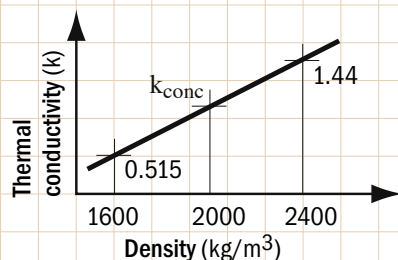
Density of concrete

$$\rho_{\text{conc}} = 2000 \text{ kg/m}^3$$

Thermal conductivity of concrete

$$k_{\text{conc}} = 1.44 - \left[\frac{2400 - 2000}{2400 - 1600} \right] (1.44 - 0.515)$$

$$= 0.978 \text{ W/m.K}$$



Thermal conductivity of mineral wool insulation

$$k_{\text{ins}} = 0.045 \text{ W/m.K}$$

THERMAL RESISTANCE

Resistance of webs

$$R_w = \frac{(t - s_1 - s_2)}{k_{\text{conc}}}$$

$$= \frac{(190 - 33 - 33)}{0.978 \times 1000}$$

$$= 0.127 \text{ m}^2.\text{K/W}$$

Resistance of core insulation

$$R_w = \frac{(t - s_1 - s_2)}{k_{\text{ins}}}$$

$$= \frac{(190 - 33 - 33)}{0.045 \times 1000}$$

$$= 2.75 \text{ m}^2.\text{K/W}$$

Resistance of web rebates (air gap)

$$R_r = 0.14 \text{ m}^2.\text{K/W}$$

Resistance of joints (air gap)

$$R_j = 0.14 \text{ m}^2.\text{K/W}$$

Effective resistance of webs/cores/rebates/joints

$$R_e = \frac{1}{\frac{A_w/A_t}{R_w} + \frac{A_c/A_t}{R_c} + \frac{A_r/A_t}{R_r} + \frac{A_j/A_t}{R_j}}$$

$$= \frac{1}{\frac{0.238}{0.127} + \frac{0.689}{2.75} + \frac{0}{0.14} + \frac{0.074}{0.14}}$$

$$= 0.374 \text{ m}^2.\text{K/W}$$

Resistance of outer face-shell

$$R_{s1} = \frac{s_1}{k_{\text{conc}}}$$

$$= \frac{33}{0.978 \times 1000}$$

$$= 0.034 \text{ m}^2.\text{K/W}$$

Resistance of inner face-shell

$$R_{s2} = \frac{s_2}{k_{\text{conc}}}$$

$$= \frac{33}{0.978 \times 1000}$$

$$= 0.034 \text{ m}^2.\text{K/W}$$

Total thermal resistance of concrete block

$$R = R_{s1} + R_e + R_{s2}$$

$$= 0.034 + 0.374 + 0.034$$

$$= 0.45 \text{ m}^2.\text{K/W}$$

This is the thermal resistance of the concrete block and any internal insulation. To it must be added the thermal resistance of the following:

- External air film
- Internal air film
- Cavity air spaces
- Other materials and leaves
eg, cladding
render
plasterboard
other masonry leaves