

Calculating the Total R-Value

Fibre cement cladding on a timber framed wall

J1.2



This case study shows how to calculate the Total R-Value for a Class 3 residential building with an external wall system consisting of fibre cement cladding on a timber wall frame, in a climate zone 5 location. The case study shows how to calculate the Total R-Value, including thermal breaks, in accordance with the J1.2 Thermal construction Deemed-to-Satisfy (DTS) Provisions in NCC Volume One Section J Energy efficiency.

Scenario

A Class 3 residential building is located in climate zone 5. A wall component consists of 14 mm thick fibre cement sheeting, a pliable building membrane, 90 mm thick bulk insulation with a nominal R-Value of 2.2 (m².K/W), and 13 mm thick gypsum plasterboard. The insulation layer is bridged by 90 mm x 35 mm framing studs at 600 mm centres, central noggings, and 35 mm height top and bottom plates. The wall is 2.4 m tall. Figure 1 illustrates this wall system.

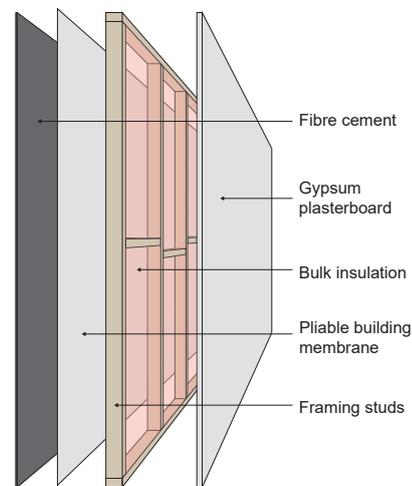


Figure 1 Illustration of a wall system with fibre cement cladding on a timber frame

Construction material and layer properties

Table 1 (below) outlines the construction material and layer properties in this abovementioned wall system. Known properties include thickness, thermal conductivity and R-Value.

Table 1 Construction material and layer properties (climate zone 6 – downward heat flow)
(From the outside (top of the table) to the inside (bottom of the table))

Layer	Material	Thickness (mm)	Thermal conductivity $\frac{W}{m.K}$	R-Value $\frac{m^2.K}{W}$
Exterior surface resistance	Air films – moving air (assuming wind speed of greater than 3 m/s and not more than 7 m/s)	n.a.	n.a.	0.030
Layer 1	Fibre cement	14	0.25	0.056
Layer 2	Pliable building membrane	<1	negligible	negligible
Layer 3	Bulk insulation	90	0.041	2.200
Layer 3 (continued)	Framing studs (radiata pine)	90	0.10	0.900
Layer 4	Gypsum plasterboard	13	0.17	0.076
Interior surface resistance	Air films – still air	n.a.	n.a.	0.120

Note: Thermal conductivity and R-Values are as per NCC Specification J1.2 or for specific products, from manufacturer and supplier data. Layer 3 is the thermal bridge.

Total R-Value calculation

This method of calculating Total R-Value is as outlined in New Zealand Standard (NZS) 4214 'Methods of determining the total thermal resistance of parts of buildings'.

In general, the R-Value of a material is determined by dividing the thickness of the material (in metres) by the thermal conductivity (in W/m.K). The Total R-Value of the construction is the sum of the thermal resistance of each layer, surface air film resistance, and any bridged layers.

Using the information provided in Table 1, we know the thicknesses, thermal conductivity, and R-Values, of the individual materials and layers involved in this wall system. Now, let's look at their individual resistance values.

Exterior surface air film resistance (R-Value)

$R = 0.030 \text{ m}^2 \cdot \text{K/W}$

Layer 1 – 14 mm fibre cement resistance (R-Value)

$R = 0.056 \text{ m}^2 \cdot \text{K/W}$

Layer 2 – Pliable building membrane resistance (R-Value)

The pliable building membrane is applied to the outside of the building frame to provide weather protection and to reduce the risk of condensation forming inside the building frame. As the pliable building membrane is less than 1 mm in thickness, the R-Value is negligible in this case study.¹

Layer 3 - Insulation and timber stud – calculating the thermal bridge resistance (R-Value)

The key difference with this layer is that a timber frame bridges the insulation. This means the timber stud will act as a thermal bridge. To calculate the thermal resistance of the bridged layer, we need to split it into regions, so each region has only one set of stacked 'layers' within it. There are two regions within the bridged layer: Region 1 the bulk insulation; and Region 2 the timber frame. Figure 2 illustrates the bridged layer regions in this case study.

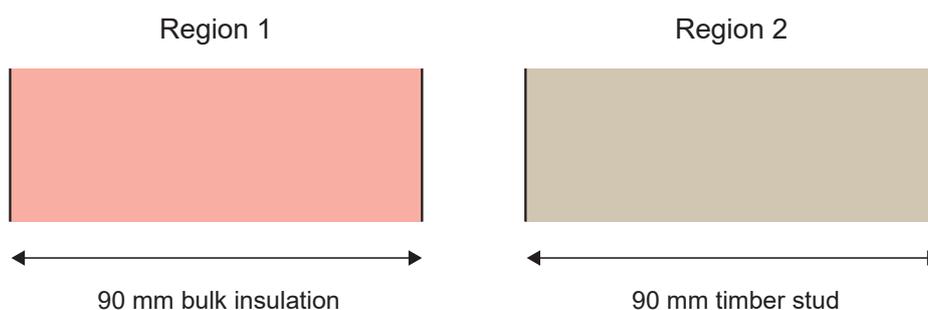


Figure 2 Bridged layer regions

Let's go through the steps of calculating the overall thermal resistance of this layer taking into account the 'thermal bridge' effect of the timber frame.

The overall rate of heat transfer through the bridged layer is proportional to the area-weighted average of the heat transfer rate through each region. In steps 1 and 2, we calculate the thermal resistance and the area of each region, which together determine the rate of heat transfer through each region. In step 3, we calculate the total thermal resistance of the bridged layer, which is just the inverse of the overall rate of heat transfer through the layer.

¹ Note for users of the ABCB Façade Calculator, it is not recommended that pliable membranes be included in a wall build up as they have negligible thermal resistance.

Step 1

Calculate the thermal resistance of each region (using the R-Values in Table 1).

$$R_1 \text{ (Region 1 - insulation)} = 2.200 \text{ m}^2\cdot\text{K}/\text{W}$$

$$R_2 \text{ (Region 2 - stud/nogging)} = 0.900 \text{ m}^2\cdot\text{K}/\text{W}$$

Step 2

Calculate the area fraction for each region. The area fraction is the ratio of the cross-section area, at right angles to the direction of heat flow, occupied by each region. For this case study, one repeated section of the wall will be examined to determine the fraction of each region in the layer. This is shown in Figure 3 below.

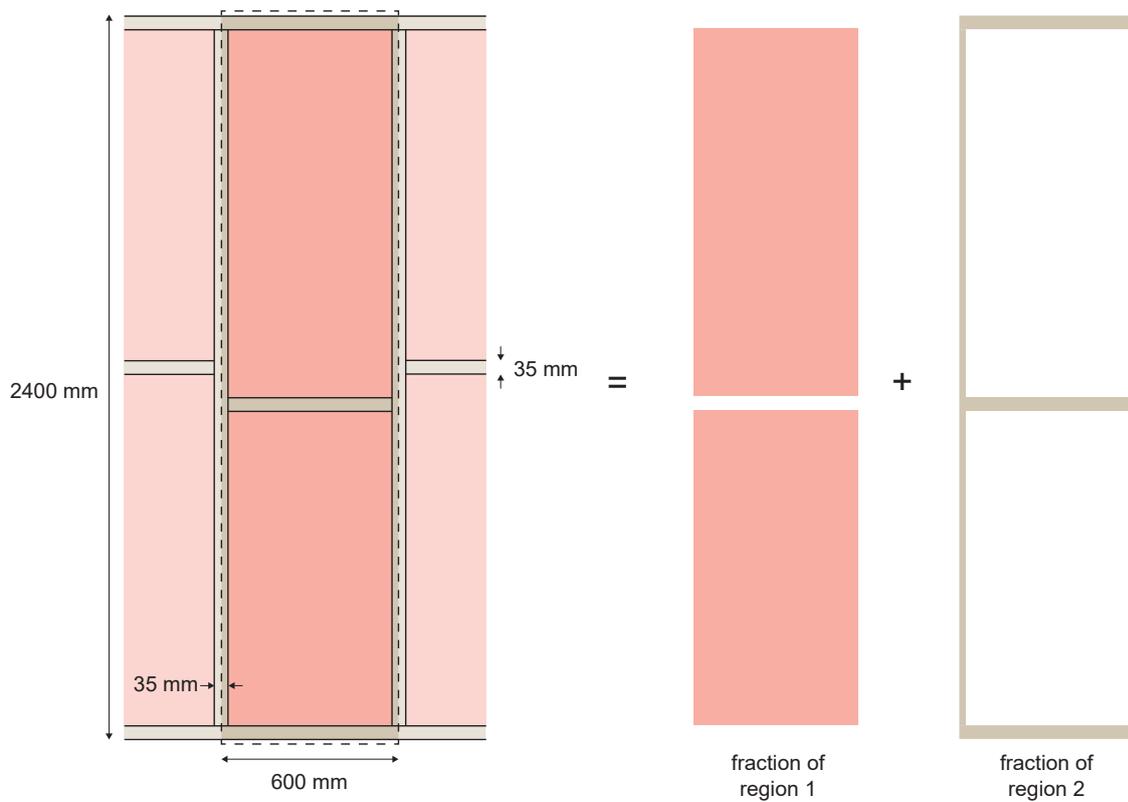


Figure 3 Area fractions for each region of the wall

Region 1 area fraction

$$f_1 \text{ (region 1)} = \frac{\text{Cross section area of region 1}}{\text{Total cross section area}}$$

$$f_1 = \frac{(600 \times 2400) - ((2400 \times 35) + ((600 - 35) \times 35 \times 3))}{600 \times 2400}$$

$$f_1 = 0.90$$

Region 2 area fraction

$$f_2 \text{ (region 2)} = \frac{\text{Cross section area of region 2}}{\text{Total cross section area}}$$
$$f_2 = \frac{(2400 \times 35) + ((600 - 35) \times 35 \times 3)}{600 \times 2400}$$
$$f_2 = 0.10$$

Or given there is only 2 regions:

$$f_2 = 1 - f_1$$
$$f_2 = 1 - 0.90$$
$$f_2 = 0.10$$

Step 3

The total resistance of the bridged layer is calculated as per equations 5 and 6 of NZS 4214.

$$\frac{1}{R_b} = \frac{f_1}{R_1} + \frac{f_2}{R_2} = \frac{0.90}{2.20} + \frac{0.10}{0.90} = 0.520$$

$$R_b = \frac{1}{\left(\frac{1}{R_b}\right)} = \frac{1}{0.520}$$

$$R_b = 1.923 \text{ m}^2 \cdot \text{K/W} \quad (\text{Total resistance (R-Value) of Layer 3 – insulation and timber stud})$$

Layer 4 - 13 mm gypsum plaster board resistance (R-Value)

$$R = 0.076 \text{ m}^2 \cdot \text{K/W}$$

Interior surface air film resistance (R-Value)

$$R = 0.120 \text{ m}^2 \cdot \text{K/W}$$

Calculating the total thermal resistance (Total R-Value)

You can now calculate the total thermal resistance (Total R-Value). This is the sum of all the layers, the surface layers and any bridge layers (i.e. Layer 3).

$$\text{Total R-Value} = 0.030 + 0.056 + 1.923 + 0.076 + 0.120$$

$$\text{Total R-Value} = 2.205 \text{ m}^2 \cdot \text{K/W}$$

Further considerations

The calculated Total R-Value is representative of an external wall system where the timber frame and insulation batts are consistent with the area fractions used in this case study. Other areas, such as on the edge of the wall, or areas that may include doors and windows, would have a different Total R-Value as the fraction of timber would be different due to the additional framing. The area calculation could be carried out for the entire wall to account for this in an overall value.

Want to know more?

The ABCB has developed a range of detailed case studies showing how to calculate Total R-Values with thermal bridges for different wall and roof constructions. They are freely available through the ABCB website (www.abcb.gov.au).