The Mass-Enhanced R-value
of
Precast Concrete Sandwich Panels

An Industry Standard

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Contents

Abbreviations

ABCB - Australian Building Codes Board

ASHRAE – American Society of Heating Refrigeration and Air-conditioning Engineers

BCA - Building Code of Australia

DTS – Deemed-to-Satisfy (a compliance method in the BCA)

NPCAA – National Precast Concrete Association Australia

WHS – Workplace Health and Safety

Summary

This document describes the background and details of an Industry Standard for the determination of a Mass-Enhanced R-value of precast concrete sandwich panel wall elements.

The Mass-Enhanced R-value of a precast concrete sandwich panel wall is that R-value that provides the same energy loads (for heating & cooling) as a wall of lightweight construction. The Mass-Enhanced R-value is derived from the Steady State R-value taking into account the beneficial effects of mass.

Deemed-to-Satisfy (DTS) R-values for wall elements are given in the Building Code of Australia (BCA). The Mass-Enhanced R-value described in this Standard will give calculated energy loads over a large range of buildings and designs no greater than the BCA DTS solutions. The BCA for both commercial buildings (Volume 1) and domestic buildings (Volume 2) provides for adjustments to the Steady State R-value to account for mass walls with a surface density greater than 220 kg/m^2.

This Standard describes a rigorous method to account for the mass effects of precast concrete sandwich panels. The Mass-Enhanced R-value in general allows for an improved economy of this form of construction.

Determination of the Mass-Enhanced R-value of a precast concrete sandwich panel wall element is facilitated by a publically accessible Calculator available on the National Precast Concrete Association's website at www.nationalprecast.com.au. A printed certificate available via the Calculator provides documentary evidence of compliance to the BCA – DTS requirements.

Details of the methodology employed to derive the Mass-Enhanced R-values has been peer reviewed by international experts who found it to be sound and an advance on the Steady State traditional R-value.

About National Precast Concrete Association Australia

National Precast Concrete Association Australia was established in 1990 to represent and promote the Australian precast concrete industry. Membership is made up of precast manufacturers (Corporate Members), as well as suppliers to the industry (Associate and Professional Associate Members), overseas precast manufacturers (Overseas Members) and affiliated organisations (Affiliate Members). National Precast members manufacture high quality precast construction elements such as walling, flooring, structural sections, drainage, civil and environmental products.

MISSION
National Precast's mission is to be the recognised agency of the Australian precast concrete industry promoting and representing manufacturers of high quality factory-made precast concrete components and promoting precast concrete as the material of choice to the building and civil construction industry.

This is achieved by:-

- promoting Members' products through the website, publications and exhibitions
- representing the precast concrete industry to government and other authorities
- participating in industry-related technical activities including developing and improving standards and specifications
- providing technical advice to specifiers and potential clients
- referring Members to specifiers and potential clients
- conducting training and information events
- providing resources to tertiary education institutions
- promoting best-practice in occupational health and safety in the workplace
- promoting best-practice in product design and manufacturing processes
- sourcing and disseminating new and relevant industry information
- creating opportunities for Members to network among themselves and with others in the construction industry.

Precast as a Sustainable Construction Solution

Sustainable design takes into consideration the environment, society and economy. Precast concrete's inherent properties make it a natural choice for achieving sustainability in today's modern buildings. Locally manufactured using local products (lower transport costs) in reuseable moulds, precast produces minimal waste and most manufacturing waste is recycled. Recycled or waste materials can be included in the concrete mix, such as slag, flyash, aggregate, steel and water. Exact elements are delivered to site meaning fast construction, less disruption to neighbouring properties, less site trades (WHS benefits) and less site waste (less transportation and disposal of waste). Precast concrete's low water-cement ratio means precast is extremely durable. Its long life offers minimal maintenance and reuseable, recyclable structures which contain less concrete and steel and absorb CO_2. Structures are also fire resistant and perform well acoustically. When incorporated into passive solar design, the high thermal mass of precast concrete can reduce heating and cooling costs.

Introduction: Mass, the 'M-Factor' Method and the BCA

It has been long understood that thermally massive building elements reduce the instantaneous heat transmission under transient conditions. This in turn delivers reduced maximum temperatures in un-air-conditioned buildings, a reduction in the overall energy load for heating and cooling in conditioned buildings, and can also reduce the peak loads. The Australian Government's Your Home Manual (DCCEE, 2010) says "*Appropriate use of thermal mass throughout your home can make a big difference to comfort and heating and cooling bills*" and further "*Thermal mass is particularly beneficial where there is a big difference between day and night outdoor temperatures*." Building regulations based only on the Steady State R-value (or U-value) of elements do not account for this effect. Hunn (1997) and others have detailed a number of techniques aimed at expressing the benefits of thermal mass.

During the 1970s the Masonry Industry Committee (MIC)[1] in the USA developed the M-Factor concept to account for the mass effect in exterior walls of buildings (MIC, 1976). The M-Factor provided a correction factor to conventional Steady State heat flow through massive building elements. The product of the M-Factor and the Steady State R-value gives a Mass-Enhanced R-value.

$R' = m * R$ ………………………….…………… Eq(1)

where R' is the Mass-Enhanced R-value

m is the M-Factor, and

R is the Steady State R-value.

By the late 1970s the M-Factor method had found its way into a number of codes and standards in the US, including ASHRAE Standard 90-75 *Energy Conservation in New Building Design*.

Starting with the 2010 update of the Building Code of Australia (BCA), the energy efficiency provisions have been increased to a 6 Star energy rating or equivalent for new residential buildings, along with a corresponding significant increase in the energy efficiency requirements for new commercial buildings. In addition to the energy efficiency objective, functional statements and some performance requirements have been revised to recognise that the goal is greenhouse gas emission reduction, rather than energy efficiency per se. The revised Code sets stringency requirements for all elements covered by the Deemed-to-Satisfy provisions, for example, thermal resistance requirements for roof/ceiling, wall and floor elements. Earlier versions of the BCA specified the required R-value for walls as a function of the Climate Zone (see Figure 1) and also, in what seems like an echo of the M-Factor method, allowed for modifications of this value for walls of higher thermal mass and/or when shading was provided. BCA 2010 continued with allowable R-value modifications for heavyweight elements with a surface density greater than 220 kg/m^2, albeit expressed a little differently. The reasons or logic for these 'thermal mass' allowances appear never to have been documented by the ABCB.

[1] The Masonry Industry Committee consisted of a consortium that included Brick Institute of America, National Concrete Masonry Association and Portland Cement Association.

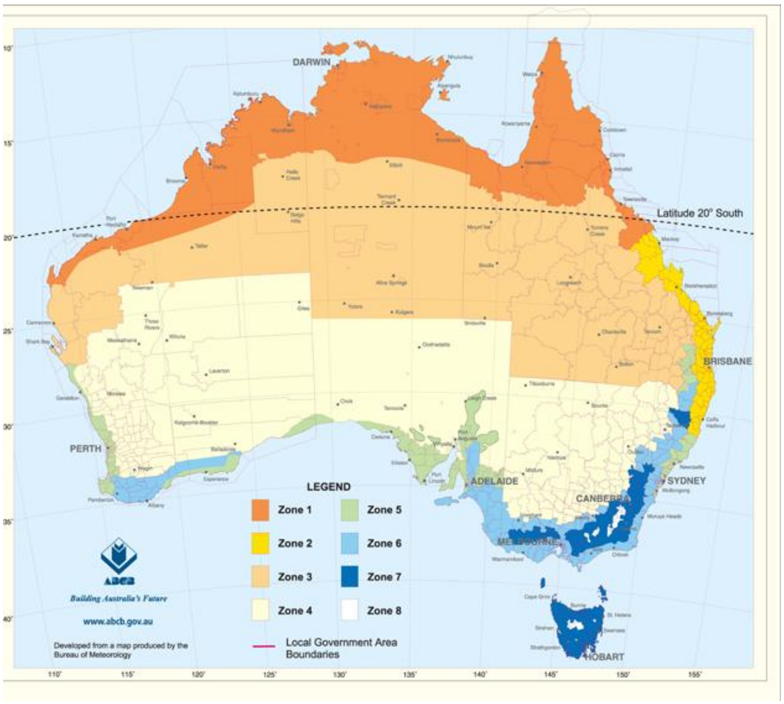


Figure 1: BCA Climate Map

Background to the 'M-Factor'

The development of the M-Factor method was done on behalf of the MIC by Hsing-Chung Yu working in a firm of consulting engineers Hankins and Anderson Inc. (Yu, 1978).

The M-Factor was defined as

$$M = Q'/Q$$

where Q' is the instantaneous heat flux through a wall calculated by computer program at a specific time, and

Q is heat flux through a wall calculated by the Steady State method, calculated as $UA(T_i - T_{design})$.

Yu used subroutines from the dynamic thermal simulation computer program NBSLD (developed by Tamami (Tom) Kusuda at the US National Bureau of Standards) to determine the value of Q' which he took to be the average January heat flow through the wall elements at 8.00am. This time was assumed to represent the most critical time for heating during the year.

The derived M-Factor chart (converted to SI units) is given in Figure 2 shown as a function of Heating Degree Days (HDD). It shows that the M-Factor correction is less in areas having large heating degree day values. To understand how this concept might be translated to Australian conditions, Table 1 shows, in approximate terms, the HDD for several BCA Climate Zones. It can be seen that as a rough guide, applying the concept across Climate Zones 4,5, 6 and 7 for buildings with a surface density that exceed 220 kg/m^2, an M-Factor of 0.82 would be a reasonable guess. In other words, if the concept were robust, multiplying a required Steady State R-value of a wall by 0.82 will give a Mass-Enhanced R-value so that its performance is the same as a "weightless" wall.

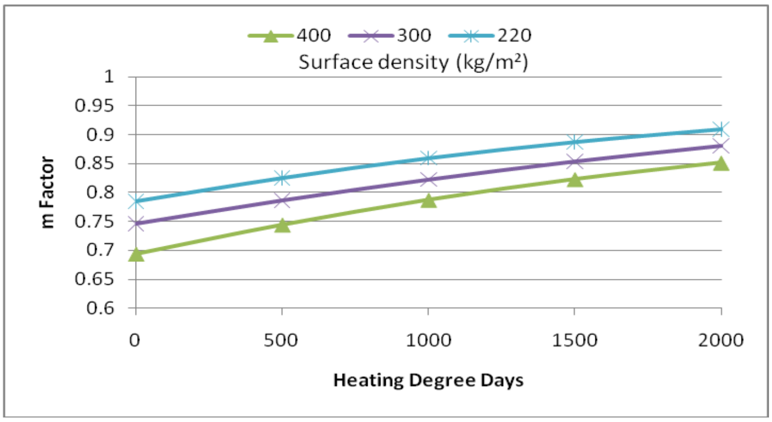


Figure 2: Mass Factor 'm' vs Heating Degree Days (HDD)

Table 1: Approximate heating degree day for selected BCA Climate Zones

Climate Zone	HDD
4	700
5	500
6	850
7	950
8	1450

Note: Refer to Climate Map Figure 1 for Zones.

The validity of the M-Factor method was however, questioned by a number of authors because of the empirical basis of its development. A conference paper by Godfrey, Wilkes and Lavine (1979) concluded "the M-Factor, as defined by Yu, has been shown to be without technical justification" and recommended that "reference to the M-Factor method in codes and standards be deleted" (p 50). A larger study by Childs (1980) prepared for the US Department of Energy reached the same conclusion.

In 1983 the US Oak Ridge National Laboratory (Childs, Courville, & Bales, 1983) conducted research aimed at addressing the controversy regarding building mass and energy consumption for heating and cooling, and in particular Building Code requirements. They investigated a number of techniques suggested for taking into account the beneficial effects of mass (including the M-Factor). They found no simple theoretical way of accounting for the mass effects because the heat flow through individual elements was dependent *inter alia* on the form of construction, orientation, colour, building use pattern, thermostat settings and climate. They did find, however, that in addition to the effect on energy consumption, mass also affected peak loads, equipment cycling, thermostat setback, and importantly it could have a beneficial effect on overall comfort.

The methodology used in the development of this Standard overcomes the various objections found in relation to the M-Factor.

A Mass-Correction Factor for Precast Concrete Sandwich Panels

The following discussions and information apply exclusively to precast concrete sandwich panels of the form shown in Figure 1.

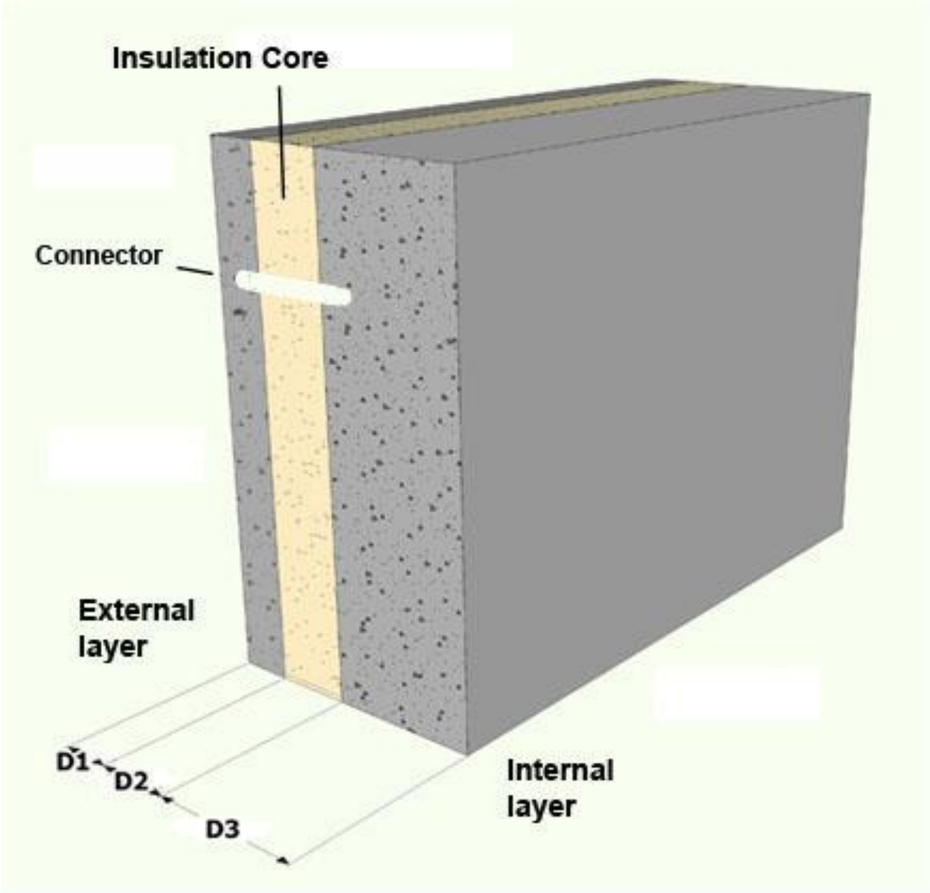


Figure 3: Precast concrete sandwich panel

The data from computer simulations of a range of case study buildings shows that thermally massive sandwich panel walls may be used to advantage in reducing the estimated overall energy load.

This effect is shown in Figure 4 for one building. The percentage reduction in total energy load is seen to vary with location (or Climate Zone).

It is clear from these results that increasing the thermal mass of the external walls (all other variables remaining constant) can produce a substantial reduction in the total energy load. The effect is greatest in climates where both summer and winter seasons are prominent (e.g. Zones 3 and 4).

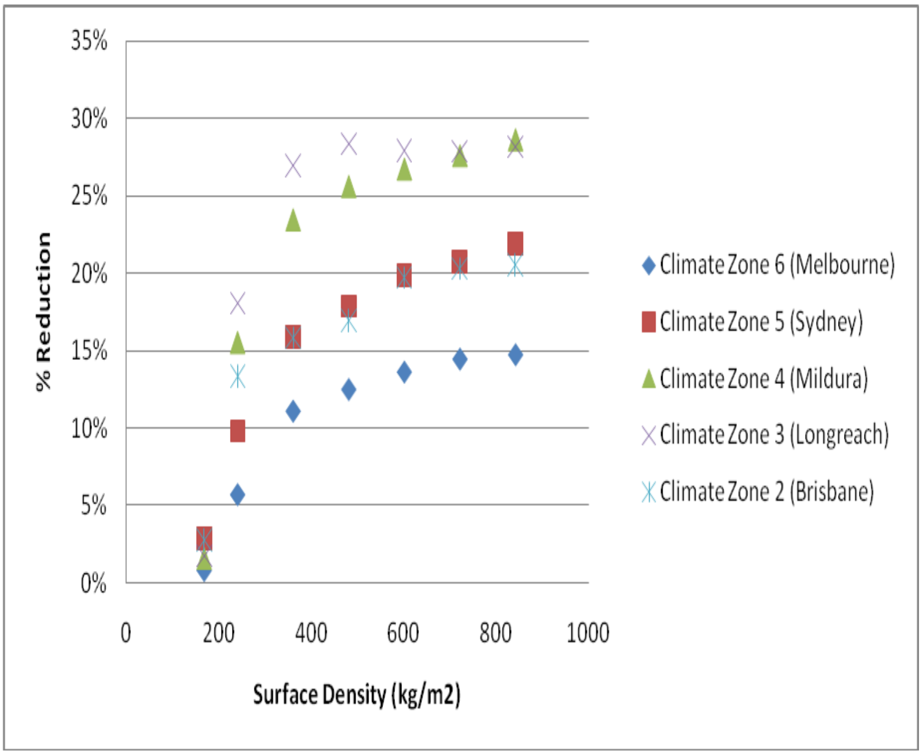


Figure 4: Surface density v reduction in total energy load for various locations

Assuming that the BCA "basic" R-value requirements in effect apply to lightweight construction, then an adjustment to these values would seem possible so that the total energy load is constant.

A **Mass-Correction Factor** may therefore be defined so that,

$$m = {R'}/{R}$$

Where *R'* is the R-value determined for massive construction at constant Q

R is the R-value specified in BCA for location, and

Q is the energy load (MJ/m^2) estimated for wall with *R*.

Determination of Mass-Correction Factor

Simulations of whole buildings involve complex input and it can be difficult to determine the impact of different factors. In order to try and narrow down some of the differences a BESTEST type building model was developed for the testing. This model is essentially a square single zone "building" 2.7m high. Four plan area variations were used including 8m*8m, 12m*12m, 16m*16m and 32m*32m. Figure 5a shows a diagram of the basic 8m *8m test building. This basic model consists of a concrete slab-on-ground, flat ceiling with the insulation R-value required by the BCA appropriate to the Climate Zone, external walls initially of lightweight construction with standard insulation as specified for the Climate Zone and standard aluminium-framed windows with glazing 3mm clear (U=7.32, SHGC=0.77) and 45% openable. The windows were equally disposed in the four facades with a total area corresponding to 18.75% of the floor area. Occupancy profiles and thermostat controls, etc were set initially to conform to a Class 5 "Office" type building. A similar multi-floor model, Figure 5b, was developed to test intermediate floors of a building.

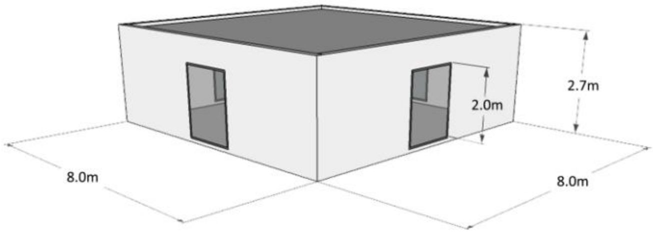


Figure 5a: Basic BESTEST building model, 8m x8m, single storey

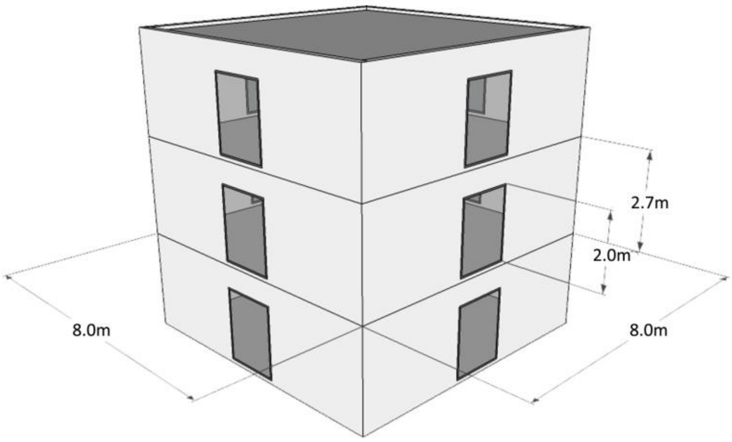


Figure 5b: Basic BESTEST building model, 8m x 8m, multi storey

Numbers of variations were tested for each Climate Zone. These included,

- Plan size variations 8m*8m, 12m* 12m, 16m*16m, 32m*32m;
- Ground floor, second or intermediate storey;

- Variations in window type, area & disposition;
- Variations in occupancy profile (commercial & domestic); and
- Variations in shading (unshaded, 720mm eaves, 2700mm eaves).

Shading is defined by the shading angle corresponding to the eave dimensions as shown in Figure 6.

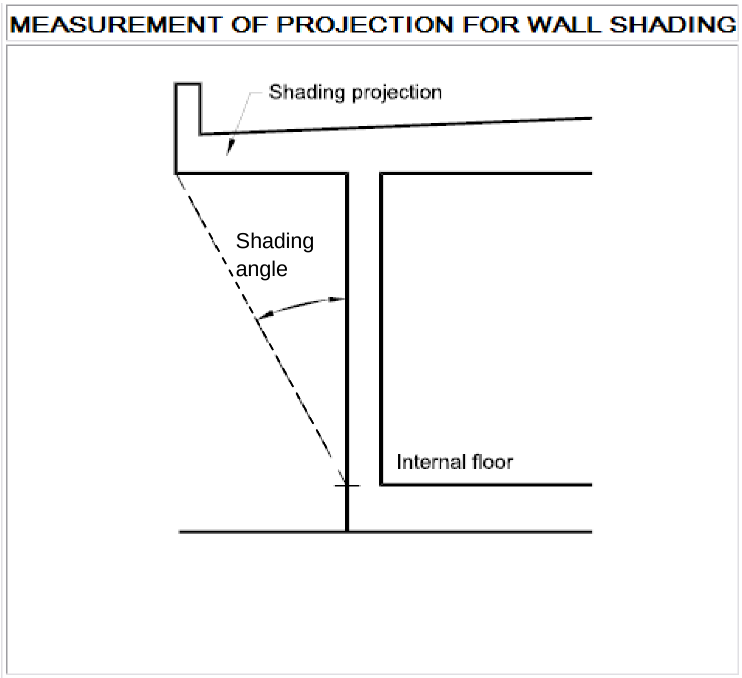


Figure 6: Definition of shading angle

All simulations were conducted using the CSIRO AccuRate energy simulation software for buildings version 1.1.4.1. MsDOS batch routines were written to perform the many simulation runs and data manipulations. These batch programs employed the sed text file editor to alter as required the AccuRate "Scratch" file that holds input data to the computational engine. Occupancy profiles (e.g. thermostat settings, casual loads, times of occupation etc) were altered to comply with BCA requirements for Class 1 and 2 buildings.

As part of the batch procedures a Fortran routine was written to interrogate the various output files and write the required data to an Excel comma delineated *.csv file for analysis.

Following the initial "lightweight" case, walls were altered to precast concrete sandwich panel construction. The internal layer thickness was varied to result in a range of surface density solutions from 169 kg/m^2 to 841 kg/m^2.

The limitation of any particular Mass-Correction Factor calculation is that it is specific to a climate and the building variation considered in the simulation. Figures 7 to 11 show the results of a series of simulations as described for several locations.

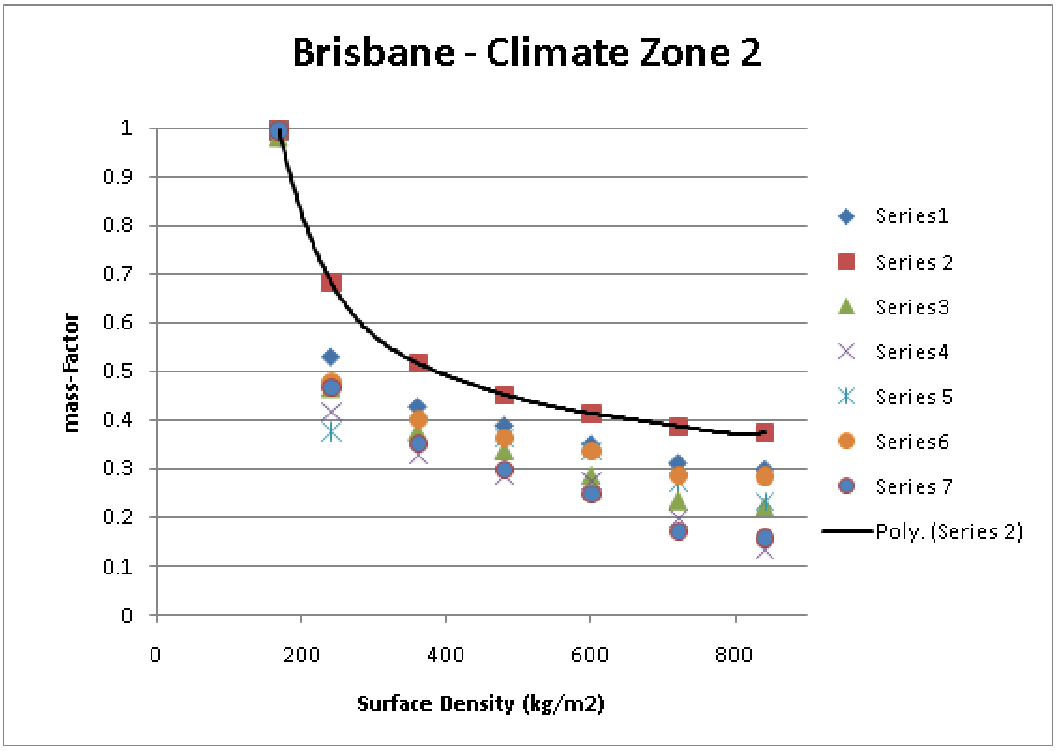


Figure 7: Simulation series for Brisbane (unshaded walls)

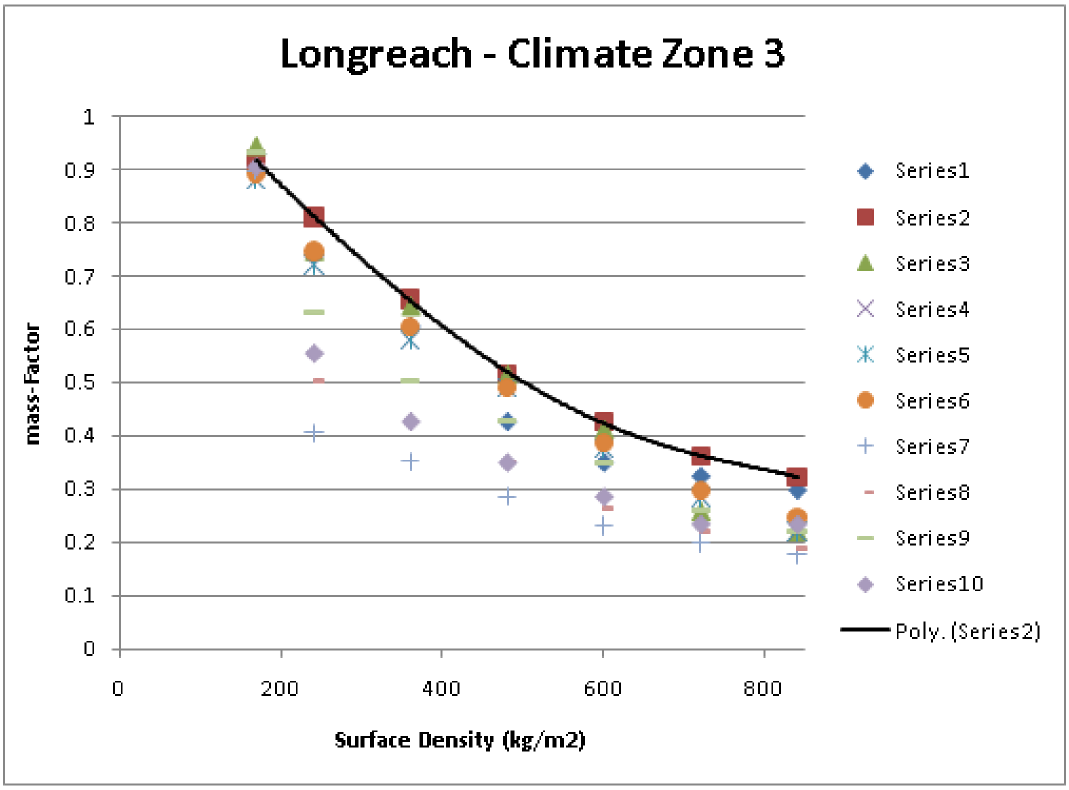


Figure 8: Simulation series for Longreach (unshaded walls)

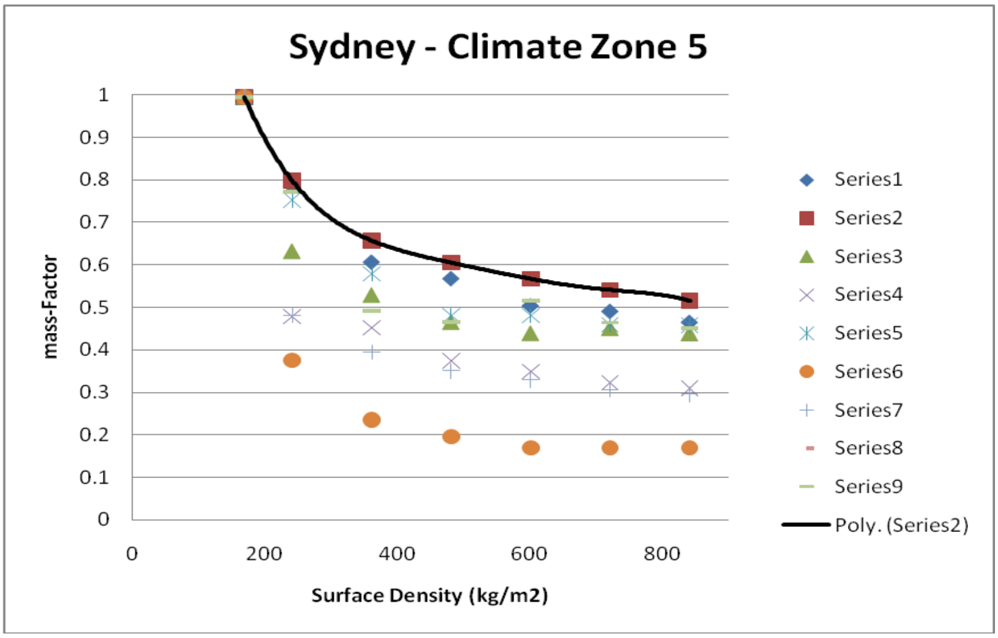


Figure 9: Simulation series for Sydney (unshaded walls)

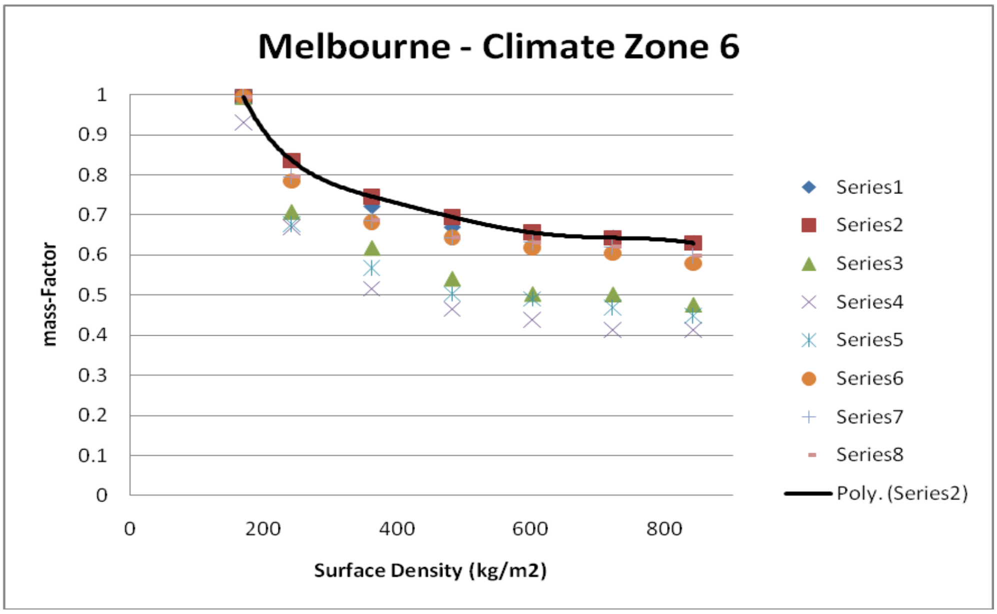


Figure 10: Simulation series for Melbourne (unshaded walls)

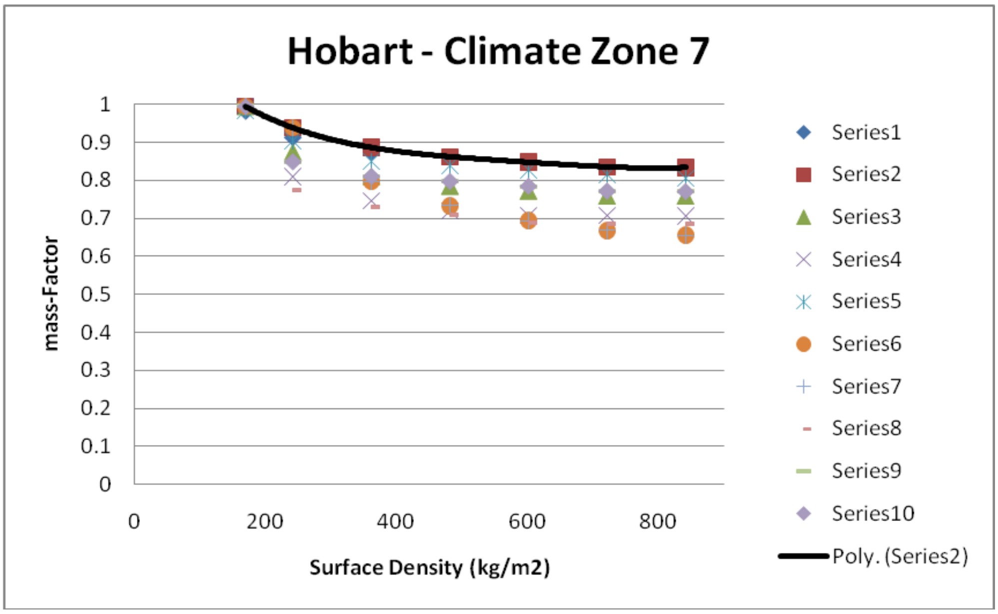


Figure 11: Simulation series for Hobart (unshaded walls)

After the full series of simulations were completed for each location corresponding to a shading configuration, a polynomial best-fit line was constructed for the series that produced the most conservative set of Mass-Correction Factors. Note all other variations will produce a lower Mass-Correction Factor, that is, the energy performance will be better than indicated by the conservative value used in the Mass-Enhanced R-value calculation.

The final Mass-Correction Factors for BCA Climate Zones 1-7 for an unshaded building are shown in Figure 12. The polynomial co-efficients of the best fit equations are given in Table A1 for the unshaded cases and Table A2 for the 45 degree shaded cases. The Mass-Correction Factor for different shading angles is found by interpolation.

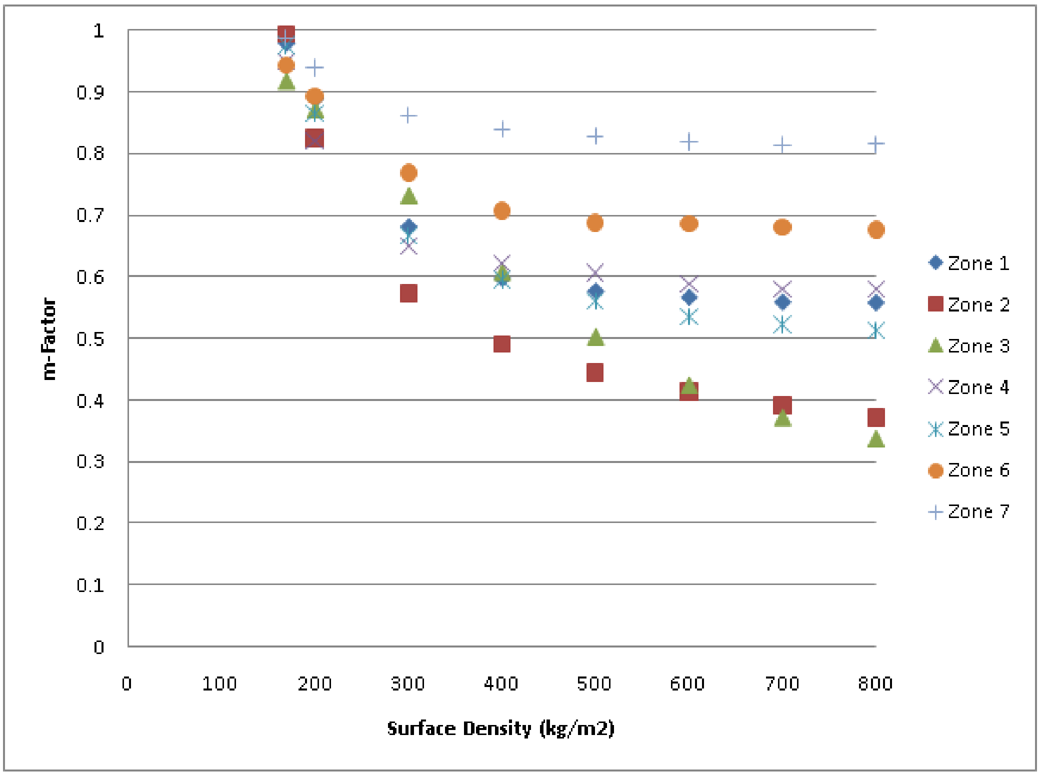


Figure 12: Composite Mass-Correction Factors (unshaded building)

Mass-Enhanced R-value

The Mass-Enhanced R-value of a concrete sandwich panel wall is calculated as

$$R_{ME} = R/m$$

Where *m* is the Mass-Correction Factor, and
R is the Steady State thermal resistance or R-value of the element.

The Mass-Enhanced R-value is determined using a spreadsheet Calculator available to the general public on the National Precast website at www.nationalprecast.com.au. A screen shot of the calculator is shown in Figure 13. The user inputs the layer thicknesses of the proposed panel, type of material, the BCA Climate Zone and shading angle.

The results show the Steady State R-value, the surface density of the wall (kg/m^2) and the Mass-Enhanced R-value.

A secure certificate showing the results may be printed. This certificate provides documentary evidence of an alternative solution that complies with the BCA Deemed-to-Satisfy requirements (see Appendix B for example).

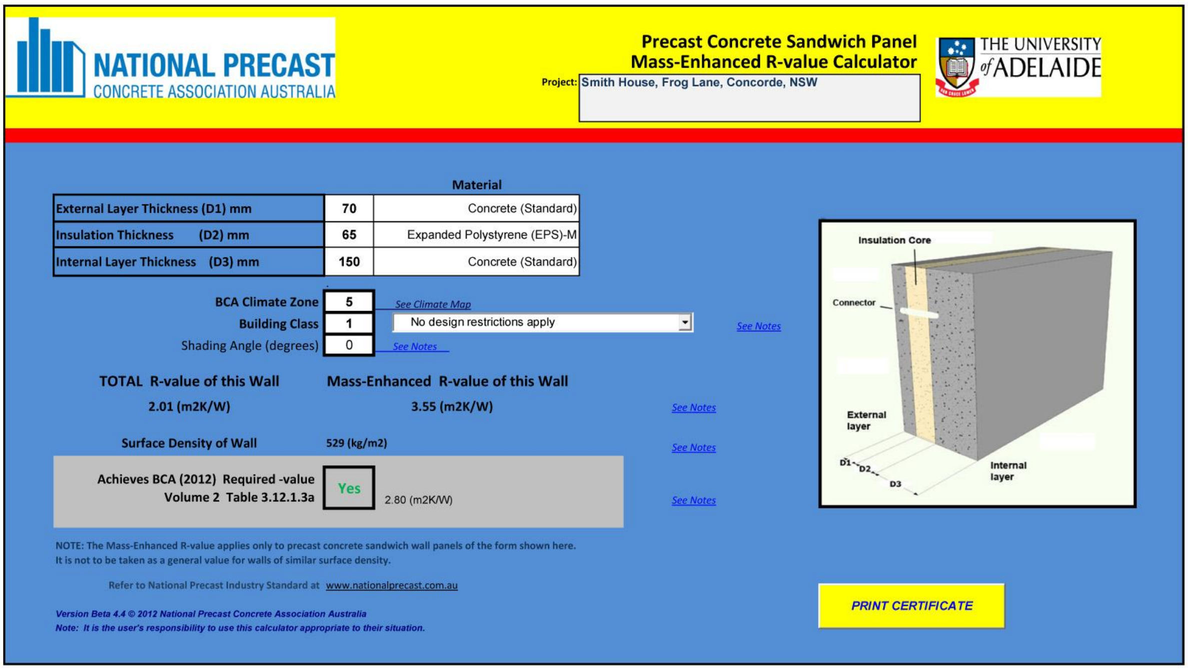


Figure 13: Screen shot Mass-Enhanced R-value Calculator

While the steady state R-value shown in the Calculator is a constant for a wall panel of a given layer thicknesses, the Mass-Enhanced R-value depends as well on the surface density, the Climate Zone, the shading condition of the wall and other factors.

Taking these many factors into account, the resultant values provided by the Calculator will always be conservative. The *actual* performance of a building may better than that indicated by the Mass-Enhanced R-value result from this Calculator, in particular if the building is carefully designed along solar passive principles.

As an example, in the colder BCA climates 6, 7 and 8 a design that provides northern windows to allow solar radiation access during winter will enable the full thermal mass effect to kick in and will reduce the requirement for supplementary heating. Likewise if these windows are adequately shaded during the summer months, the temperature stabilizing effect of the mass will reduce or eliminate the need for air-conditioning.

Corroboration of Method

Corroboration of the method is demonstrated by a series of simulated test cases. Details of the case study buildings are shown in Appendix C.

In each case the building is simulated first with a lightweight external wall with an R-value corresponding to the minimum requirement specified in the BCA for the Class of building and Climate Zone. The total energy load (MJ/m^2) for this case is then compared with the case where all the external walls have a Mass-Enhanced R-value, equivalent to the BCA minimum, as determined from the National Precast Calculator. No other changes are made in the simulations.

The results show that (within the limits of rounding errors, etc) the building with the precast concrete panel walls has an energy performance less than or equal to the lightweight wall case.

BCA Compliance Checking

The Mass-Enhanced R-value Calculator provides for checking of BCA 2011 DTS compliance.

In checking compliance against Volume 1 requirements, the provisions of Table J1.5a Parts (a) are used, however, for Climates Zones 1,2,3,4,5 and 6 the concession for a wall with a surface density not less than 220 kg/m^2, part (a) (ii) (A), is not applied.

In checking Volume 2 requirements the user is presented with the Option “No Design Restrictions Apply”. With this Option picked the provisions of Table 3.12.1.3a only are used and compared with the calculated Mass-Enhanced R-value. If an Option with “Design Restrictions” is picked, the concessions given in Table 3.12.1.3b for a wall with a surface density not less than 220 kg/m^2 are applied, but in this case the Mass Enhance R-value is not a factor and is given for information only. In these cases however, information of the required R-value of incorporated insulation is given together with the actual value. Information in the Calculator’s Notes tab draws the user’s attention to the implications of “No Design Restrictions” or “Design Restrictions” when considering Volume 2 compliance.

> In Table 3.12.1.3b BCA Volume 2, depending on the Climate Zone, various insulation options are given for walls that have a surface density not less than 220 kg/m^2. Employing any of these options will place restrictions on the building design (eg shading requirements) and impose requirements for glazing.
> Table 3.12.1.3a applies to walls with any surface density and "No design restrictions apply" (meaning no restrictions on design and glazing) when using this Table for compliance. The result is likely to be a better and more cost effective overall design solution.
> The Calculator user should be familiar with the BCA requirements and choose the appropriate option.

Appendix A

This appendix shows the results of a number of variations examined in the derivation of the Mass-Correction Factor. Note, only a small sample of the hundreds of computer simulation results are shown here. Tables A1 and A2 give the polynomial co-efficients used in the Calculator to derive the Mass-Correction Factor as a function of the Surface Density of the precast concrete sandwich panel (kg/m^2).

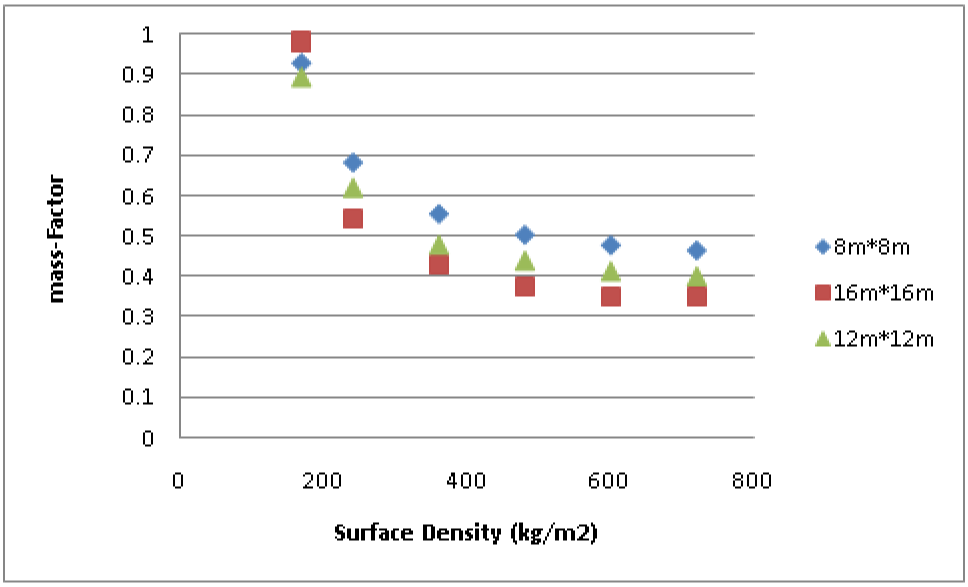


Figure A1: Effect of floor area/size – Adelaide
Smallest building 8m x 8m used for critical case.

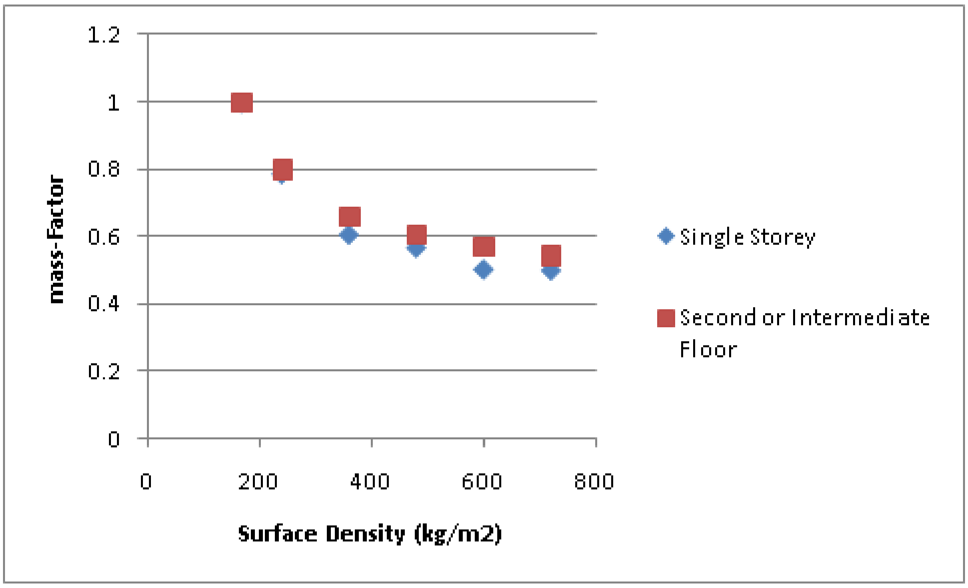


Figure A2: Effect of numbers of storey – Sydney
Number of storeys has little effect on Mass-Correction Factor – in general single storey building used for critical case.

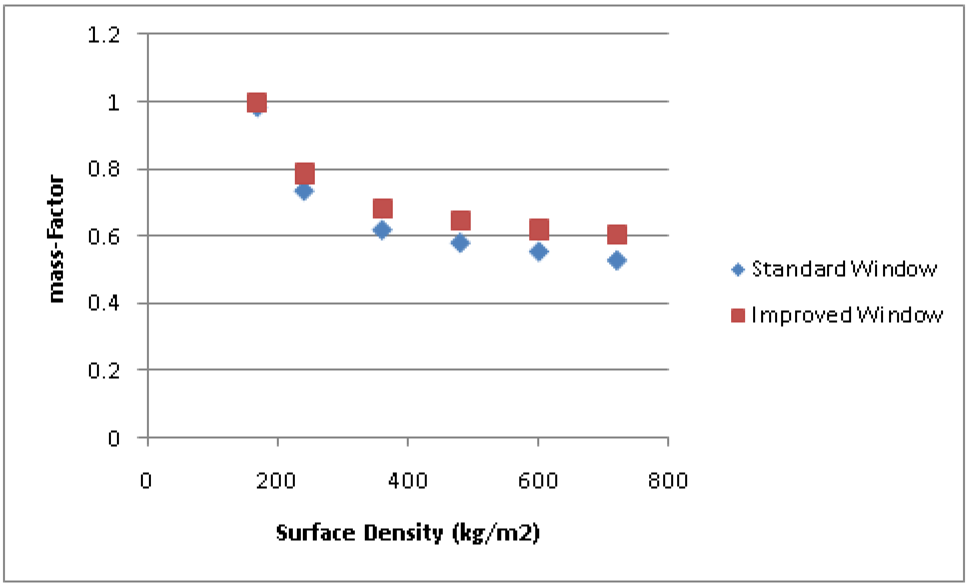


Figure A3: Effect of window type – Melbourne
Window type has little effect on Mass-Correction Factor – improved window used for critical case.

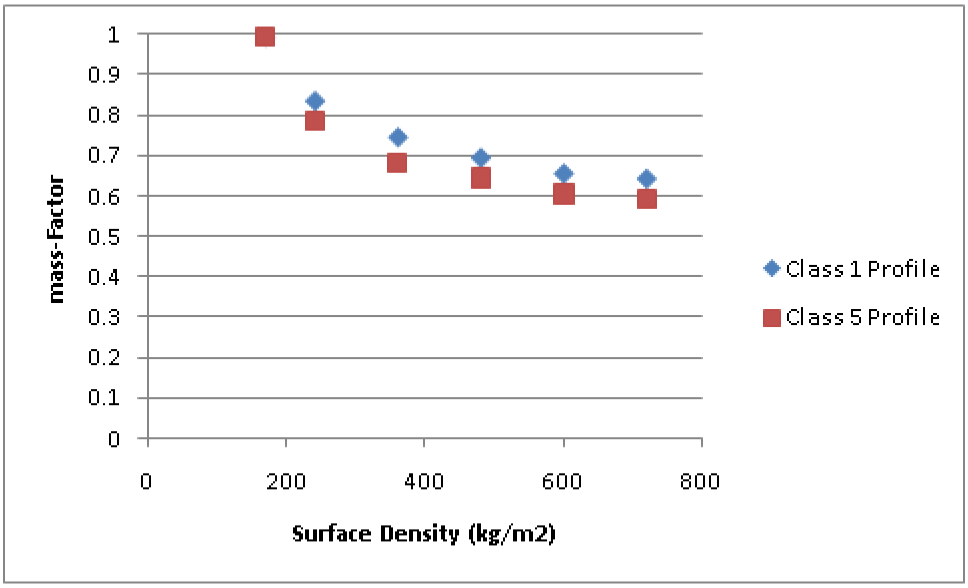


Figure A4: Effect of building occupancy profile – Sydney
Occupancy profile has little effect on the Mass-Correction Factor.

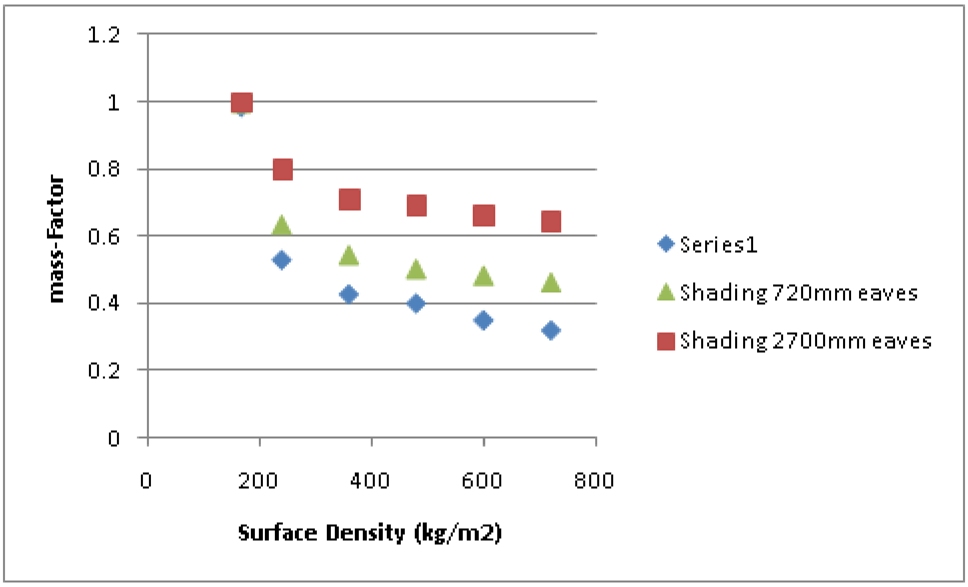


Figure A5: Effect of shading - Brisbane
Shading angle is accounted for in calculation of Mass-Correction Factor.

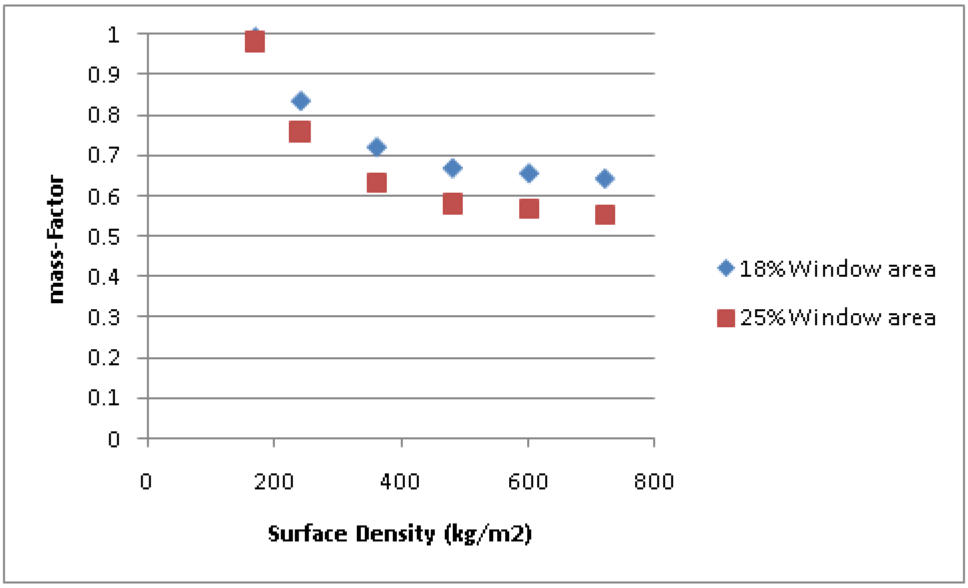


Figure A6: Effect of window/floor ratio – Melbourne
18% window produces critical case in this location.

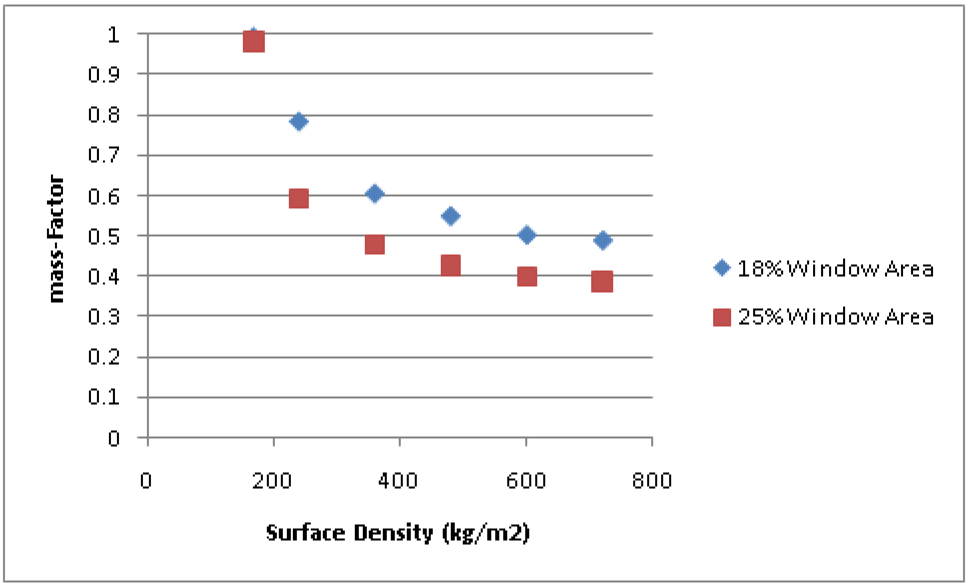


Figure A7: Effect of window/floor ratio – Sydney
18% window produces critical case in this location.

Table A1: Polynomial co-efficients for calculation of Mass-Correction Factor

Climate Zone	Polynomial Co-efficients (Unshaded)						
	x^6	x^5	x^4	x^3	x^2	x	Constant
1(1)	-8.720430E-17	2.636410E-13	-3.098720E-10	1.734790E-07	-4.287050E-05	1.558690E-03	1.322120E+00
2(2)	0.000000E+00	-3.324461E-14	1.020053E-10	-1.235888E-07	7.393153E-05	-2.199308E-02	3.016132E+00
3(3)	9.223050E-17	-3.167950E-13	4.504440E-10	-3.411340E-07	1.460420E-04	-3.373390E-02	3.742600E+00
4(4)	6.223550E-17	-2.389397E-13	3.721335E-10	-3.002620E-07	1.323206E-04	-3.037020E-02	3.479985E+00
5(5)	-1.261670E-17	7.673730E-15	4.107279E-11	-7.040176E-08	4.658492E-05	-1.463968E-02	2.424749E+00
6(6)	0.000000E+00	1.075330E-14	-2.398340E-11	1.687630E-08	-1.967170E-06	-2.126900E-03	1.296500E+00
7(7)	0.000000E+00	-1.486881E-14	4.326094E-11	-4.917368E-08	2.744981E-05	-7.654916E-03	1.701247E+00
8(8)	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	1.000000E+00

Notes:
(1) Location Darwin
(2) Location Brisbane
(3) Location Longreach
(4) Location average of Wagga Wagga & Mildura
(5) Location average Adelaide & Sydney
(6) Location Melbourne
(7) Location average of Hobart & Canberra
(8) Location Alpine (Cabramurra).

Table A2: Polynomial co-efficients for calculation of Mass-Correction Factor

Climate Zone	Polynomial Co-efficients (45 degree shading)						
	x^6	x^5	x^4	x^3	x^2	x	Constant
1(1)	0.00000E+00	-6.80954E-15	2.55814E-11	-3.66094E-08	2.56117E-05	-9.18128E-03	1.90045E+00
2(2)	0.00000E+00	-3.84134E-14	1.11925E-10	-1.27007E-07	7.00106E-05	-1.88673E-02	2.71084E+00
3(3)	1.90376E-16	-6.68195E-13	9.48694E-10	-6.95475E-07	2.77295E-04	-5.74158E-02	5.37218E+00
4(4)	6.14813E-17	-2.02079E-13	2.71324E-10	-1.90740E-07	7.42063E-05	-1.53263E-02	2.18501E+00
5(5)	0.00000E+00	-9.82770E-15	3.24800E-11	-4.15062E-08	2.57635E-05	-7.98765E-03	1.77738E+00
6(6)	2.26827E-17	-8.03260E-14	1.14641E-10	-8.40924E-08	3.34104E-05	-6.98591E-03	1.54431E+00
7(7)	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	9.95000E-01
8(8)	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E+00

Notes: (1) Location Darwin
(2) Location Brisbane
(3) Location Longreach
(4) Location average of Wagga Wagga & Mildura
(5) Location average Adelaide & Sydney
(6) Location Melbourne
(7) Location average of Hobart & Canberra
(8) Location Alpine (Cabramurra).

Appendix B – Sample certificate of compliance

NATIONAL PRECAST
CONCRETE ASSOCIATION AUSTRALIA

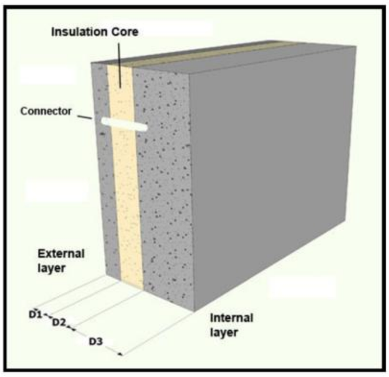
Precast Concrete Sandwich Panel
Total R-value and Mass Enhanced R-value

Project	Smith House, Frog Lane, Concorde, NSW		
BCA Building Class	**1**		
BCA Climate Zone	**5**		
Construction			**Material**
External Layer	**Dimension D1**	**70 mm**	Concrete (Standard)
Insulation Layer	**Dimension D2**	**65 mm**	Expanded Polystyrene (EPS)-M
Internal Layer	**Dimension D3**	**150 mm**	Concrete (Standard)
			Shading Angle **0 deg**

System Mass-Enhanced R-value **3.55 (m2K/W)**

System Steady State R-value **2.01 (m2K/W)**

Minimum Required R-Value BCA (Vol 2) 2.80 (m2K/W)



This certificate constitutes documentary evidence of an Alternative Solution that complies with the Building Code of Australia (2012) - Elemental Deemed-to-Satisfy requirements, Volume 2, Section 3.12.1.4 External Walls

Disclaimer
While every effort has been made to ensure the R-values given are accurate, the document has been compiled as a design aid and the input data should be verified before any person uses it. Any user of the calculator will do so at his/her own risk. The user should also establish the applicability of the R-values in relation to specific circumstances and applications. In circumstances when third party proprietary insulation products are used they should be installed in accordance with the manufacturer's recommendations.

NOTE: The Mass-Enhanced R-value applies only to precast concrete sandwich wall panel of the form shown here. It is not be taken as a general value for walls of similar surface density. Calculations in accordance with provisions of AS/NZS 4859.1-2002 & ISO 6946.

THE UNIVERSITY of ADELAIDE

17/05/2012

Precast Concrete Sandwich Panel R-Value Calculator Version Beta 4.4

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Appendix C

These examples demonstrate that a building with precast concrete panel sandwich panel walls with a Mass-Enhanced R-value equivalent to the minimum required R-value will have an equal or better energy performance.

BCA Volume 2

1 - Detached single storey detached house

Location	BCA Climate Zone	Minimum required R-value for lightweight wall m^2K/W (1)	Sandwich Panel Dimensions to achieve equivalent Mass Enhance R-value (3)	Steady State R-value of Panel m^2K/W	Lightweight Wall Performance Heating & Cooling MJ/m2	Concrete Sandwich Panel Heating & Cooling MJ/m2
Darwin	1	2.4(2)	50/50/100	1.57	574.5	579.4
Brisbane	2	2.8	50/40/100	1.31	H=5.7 C=66.1 Tot=71.8	H=2.6 C=64.0 Tot=66.5
Longreach	3	2.8	50/40/100	1.31	413.3	374.4
Wagga Wagga	4	2.8	50/60/100	1.83	163.2	141.5
Sydney	5	2.8	50/60/100	1.83	45.9	39.3
Melbourne	6	2.8	50/70/100	2.09	121.2	109.7
Hobart	7	2.8	50/80/100	2.35	193.1	181.5
Cabramurra	8	3.8	50/135/100	3.79	482.9	481.5

(1) See BCA Section3.12.1.4, unless indicated no shading applied
(2) Shading with angle 30 degree applied.
(3) Panel core insulation extruded polystyrene (XPS).

2 - Detached two storey house

Location	BCA Climate Zone	Minimum required R-value for lightweight wall m^2K/W (1)	Sandwich Panel Dimensions to achieve equivalent Mass Enhance R-value (4)	Steady State R-value of Panel m^2K/W	Lightweight Wall Performance Heating & Cooling MJ/m2	Concrete Sandwich Panel Heating & Cooling MJ/m2
Darwin	1	2.4(3)	50/50/100	1.57	664.8	676.7
Brisbane	2	2.4 (2)	50/40/100	1.31	H=9.7 C=100.0 Tot=109.7	H=5.6 C=88.0 Tot=93.6
Longreach	3	2.4 (2)	50/35/100	1.18	358.7	320.9
Wagga Wagga	4	2.4 (2)	50/55/100	1.70	160.4	151.8
Sydney	5	2.4 (2)	50/55/100	1.70	81.9	67.0
Melbourne	6	2.8	50/75/100	2.22	113.6	103.5
Hobart	7	2.8	50/80/100	2.48	149.3	151.5
Cabramurra	8	3.8	50/135/100	3.79	342.5	328.8

(1) See BCA Section 3.12.1.4
(2) Shading with 15 degree angle applied.
(3) Shading with 30 degree angle applied
(4) Panel core insulation expanded polystyrene (EPS) – VH grade.

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