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Ozwall Manufacturing Pty Ltd

Thermal Resistance of Insulated and Uninsulated Ungrouted Ozwall Partitions

This report has been prepared on behalf of **ELECTRONIC BLUEPRINT** by:

Rod Johnston
B Tech, M Eng Sc, MICD, CP Eng, NPER, MIE Aust, RPEQ

Quasar Management Services Pty Ltd
Incorporated in NSW ABN 21 003 954 210

Design Detail & Deliver Pty Ltd Trading as **ELECTRONIC BLUEPRINT** ABN 31 088 338 532 Inc in NSW
49A Parklands Road, Mt Colah NSW 2079, Australia www.electronicblueprint.com.au
Phone: +61 2 4360 2255 Fax:+61 2 4360 2256 email info@electronicblueprint.com.au

Thermal Resistance of Insulated and Uninsulated Ungrouted Ozwall Partitions

Scope

This report considers thermal resistance of 120 mm Ozwall partitions (without concrete or grout fill) both with and without Tontine polyester insulation placed in the cores. This form of construction may be used to enhance the thermal performance of buildings, in particular, housing.

Background

All building design must comply with the relevant State Building Regulations, which are set out in the BCA (Building Code of Australia) Volumes 1 and 2. The BCA defines the performance requirements, generally in very broad terms, and the means of compliance through:

- Deemed-to-Satisfy Provisions, which may include:
    - Acceptable Construction Manuals (e.g. nominated Australian Standards and the like)
    - Acceptable Construction Practice (e.g. forms of construction reproduced in the BCA itself

  or

- Alternative Solutions (e.g. Designs based on test results and engineering principles).

Each of these paths to compliance has equal status under the BCA.

Designers are often asked to incorporate new products into their designs. The performance of such products is justified by test because they are outside the scope of the various forms of construction specified by the BCA as Deemed-to-Satisfy. The requirements are set out in BCA Vol 1 Clauses A0.8, A0.9 and A0.10, and BCA Vol 2 Clauses 1.0.8, 1.0.9 and 1.0.10.

In many cases, designers prefer to use the Deemed-to-Satisfy Solutions. However, one exception is Energy Efficiency, where the Deemed-to-Satisfy provisions are not necessarily the most cost-effective means of providing the required performance. In this case, it may be preferable to use simulation software (such as AccuRATE) to verify performance as an Alternative Solution.

Methodology to be Used

This report provides the properties of Ozwall partitions with and without Tontine polyester insulation, relevant to its verification in buildings assessed using software such as AccuRATE as an Alternative Solution, in accordance with the following BCA Clauses.

Alternative Solutions [BCA Vol 2 Clause 1.0.8]

→ Assessment Method using Verification Method in the BCA [BCA Vol 2 Clause 1.0.9(b)(i)]

→ Relevant Performance Requirement [BCA Vol 2 Clause 1.0.10(c)]

→ Verification Methods [BCA Vol 2 Clause V2.6]

The methodology used to determine the thermal resistance is as follows:

1. **Calculation**
   Calculate the theoretical thermal resistance of the Ozwall/Tontine composite by determining resistance to the combined parallel heat flow through webs and insulation-filled cores, and then adding this to the series resistance to heat flow through the two face shells.

   This is a well established methodology supported by test and theory, and has been adopted for the inclusion of thermal resistances into the AccuRATE simulation software by the CSIRO.

2. **Check by Test**
   Compare the calculated thermal resistance to the values determined by test carried out by United Bonded Fabrics Pty Ltd (Test No TD 0620, 21/4/06) and reproduced in Appendix A.

3. **Check by Comparison to Similar Forms of Construction**
   Use engineering judgment based on the performance of similar forms of construction to check the credibility of both the theoretical and test values.

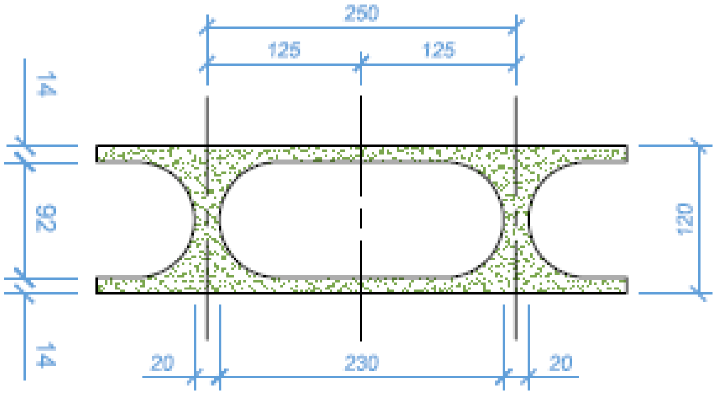
4. **Recommended Design Value**
   Giving consideration to the process above, the reliability of the data and the level of testing, adopt a value (a little less than each of the above values) that will be recommended for use in design.

Part 1 - Calculation

Geometry of Ozwall Panels
The following diagram shows the geometry of the glass-reinforced gypsum-plaster Ozwall partitions. The essential features are:

- Face shell thickness of 14 mm
- Web thickness of 20 mm at its narrowest point. In the case where there is no polyester insulation, the 20 mm thickness will be used. This is conservative, ignoring the insulating effect of the thickened part of the webs.
- Average web thickness of 40 mm in the case where there is polyester insulation inserted into the core. This is also conservative. Although there is an increased contribution by the web, the contribution of the insulation is probably underestimated (because of the assumed shorter insulation-filled core).

On balance, considering each of the above points, the assumed geometry is considered to be appropriate.



Thermal Conductivity of Plaster Partitions
The Thermal Conductivity, k, for the glass-reinforced gypsum-plaster used to manufacture the Ozwall partitions, used in the theoretical determination for the wall system, is 0.23 m^2.K/W. The basis of this is value is as follows:

- The published Thermal Conductivity, k, for plasterboard with a density of 880 kg/m^3 is 0.17 m^2.K/W. (Williamson, T., 2001). Because the plaster used in the partitions is probably more dense that ordinary plasterboard, a slightly higher value would be appropriate.
- The published Thermal Conductivity, k, for fibre cement with a density of 1,360 kg/m^3 is 0.25 m^2.K/W. (Williamson, T., 2001). Because the plaster used in the partitions is less dense than fibre cement, a slightly lower value would be appropriate.

On balance, considering each of the above points, a conservative thermal conductivity of 0.023 m^2.K/W is considered to be appropriate.

Thermal Conductivity of Tontine Polyester Insulation

The Thermal Conductivity, k, of Tontine Polyester Insulation, used in the theoretical determination for the wall system, is 0.060 m^2.K/W. The basis of this is value is as follows:

- The following tabulation of the Thermal Resistance, R, for various thicknesses of Tontine polyester insulation is available from the Tontine web site. The corresponding values of Thermal Conductivity, k, to be used in the calculations, have been calculated from the thermal resistances and thicknesses.

Published Thermal Resistance and Calculated Thermal Conductivity of Tontine Polyester Insulation

Thickness mm	Published Thermal Resistance, R m^2.K/W [Note1]	Calculated Thermal Conductivity, k W/m.K [Note2]
60	1.0	0.060
75	1.2	0.063
90	1.5	0.060
115	2.0	0.058
135	2.5	0.054

Notes
1. Thermal Resistance, R, for various thicknesses of Tontine polyester insulation is available from the Tontine web site
2. Thermal Conductivity, k, to be used in the calculations, have been calculated from the thermal resistances and thicknesses.

- The published values are probably a little conservative to guard against litigation. Therefore a lower thermal conductivity could be justified.

- Because it is possible the at the insulation could become compressed during its insertion into the Ozwall partitions, a higher thermal conductivity could be warranted.

On balance, considering each of the above points and making allowance for considerable compression of the insulation, a thermal conductivity of 0.070 m^2.K/W is considered to be appropriate incorporating the required degree of conservatism.

Thermal Resistance of Cores

The Thermal Resistance, R, of the air-filled cores in Ozwall partitions has been assumed to be 0.14, used in the theoretical determination for the wall system. The basis of this is value is as follows:

- The Thermal Resistance, R, of the air-filled cores is used in preference to assuming a Thermal Conductivity, k, of air and assuming an air film thickness.

- There are many references which provide estimates for the Thermal Resistance, R, of air gaps. The value of R 0.14 is slightly more conservative than the value of 0.16 given in the AIRAH Handbook.

Calculated Thermal Resistance of Cores

The following calculations show the inputs and the following calculated thermal resistances of:

- 120 mm Ozwall partitions (without concrete or grout fill) without insulation in the cores. The calculated Thermal Resistance is **0.27 m^2.K/W (surface to surface)** and 0.42 m^2.K/W (external air film to internal air film). This calculation is consistent with the test data discussed in Part 2 of this Report.

- 120 mm Ozwall partitions (without concrete or grout fill) with Tontine insulation in the cores. The calculated Thermal Resistance is **1.08 m^2.K/W (surface to surface)** and 1.23 m^2.K/W (external air film to internal air film). This calculation is slightly more optimistic that the test data discussed in Part 2 of this Report.

Manufacturer			**Ozwall**	**Ozwall**
Wall thickness			**120**	**120**
Insulation in cores?			**Insulated**	**No Insulation**
External air film	t_{ea}	mm	0.8	0.8
Wall thickness	t_{wall}	mm	120	120
Internal air film	t_{ia}	mm	3.2	3.2
Thermal conductivity of external air film	k	W/m.K	0.026	0.026
Thermal conductivity of external leaf thickness	k	W/m.K	0.102	0.445
Thermal conductivity of internal air film	k	W/m.K	0.026	0.026
Are cores filled with air(a) or insulation (i)?			**i**	**a**
Width of insulation in cores	T_i	mm	92	0
Thermal conductivity of face shells	k_f	W/m.K	0.230	0.230
Thermal conductivity of webs	k_w	W/m.K	0.230	0.230
Thermal conductivity of cores	k_c	W/m.K	0.070	0.026
Length	L	mm	250	250
Wall thickness	T	mm	120	120
Outer face shell	O	mm	14	14
Inner face shell	I	mm	14	14
Web thickness	W	mm	40	20
Number of cores	C	mm	1	1
Core length	L_c	mm	210	230
Core width	T_c	mm	92	92
Material thickness	ET	mm	43	35
Surface density (assuming joints same as block)	SD	kg/m^2	38	31
Gross density (assuming joints same as block)	GD	kg/m^3	313	259
Resistance of webs	R_{web}	m^2.K/w	0.400	0.400
Resistance of cores	R_{core}	m^2.K/w	1.314	0.140
Effective resistance of cores/webs/rebates/joint space	$R_{core + web}$	m^2.K/w	0.962	0.148
Resistance of outer face shell	R_{os}	m^2.K/w	0.061	0.061
Resistance of inner face shell	R_{is}	m^2.K/w	0.061	0.061
Total thermal resistance of wall (surface/surface)	R_{wall}	m^2.K/W	**1.08**	**0.27**
Resistance of external air film	R_{ea}	m^2.K/W	0.03	0.03
Resistance of internal air film	R_{ia}	m^2.K/W	0.12	0.12
Total thermal resistance	R	m^2.K/W	**1.23**	**0.42**

Part 2 - Check by Test

Purpose
The purpose of this Part is to discuss the behaviour during tests, and how it relates to the theoretical values.

Tested Walls
This part compares the calculated thermal resistance to the values determined by test carried out by United Bonded Fabrics Pty Ltd (Test No TD 0620, 21/4/06) and reproduced in Appendix 1.

Limitation
It should be noted that the method of test reported in Appendix 1may involve some inaccuracies due to limitations on the metering area, as set in AS4859.1 Clause C1. Such inaccuracies could either over-estimate the real thermal resistance (be non-conservative) or under-estimate the real thermal resistance (be conservative).

It should be noted that AS4859.1 Clause C2 makes provision for the determination of thermal resistance by calculation, where the testing process is not suitable for multi-component systems. For this reason, the tests reported in Appendix 1 are treated as a mechanism to check the validity of the calculated values.

Comparison

- The calculated Thermal Resistance of 120 mm Ozwall partitions (without concrete or grout fill) without insulation in the cores is **0.27 m^2.K/W** (surface to surface). The corresponding value from the test is similarly 0.27 m^2.K/W (surface to surface). This agreement has been achieved principally by adjusting the Thermal Conductivity, k, of the plaster to a value of 0.23 (as discussed in Part 1).

- With the Thermal Conductivity, k, of the plaster set at a value of 0.23 (as noted above) the Thermal Resistance of Ozwall partitions (without concrete or grout fill) with Tontine insulation in the cores was calculated to be **1.08 m^2.K/W (surface to surface)**.

  The tested values of 1.04 and 1.10 m^2.K/W (surface to surface) are 97 % and 102% of the theoretical values.

  This agreement has been achieved by adjusting the Thermal Conductivity, k, of the insulation to a value of 0.07 (as discussed in Part 1), based on the conservative assumption of compression of the insulation during the insertion. However, if the test itself proved to be conservative (perhaps due to reading the losses at those points of least thermal resistance) then the conservative assumptions discussed above would be unwarranted.

Conclusion
Past experience using the theoretical method to determine the thermal resistance of concrete blocks has indicated that it is generally a little conservative when compared to test results. However, it this case, the tests appear to be a little non-conservative.

Part 3 - Check by Comparison to Similar Forms of Construction

Purpose
The purpose of this Part is to discuss the calculated thermal resistances of Ozwall partitions in the context of other relevant forms of construction, which set a practical upper-bound for calculations.

Comparison 1 - 120 mm Ozwall partitions (without concrete or grout fill) and without insulation[1]

- 120 mm Ozwall partitions (without concrete or grout fill) and without insulation
  Calculated thermal resistance R 0.27

- Composite of 14 mm plaster + 92 mm air gap + 14 mm plaster but with no consideration of bridging

  R = 0.06 + 0.16 + 0.06 [2]
  = 0.28

  Comment
  This indicates that that the bridging through the plaster webs leads to a small reduction in wall thermal resistance when the cores are air-filled.

Comparison 2 - 120 mm Ozwall partitions (without concrete or grout fill) and with Tontine polyester insulation placed in the cores[1]

- 120 mm Ozwall partitions (without concrete or grout fill) and with Tontine polyester insulation placed in the cores
  Calculated thermal resistance R 1.08 (Tests R 1.04 to R 1.10)

- Composite of 14 mm plaster + 92 mm compressed polyester insulation (k = 0.07) + 14 mm plaster but with no consideration of bridging

  R = 0.06 + 1.31 + 0.06
  = 1.43

  Comment
  This indicates that that the bridging through the plaster webs leads to a substantial theoretical reduction in wall thermal resistance when the cores are insulation filled.

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[1] All comparisons are surface to surface, ignoring the contributions by air films.
[2] Based on AIRAH Handbook

Part 4 - Recommended Design Value

Based on the theoretical calculations of Part 1, as checked against the tests of Part 2 and practical limits of Part 3, the following is recommended.

The following design values are considered to be suitable for use in an "Alternative Solution", in accordance with BCA Volume 1 Clauses A0.8, A0.9(b)(i) and A0.10(c) and BCA Volume 2 Clauses 1.0.8, 1.0.9(b)(i) and 1.0.10(c).

- The Thermal Resistance of 120 mm Ozwall partitions (without concrete or grout fill) and without insulation may be assumed to be:
  R 0.27 m^2.K/W (surface to surface)
  R 0.42 m^2.K/W (external air film to internal air film)

- The Thermal Resistance of 120 mm Ozwall partitions (without concrete or grout fill) and with Tontine polyester insulation placed in the cores may be assumed to be:
  R 1.00 m^2.K/W (surface to surface)
  R 1.15 m^2.K/W (external air film to internal air film)

These values may be used simulation software, such as AccuRATE, to determine the overall thermal performance of a building.

These values may also be used, in conjunction with added air gaps, cavity insulation, plasterboard, cladding and the like, to build up the overall thermal resistance to a value specified in the BCA.

Appendix 1 - Test Results

UNITED BONDED FABRICS PTY LIMITED

TECHNICAL DOCUMENT

Author: Graeme Wood, Technical Manager
Date: 21 April 2006
Number: TD0620

SUBJECT: THERMAL RATINGS FOR OZWALL BUILDING PANELS AND ADDED POLYESTER INSULATION

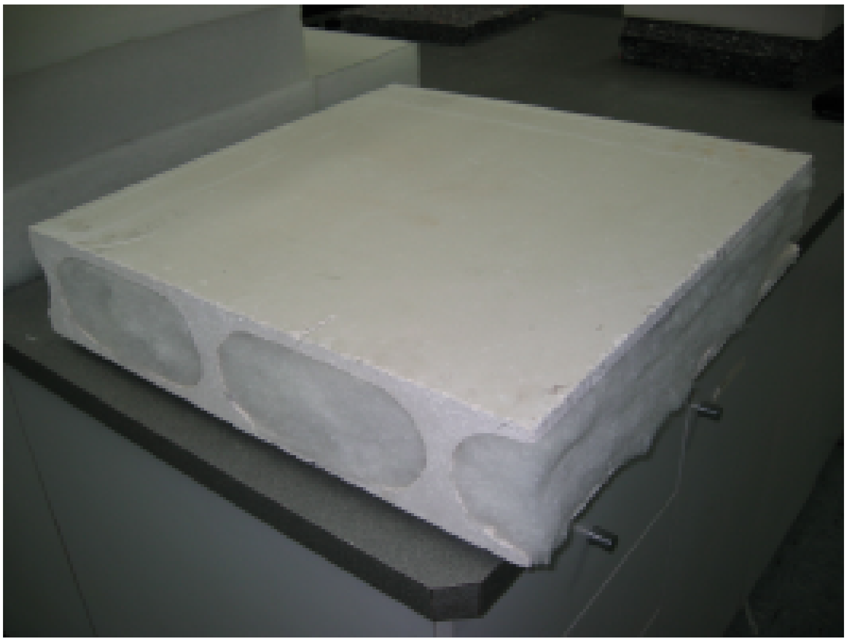
Thermal ratings were conducted on a sample of Ozwall hollow fibrous plaster shell, used in building panels. The sample provided was 125mm thick. The overall thermal rating of the panel was to be increased by filling the voids with Insuloft blanket, with the goal of achieving a rating of R1.5 or higher.

A 'material' rating for the building panel of R1.5 would enable its use in residential buildings with no other requirements for insulation or reflective foil, and still comply with the Building Code of Australia when used in all Climate Zones other than 7 and 8. This is because the addition of thermal resistances from associated building materials (plasterboard) and air surfaces will enable a 'total' wall R-rating of R1.7 or higher to be achieved. If the building panel doubles as an internal wall then a material R-rating of R1.6 or higher is sought.

Three thermal rating tests were conducted on the sample of building panel:

1. As is, with no added insulation.
2. Tontine Insuloft R1.5 insulation filling the voids.
3. Tontine Insuloft R2.5 insulation filling the voids.

The Insuloft insulation was able to neatly fill the void with no gaps (refer to image below).



The samples were analysed on the in-house Lasercomp Fox 600 heat flow meter with a nominal mean temperature of 23°C and the upper and lower plates set at 15°C and 31°C respectively.

Results

Test number	Description	k (W/m/°C)	R-value (m²°C/W)
397	Building panel with no added insulation	0.459	0.27
404	Building panel with R1.5 insulation in voids	0.120	1.04
403	Building panel with R1.5 insulation in voids	0.114	1.10

Comments

Filling the voids with R1.5 insulation increased the overall thermal rating of the panel by 0.77 m^2°C/W to 1.04 m^2°C/W, but there was little extra to be achieved with a higher grade of insulation. There is a limitation in the achievable thermal rating due to the thermal bridging through the fibrous plaster.

Depending on what other associated building materials are used (e.g. 10mm plasterboard) and air surfaces (outdoor, air gap and indoor), the extra thermal resistances may be up to 0.37 m^2°C/W without reflective foil and up to 0.55 m^2°C/W with reflective foil. However the 'total' R-rating of the sample 125mm Ozwall building panel filled with Insuloft R1.5 used in a wall construction would still fall short of the required value of R1.7 for compliance with the BCA in Climate Zones 1 – 6.

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