RCS Part 1 Foundation System

Slab NZBC R-value and Passive House Ψ and fRSI

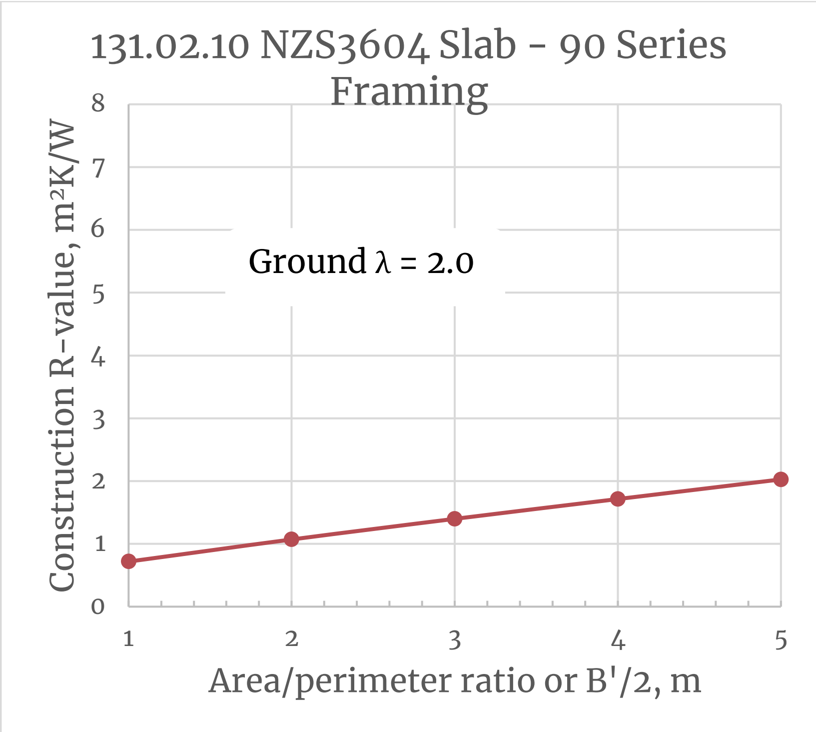
23 April 2023

Sustainable Engineering Ltd

CONTENTS

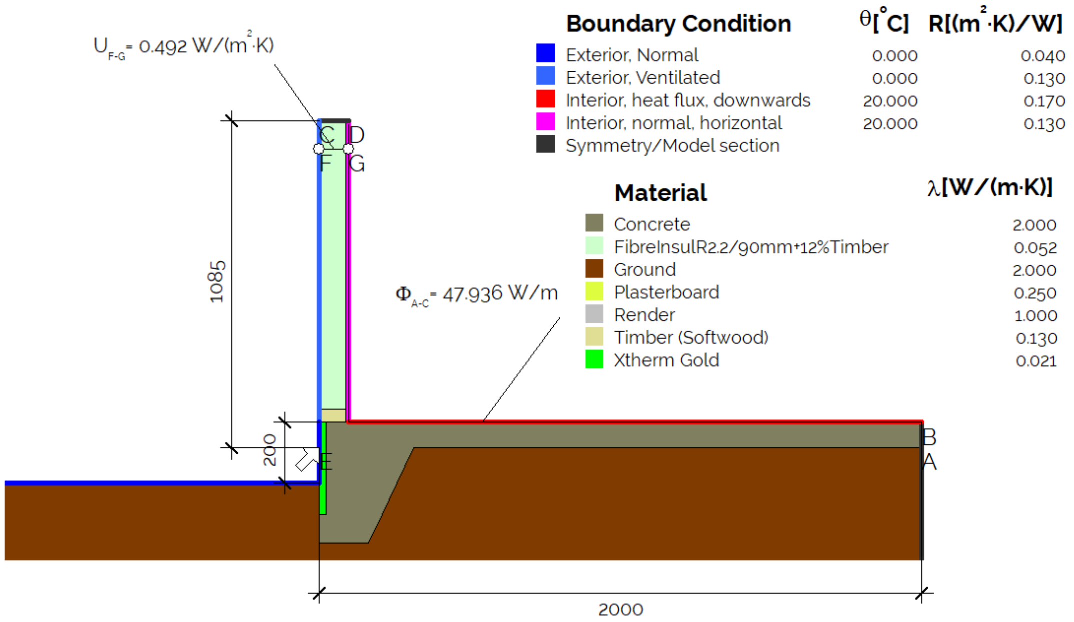
Revised 20230423 from 20220615_RCS_InsulatedFoundationSystem-RvaluesReport_Part1.pdf to update methodology section including that the calculations are in accordance with H1/VM1 5th Edition Amendment 1 effective 4Aug2022.

131.02.10 NZS3604 Slab - 90 Series Framing

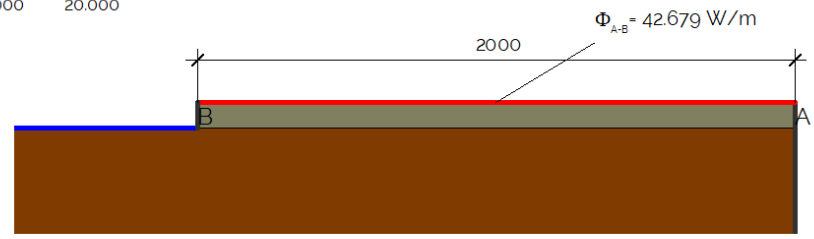


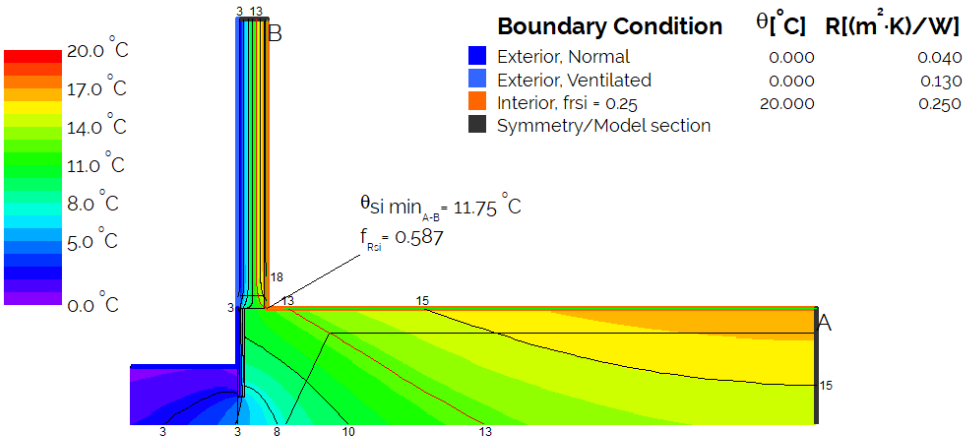
A/P, m	R-value, m²K/W
1	**0.72**
1.6	0.93
1.8	1.00
2	**1.07**
2.2	1.14
2.4	1.20
2.6	1.27
2.8	1.33
3	**1.40**
3.2	1.46
3.4	1.52
3.6	1.59
3.8	1.65
4	**1.71**
5	**2.03**

Note the above graph is for *slab area to perimeter ratio = Aslab,internal / Pslab,internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

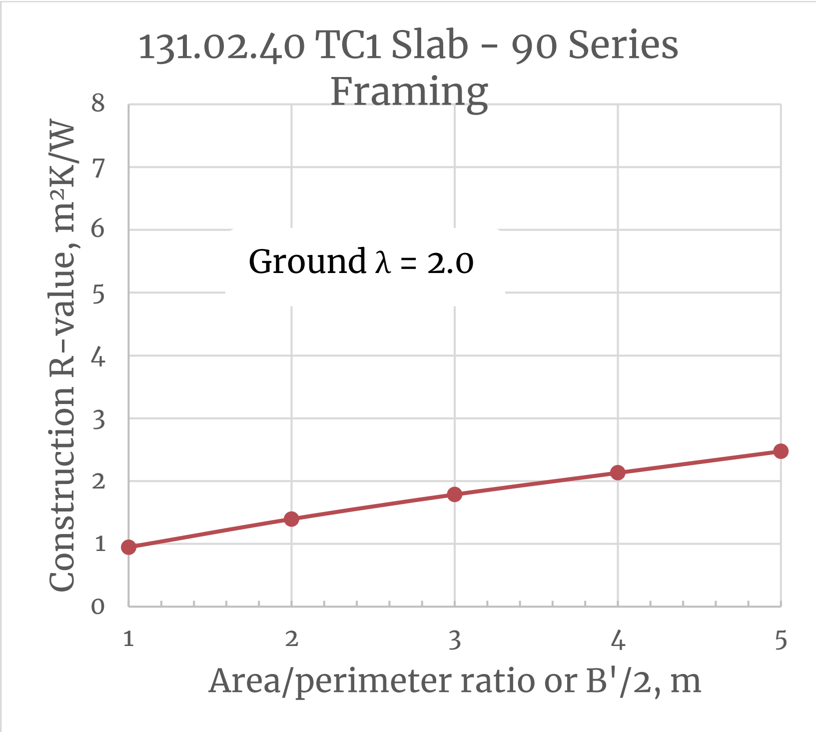


$$\psi_{A\text{-}E\text{-}C} = \frac{47.936}{20.000} - \frac{42.679}{20.000} - 0.492 \cdot 1.085 = -0.271\ \text{W/(m·K)}$$



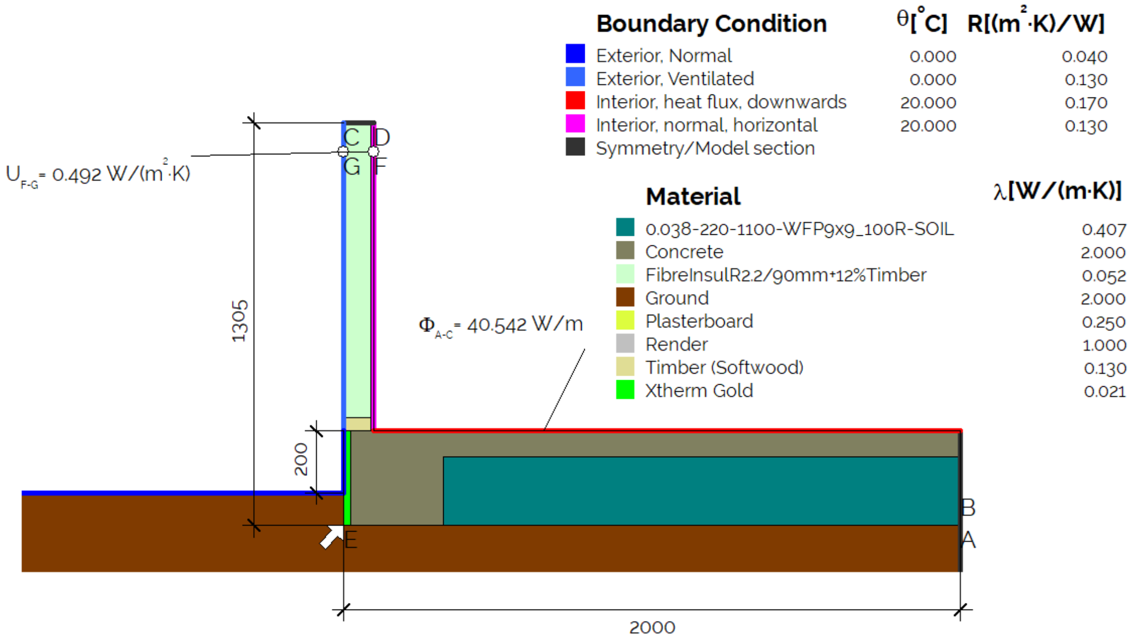


131.02.40 TC1 Slab - 90 Series Framing

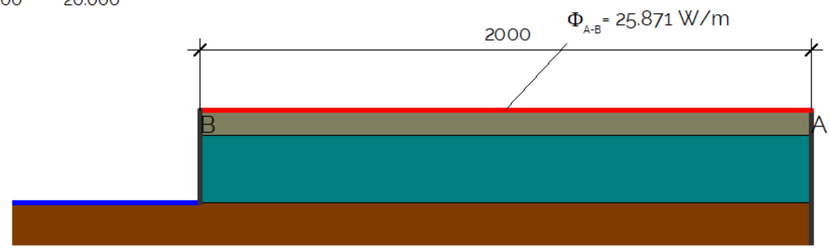


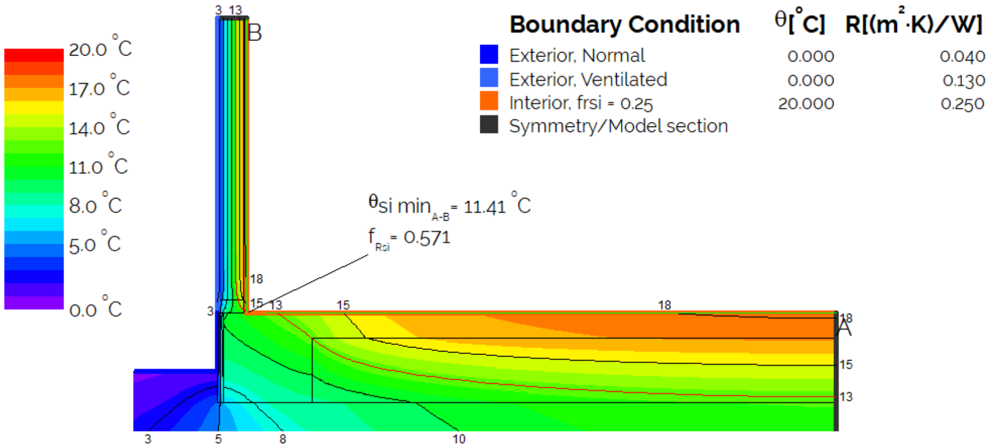
A/P, m	R-value, m²K/W
1	**0.95**
1.6	1.22
1.8	1.31
2	**1.40**
2.2	1.47
2.4	1.55
2.6	1.63
2.8	1.71
3	**1.79**
3.2	1.85
3.4	1.92
3.6	1.99
3.8	2.06
4	**2.13**
5	**2.47**

Note the above graph is for *slab area to perimeter ratio = Aslab,internal / Pslab,internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

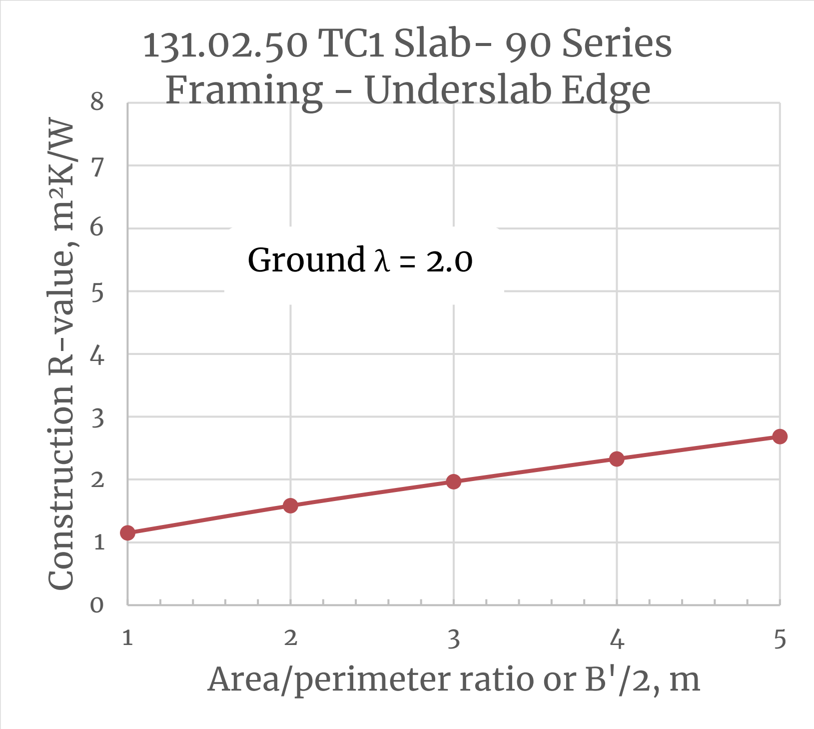


$$\Psi_{A\text{-}E\text{-}C'} = \frac{40.542}{20.000} - \frac{25.871}{20.000} - 0.492 \cdot 1.305 = 0.091\ \mathrm{W/(m \cdot K)}$$



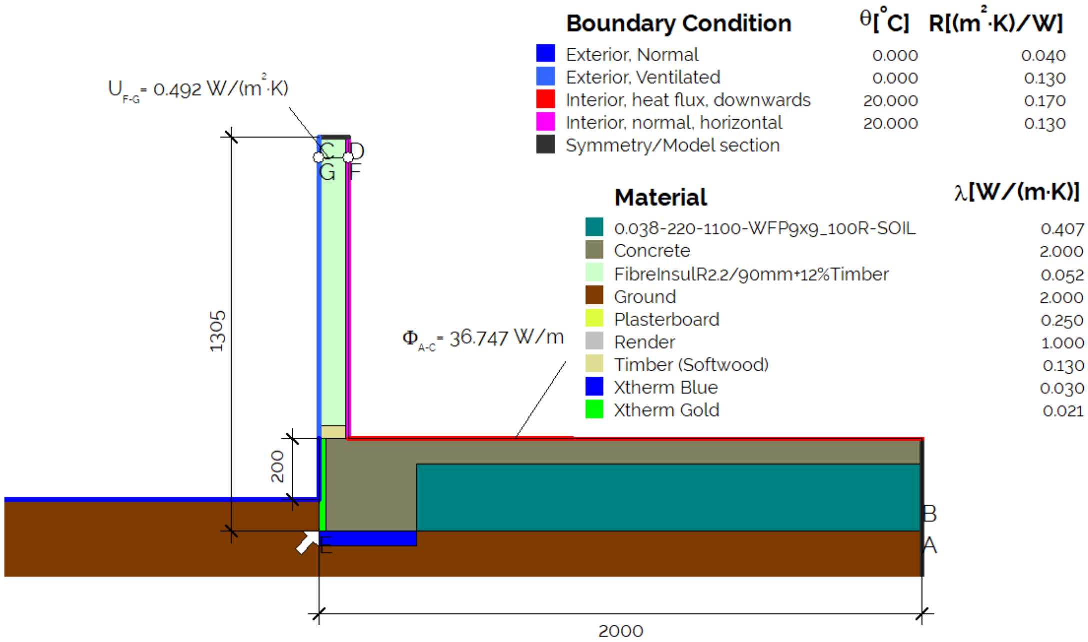


131.02.50 TC1 Slab- 90 Series Framing - Underslab Edge

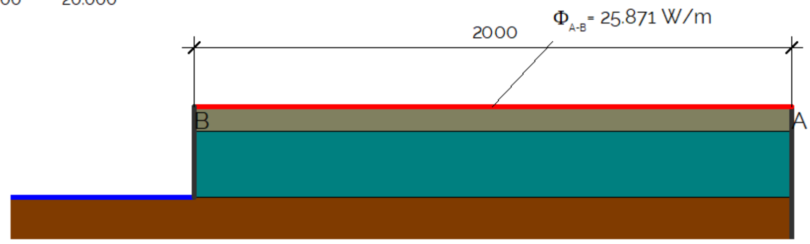


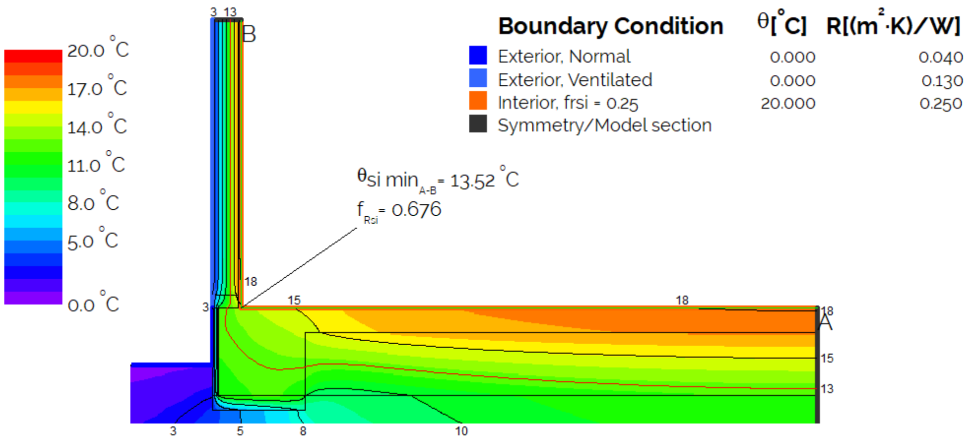
A/P, m	R-value, m^2K/W
1	**1.15**
1.6	1.41
1.8	1.50
2	**1.58**
2.2	1.66
2.4	1.74
2.6	1.81
2.8	1.89
3	**1.97**
3.2	2.04
3.4	2.11
3.6	2.18
3.8	2.26
4	**2.33**
5	**2.68**

Note the above graph is for *slab area to perimeter ratio = Aslab,internal / Pslab,internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

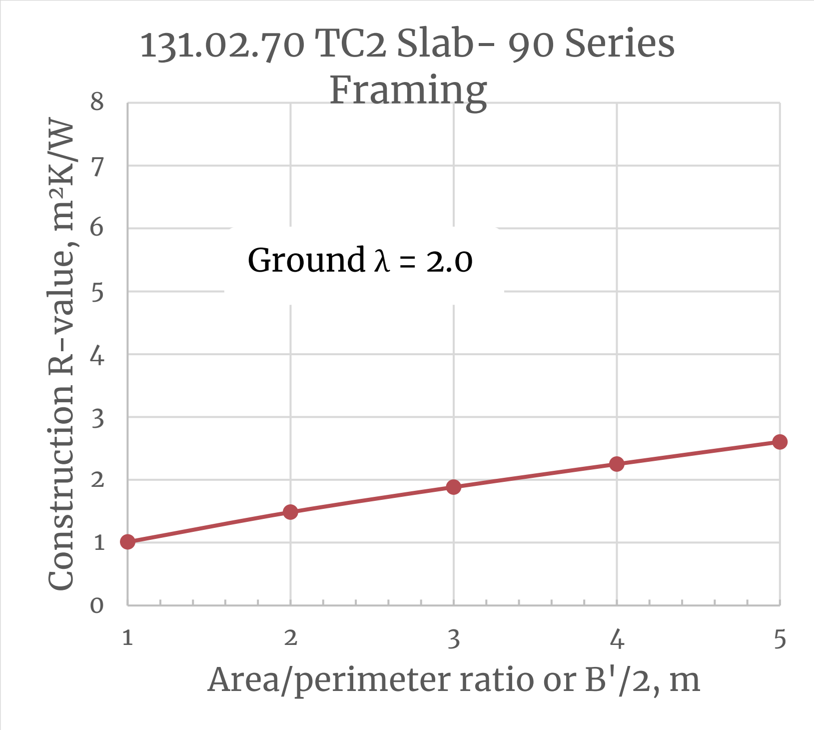


$$\Psi_{A\text{-}E\text{-}C,'} = \frac{36.747}{20.000} - \frac{25.871}{20.000} - 0.492 \cdot 1.305 = -0.099\ \text{W/(m·K)}$$



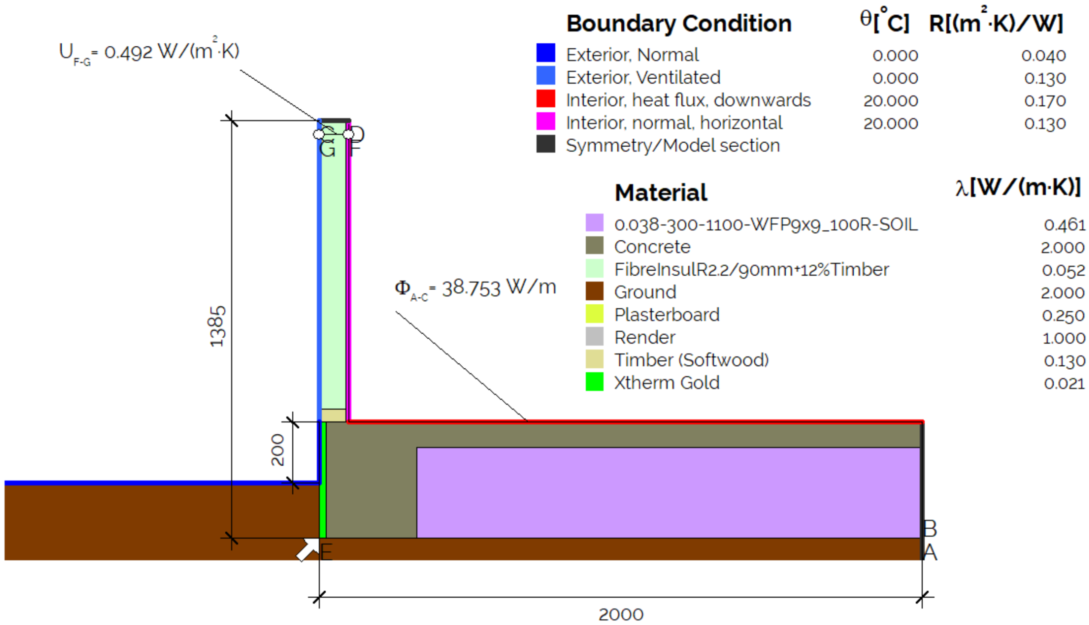


131.02.70 TC2 Slab- 90 Series Framing

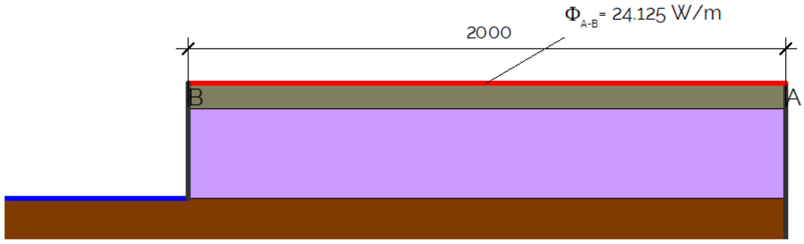


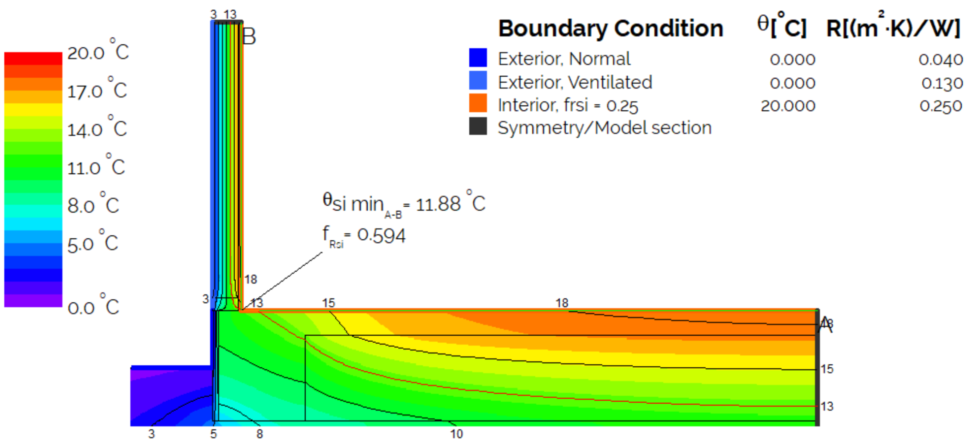
A/P, m	R-value, m^2K/W
1	**1.01**
1.6	1.30
1.8	1.39
2	**1.49**
2.2	1.56
2.4	1.64
2.6	1.72
2.8	1.80
3	**1.88**
3.2	1.96
3.4	2.03
3.6	2.10
3.8	2.18
4	**2.25**
5	**2.60**

Note the above graph is for *slab area to perimeter ratio* = *Aslab*,*internal* / *Pslab*,*internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

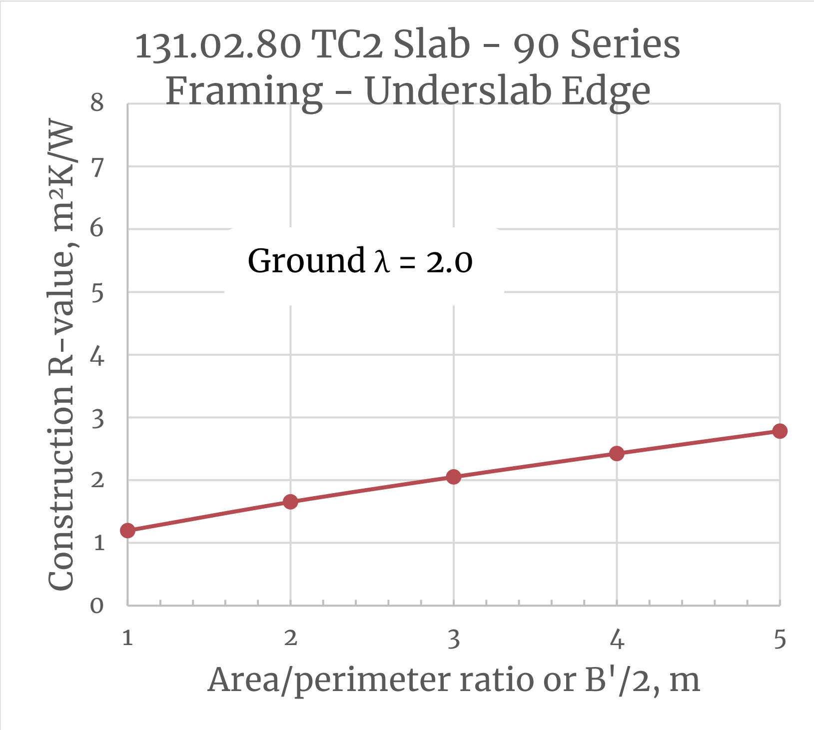


$$\Psi_{A\text{-}E\text{-}C} = \frac{38.753}{20.000} - \frac{24.125}{20.000} - 0.492 \cdot 1.385 = 0.049 \text{ W/(m·K)}$$



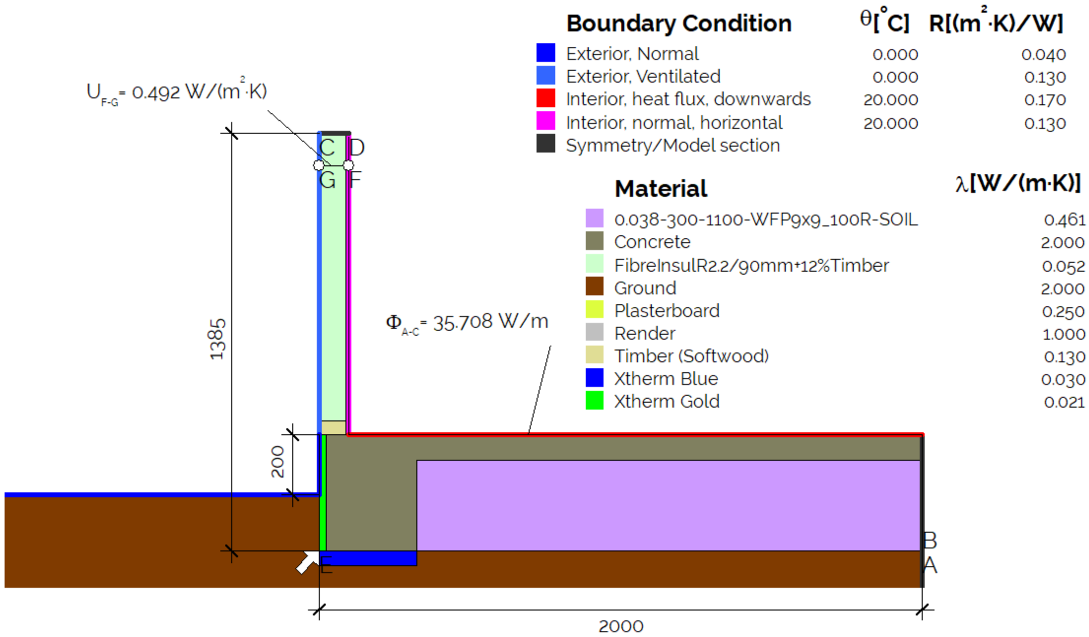


131.02.80 TC2 Slab - 90 Series Framing - Underslab Edge

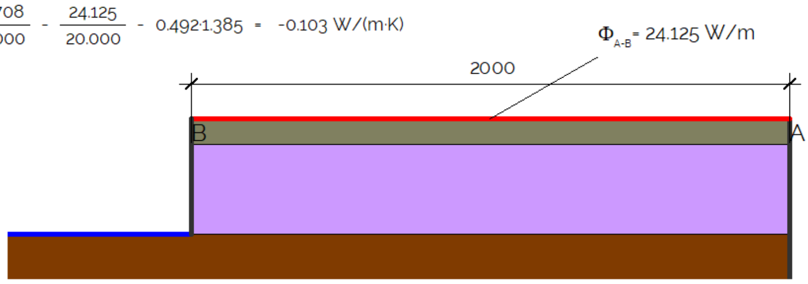


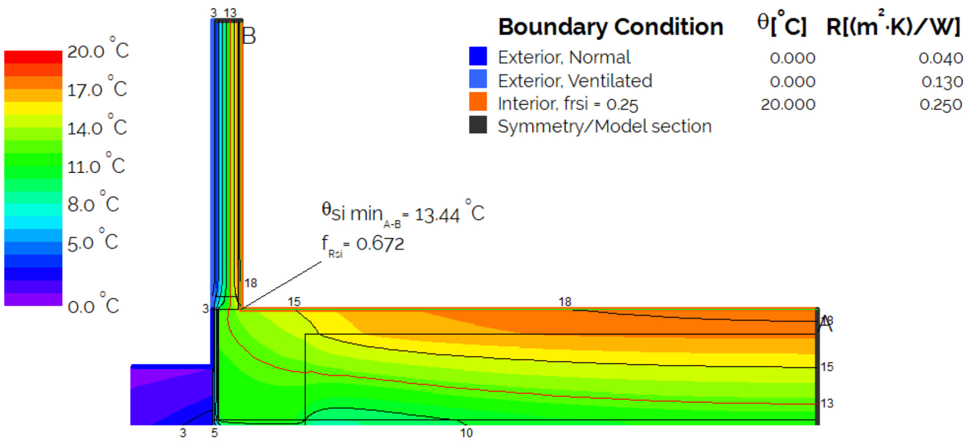
A/P, m	R-value, m²K/W
1	**1.20**
1.6	1.47
1.8	1.56
2	**1.65**
2.2	1.73
2.4	1.81
2.6	1.89
2.8	1.97
3	**2.05**
3.2	2.12
3.4	2.20
3.6	2.27
3.8	2.35
4	**2.42**
5	**2.78**

Note the above graph is for $slab\ area\ to\ perimeter\ ratio = Aslab{,}internal\ /\ Pslab{,}internal$ The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

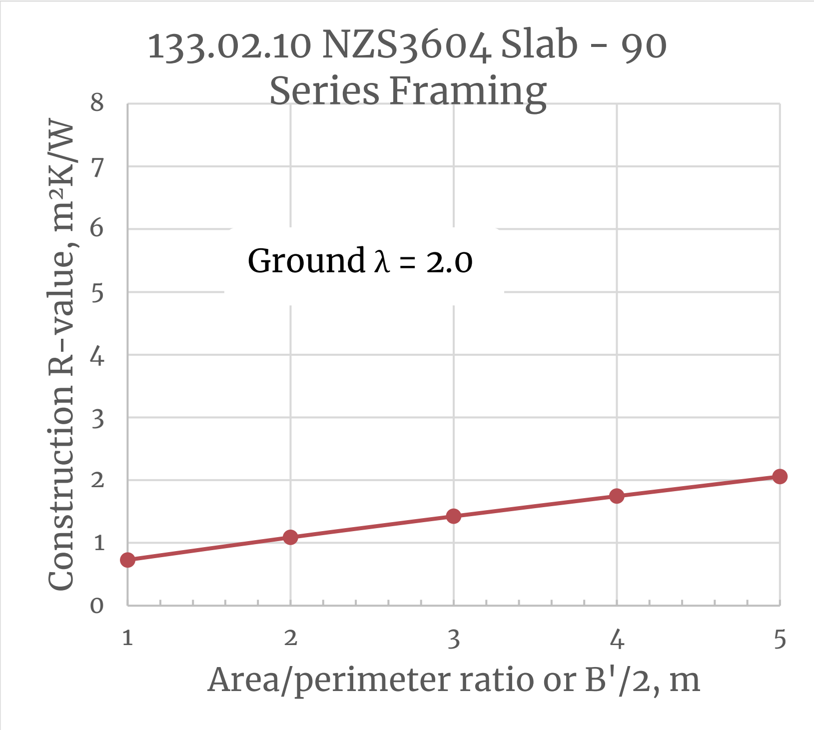


$$\Psi_{A\text{-}E\text{-}C'} = \frac{35.708}{20.000} - \frac{24.125}{20.000} - 0.492 \cdot 1.385 = -0.103 \text{ W/(m·K)}$$



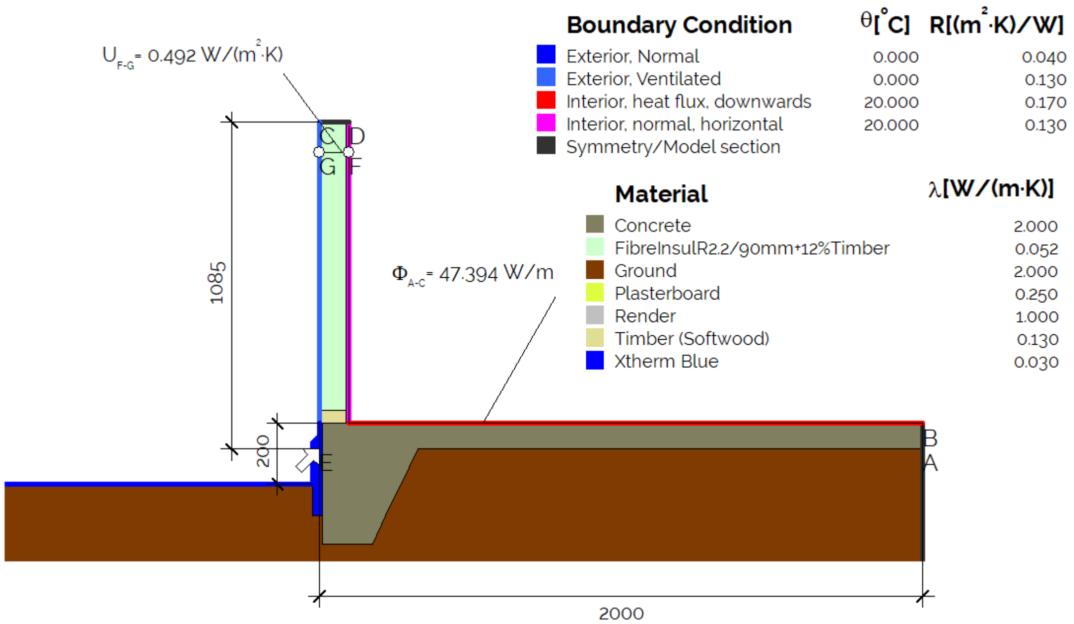


133.02.10 NZS3604 Slab - 90 Series Framing

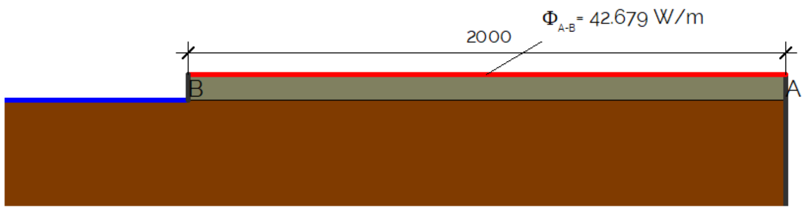


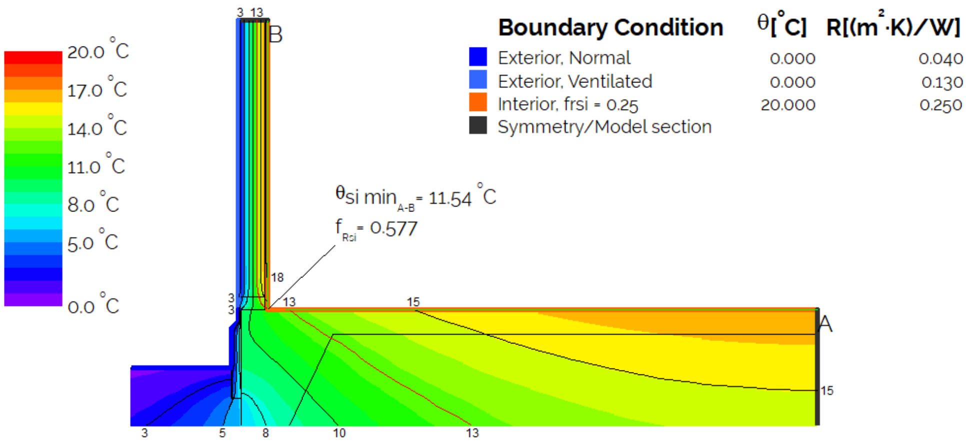
A/P, m	R-value, m²K/W
1	**0.73**
1.6	0.94
1.8	1.02
2	**1.09**
2.2	1.16
2.4	1.22
2.6	1.29
2.8	1.36
3	**1.42**
3.2	1.49
3.4	1.55
3.6	1.62
3.8	1.68
4	**1.74**
5	**2.06**

Note the above graph is for *slab area to perimeter ratio* = *Aslab,internal* / *Pslab,internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

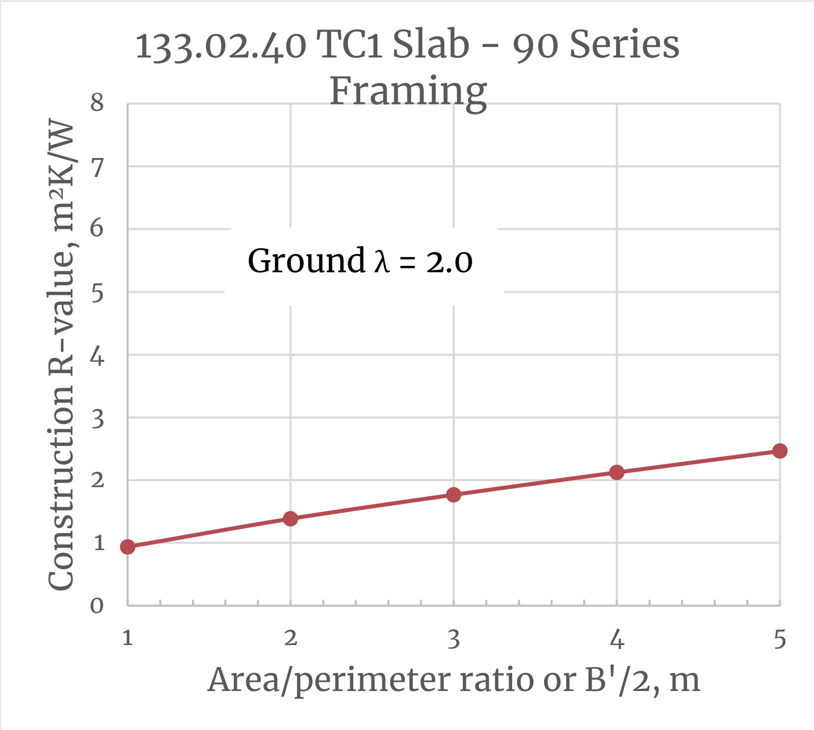


$$\psi_{A\text{-}E\text{-}C'} = \frac{47.394}{20.000} - \frac{42.679}{20.000} - 0.492 \cdot 1.085 = -0.299 \text{ W/(m·K)}$$



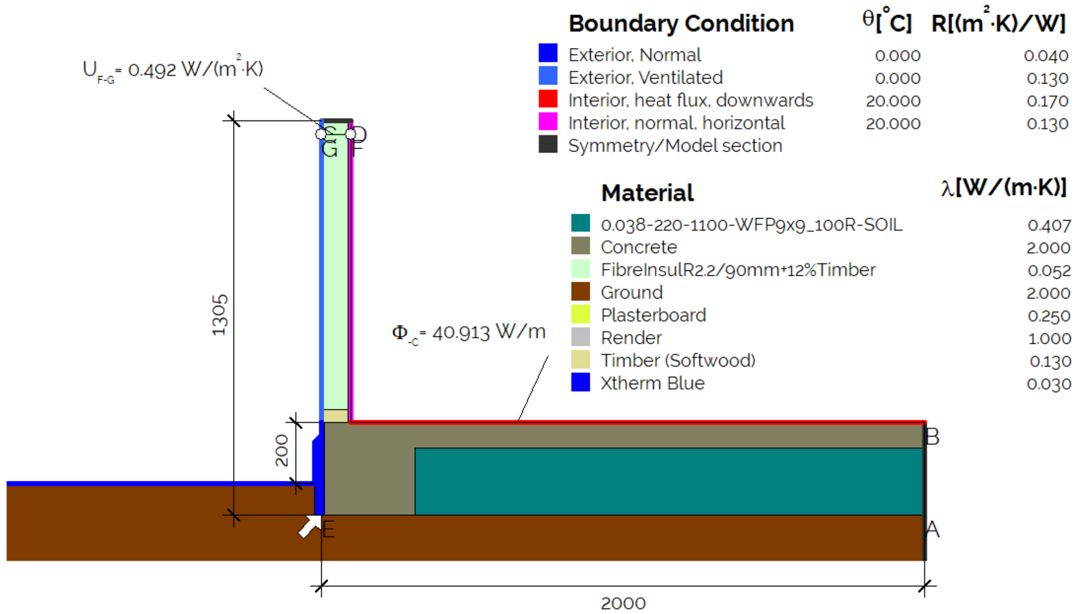


133.02.40 TC1 Slab - 90 Series Framing

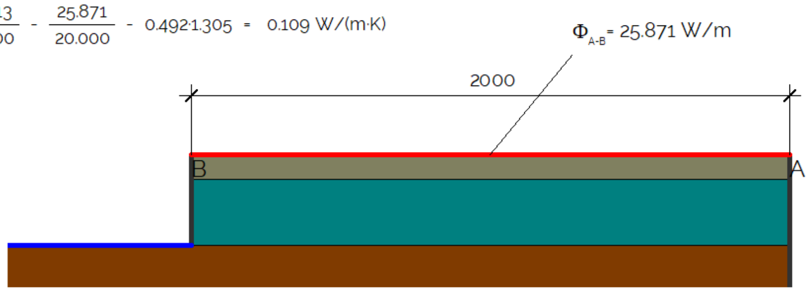


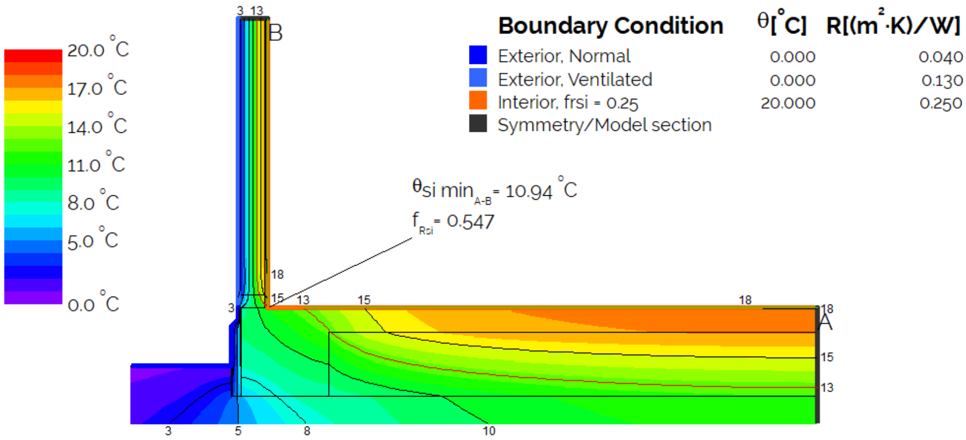
A/P, m	R-value, m^2K/W
1	**0.94**
1.6	1.21
1.8	1.30
2	**1.39**
2.2	1.46
2.4	1.54
2.6	1.61
2.8	1.69
3	**1.77**
3.2	1.84
3.4	1.91
3.6	1.98
3.8	2.05
4	**2.12**
5	**2.46**

Note the above graph is for $slab\ area\ to\ perimeter\ ratio = Aslab,internal\ /\ Pslab,internal$ The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

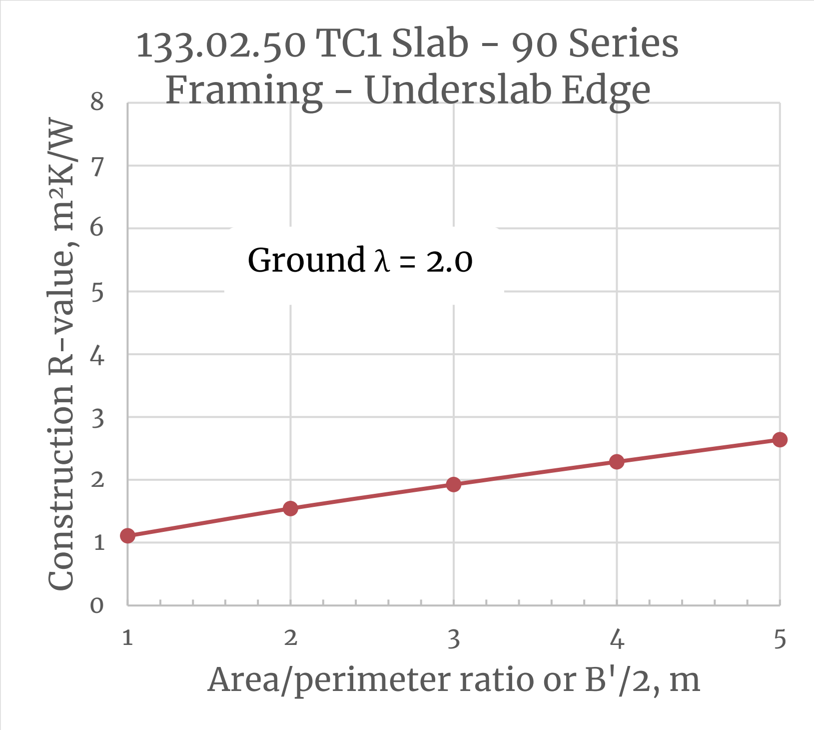


$$\psi_{A-E-C'} = \frac{40.913}{20.000} - \frac{25.871}{20.000} - 0.492 \cdot 1.305 = 0.109\ W/(m \cdot K)$$



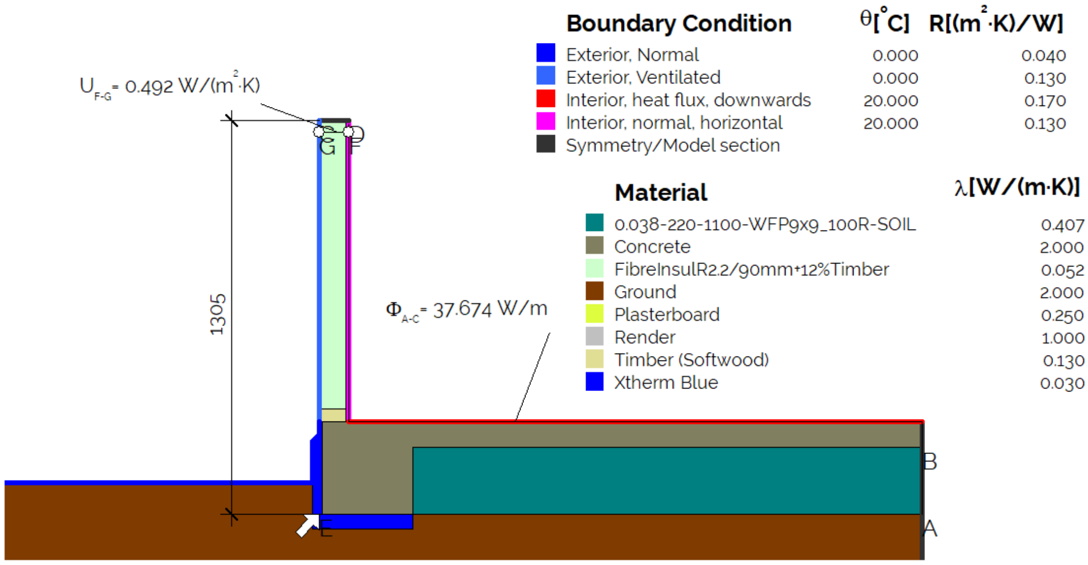


133.02.50 TC1 Slab - 90 Series Framing - Underslab Edge

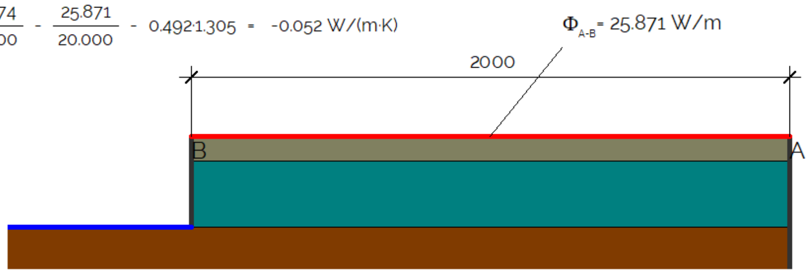


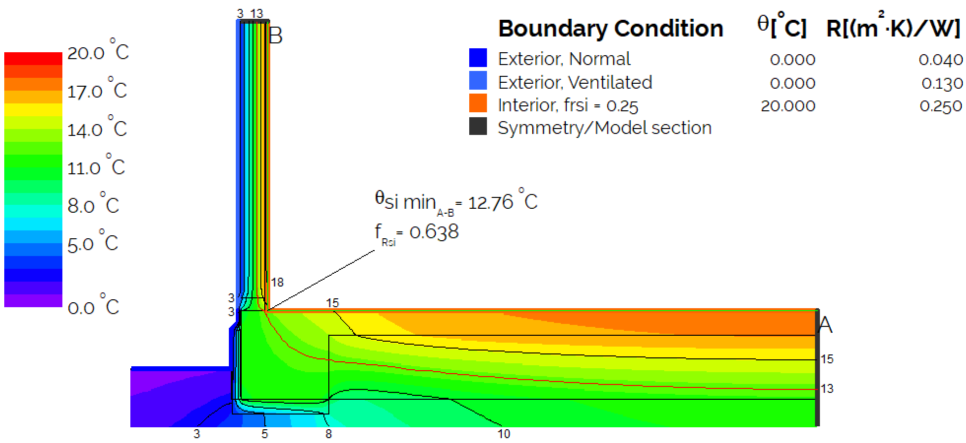
A/P, m	R-value, m²K/W
1	**1.11**
1.6	1.37
1.8	1.46
2	**1.54**
2.2	1.62
2.4	1.70
2.6	1.77
2.8	1.85
3	**1.93**
3.2	2.00
3.4	2.07
3.6	2.14
3.8	2.21
4	**2.29**
5	**2.64**

Note the above graph is for *slab area to perimeter ratio = Aslab,internal / Pslab,internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

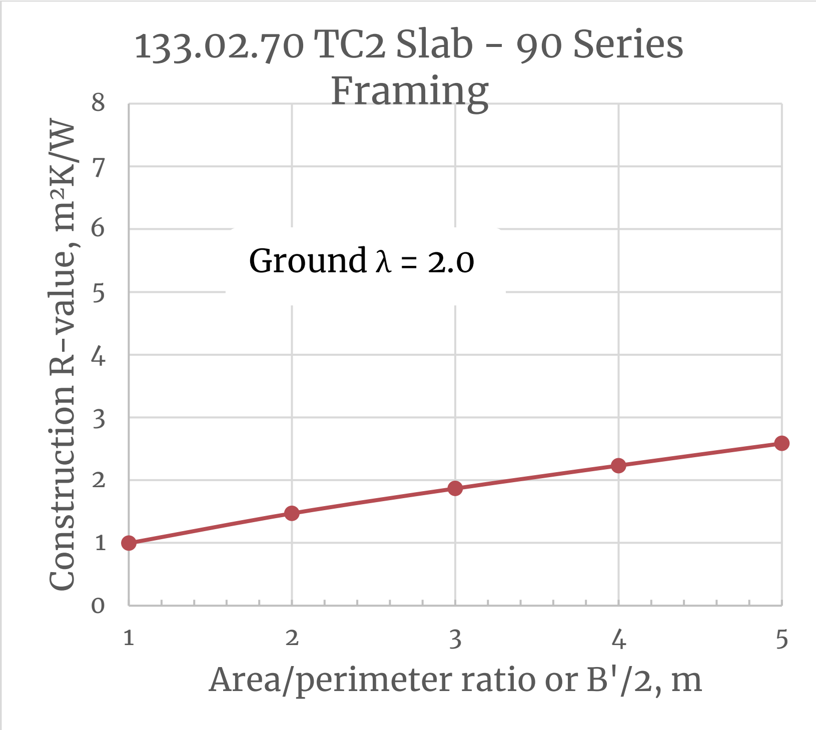


$$\Psi_{A\text{-}E\text{-}C} = \frac{37.674}{20.000} - \frac{25.871}{20.000} - 0.492 \cdot 1.305 = -0.052\ \mathrm{W/(m\cdot K)}$$



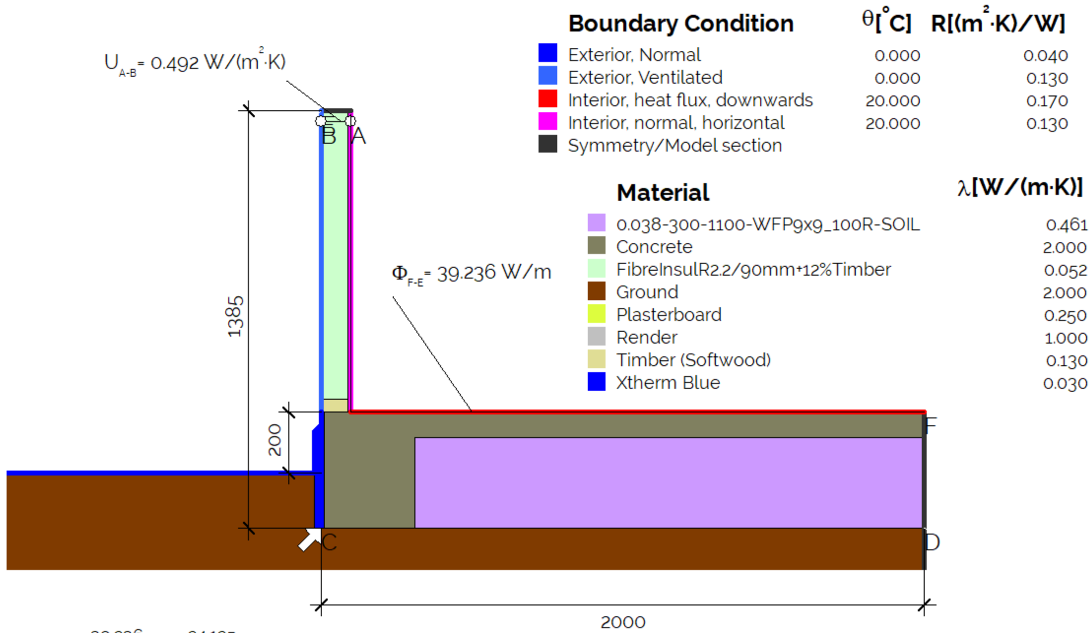


133.02.70 TC2 Slab - 90 Series Framing

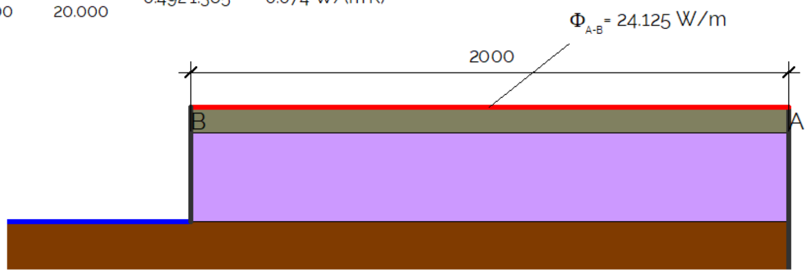


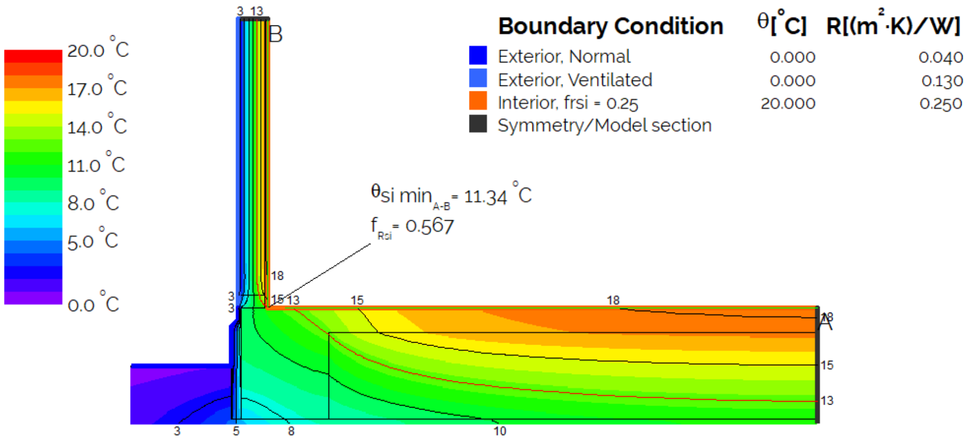
A/P, m	R-value, m²K/W
1	**1.00**
1.6	1.28
1.8	1.38
2	**1.47**
2.2	1.55
2.4	1.63
2.6	1.71
2.8	1.79
3	**1.87**
3.2	1.94
3.4	2.01
3.6	2.09
3.8	2.16
4	**2.23**
5	**2.58**

Note the above graph is for *slab area to perimeter ratio = Aslab,internal / Pslab,internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.

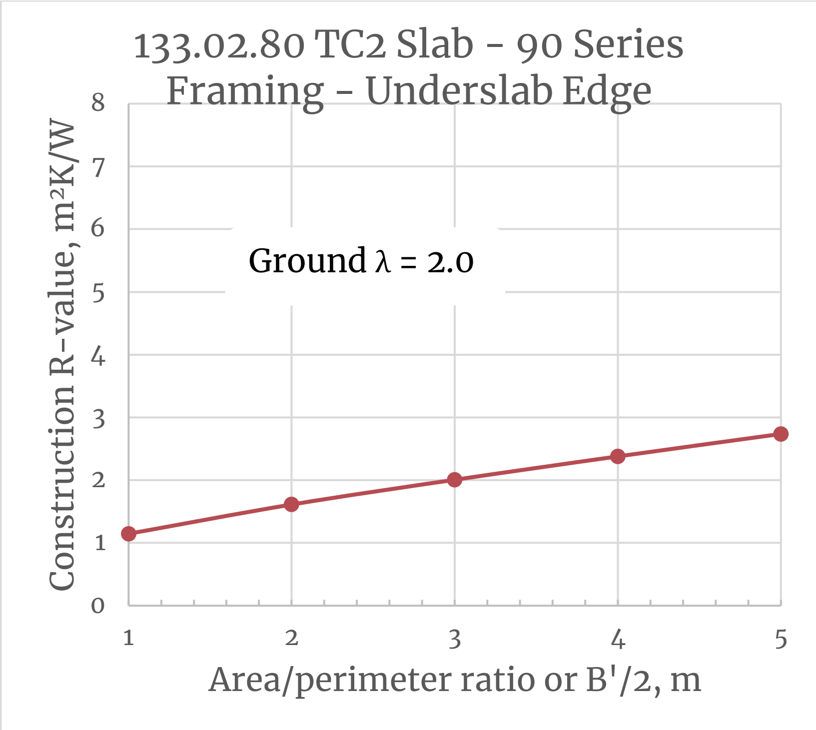


$$\Psi_{D\text{-}C\text{-}E} = \frac{39.236}{20.000} - \frac{24.125}{20.000} - 0.492 \cdot 1.385 = 0.074 \text{ W/(m·K)}$$



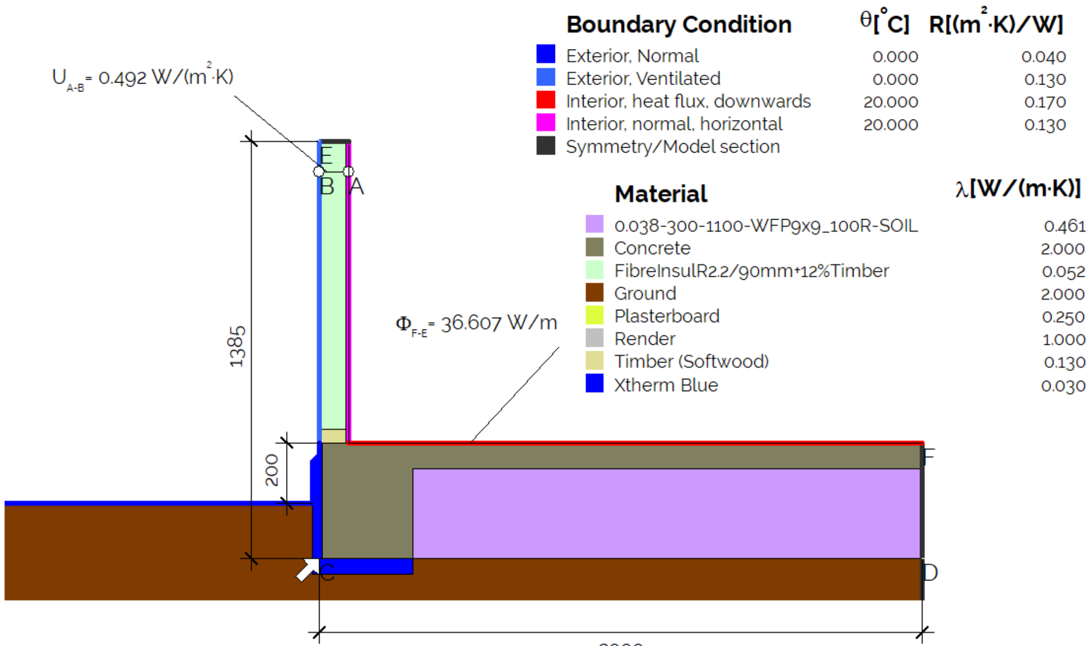


133.02.80 TC2 Slab - 90 Series Framing - Underslab Edge

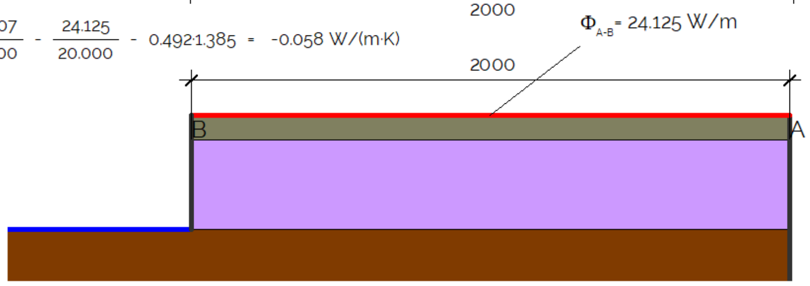


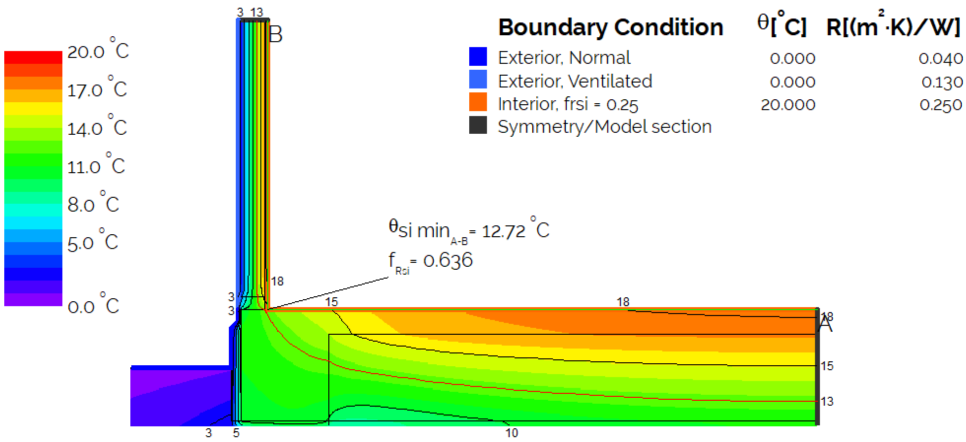
A/P, m	R-value, m²K/W
1	**1.15**
1.6	1.43
1.8	1.52
2	**1.61**
2.2	1.69
2.4	1.77
2.6	1.85
2.8	1.93
3	**2.01**
3.2	2.08
3.4	2.16
3.6	2.23
3.8	2.30
4	**2.38**
5	**2.74**

Note the above graph is for *slab area to perimeter ratio* = *Aslab*,*internal* / *Pslab*,*internal* The results are provided to two decimal places to help with Interpolation but the accuracy only justifies a single decimal place (ie R1.3 in place of R1.33). Slab R-values were calculated without any additional slab thickenings.



$$\psi_{D\text{-}C\text{-}E} = \frac{36.607}{20.000} - \frac{24.125}{20.000} - 0.492 \cdot 1.385 = -0.058 \text{ W/(m·K)}$$





Methodology

NZBC calculations are per the NZBC H1 standard Verification Method H1/VM1 Appendix F, effective 29Nov2021 and as revised 4Aug2022, summarized here:

Using internal slab dimensions.

slab area to perimeter ratio = Aslab,internal / Pslab,internal

where:

Aslab,internal is the area of the slab-on-ground floor that is part of the thermal envelope, measured between the interior surfaces of the walls that form the thermal envelope (m^2) and

Pslab,internal is the perimeter of the slab-on-ground floor that is part of the thermal envelope, measured along the interior surfaces of the walls that form the thermal envelope, including the length of any wall(s) between conditioned and unconditioned spaces (m).

To convert from interior to exterior A/P ratio use the equation from H1/AS1 (5^{th} edition) equation F1 and F2.

$$\frac{A_{slab,internal}}{P_{slab,internal}} = \frac{A_{slab,external}}{P_{slab,external}} - \frac{wall\ thickness}{2}$$

This is done using a two-dimensional numerical calculation in accordance with ISO 13370 Section 5.2b), a geometrical model in accordance with ISO 10211 Sections 7.3, 12.4.1 and 12.4.2 shall be used. The model shall have a floor width equal to half the characteristic dimension of the floor.

For slab-on-ground floors of inhomogeneous construction, such as concrete raft foundation floors, the results of the two-dimensional numerical calculation in accordance with ISO 13370 Section 5.2b) have been validated by three-dimensional numerical calculations in accordance with ISO 13370 Section 5.2a). This has been done by comparing the result of the two-dimensional model against the result of a three-dimensional numerical calculation for a sample slab across a range of floor dimensions that the resulting construction R-value is to be applied to.

COMMENT: 1. The characteristic dimension of the floor (B, see ISO 13370) equals the area of the floor divided by half the perimeter of the floor and should be determined using internal dimensions. 2. A two-dimensional geometrical model with a floor width equal to half the characteristic dimension of the floor represents a floor that is infinitely long and has a width equal to the characteristic dimension of the floor, as required by ISO 13370 Section 5.2 b).

F.1.2.5 The calculation shall use the default values for the thermal properties of the ground from ISO 13370 Table7 category 2. For other materials, thermal conductivity values from ISO 10456 shall be used and, for materials used below ground level, reflect the moisture and temperature conditions of the application. Values of surface resistance shall conform to ISO 13370 Section 6.4.3.

Note: Soil or Ground thermal conductivity = 2 W/(mK). The remaining thermal conductivities are shown in the results.

F.1.2.6 The construction R-value of the slab-on-ground floor shall be calculated according to Equation F.1.

Equation F.1: $Rfloor = 1/U$

where:

U is the temperature-specific heat flux through the internal floor surface of the two- or three-dimensional geometrical model, with the internal floor surface extending from the internal surface of the external wall to the cut-off plane of the floor (W/(m2 ·K)), determined by a numerical calculation as per F.1.2.1 to F.1.2.5.

Slab thickenings

Note that the H1/AS1 (5^{th} edition) calculations do not include slab thickenings in the R-value calculations. The methodology that has been selected would mean that every slab containing a slab thickening would need a custom two-dimensional or three-dimensional numerical calculation to take the slab thickenings into account. Given this and absent a clarification from MBIE we believe that slab thickenings can be neglected for NZBC H1 compliance. If H1/VM1 or VM2 is being used to demonstrate code compliance, the slab thickenings should be considered the same way in both the reference and proposed models.

Although we believe that the slab thickenings should be neglected for NZBC compliance we do not think this is good practice or to be recommended for high performance buildings. Slab thickenings can be a significant fraction of the slab area (we have seen over 30% of a slab area thickened) and this can significantly impact the building's performance. This is like the way the actual timber fraction in a wall can be much larger than is assumed in the NZBC H1/AS1 requirements and the result - overprediction performance is the same. In Passive House or NZGBC Homestar V5 models the slab thickenings must be considered either by using an area based different slab construction (U-value) for the area of the slab that is thickened or by using a PSI value for the specific slab thickening times the length of the thickening (this is the more accurate approach).

Hollow foundation pods (eg Expol Tuff Pods)

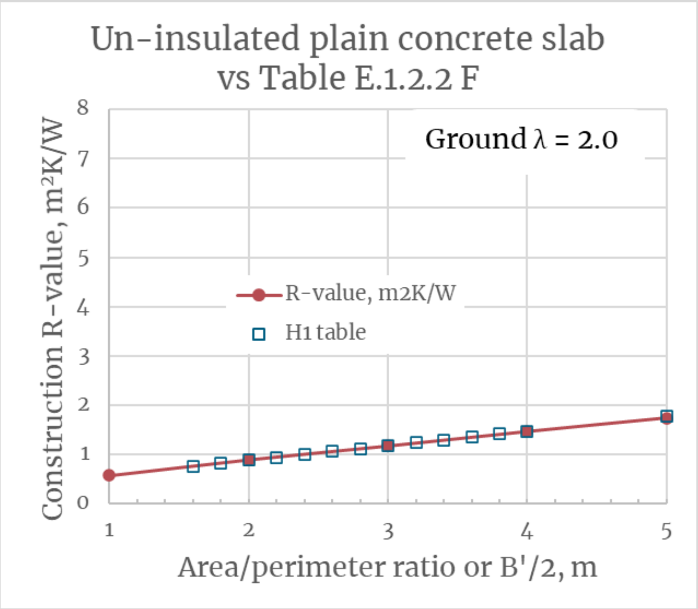
This analysis assumes the pods are un-cut. In practice the air pocket molded EPS pods and other hollow pods are cut which allows concrete to flow into the hollow pockets. This increases the amount of concrete thermal bridging through the slab and can lower the slab thermal resistance. Using similar logic to the above on slab thickenings we believe that this impact can be neglected for NZBC H1 compliance. Also similar to the above for slab thickenings, although we believe that the thermal bridging due to cut pods should be neglected for NZBC compliance we do not think this is good practice or to be recommended for high-performance buildings. In very high-performance buildings, such as Passive House, we would recommend a continuous layer of rigid insulation under any hollow foundation pods.

Wet sites and impacts on slab performance

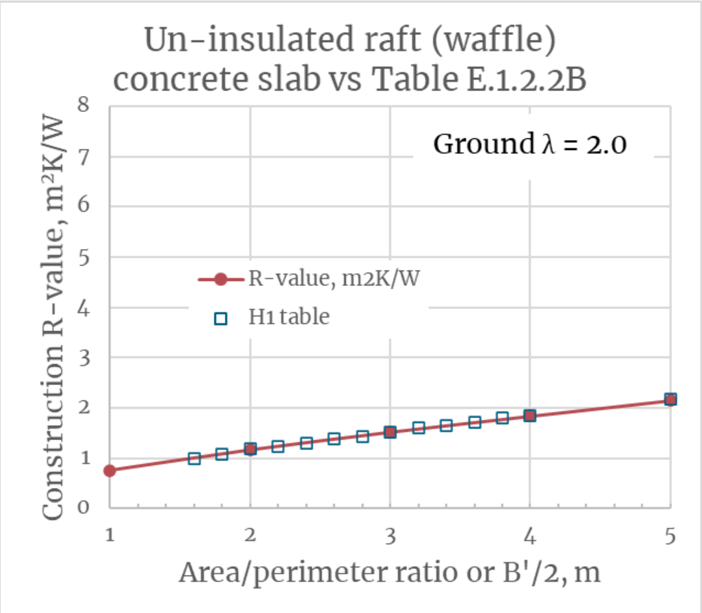
Slab performance has been calculated assuming a well-drained site. Sites with water tables that are high enough to have the under-slab insulation wet should consider a raised foundation as the thermal performance of the insulation will potentially be reduced by immersion in water.

The below two graphs compare our Implementation of the H1 methodology compared to the BRANZ calculated table values in H1/AS1. They agree to within less than 2%. The small variation is within that expected from different finite element meshing routines. The results are given to two decimal places to help with interpolation, but the accuracy only justifies a single decimal place and we'd recommend tables provided to designers show only a single decimal place (ie R1.33 show as R1.3).

NZBC R-values for an un-insulated plain concrete slab



NZBC R-values for an un-insulated raft (waffle) concrete slab

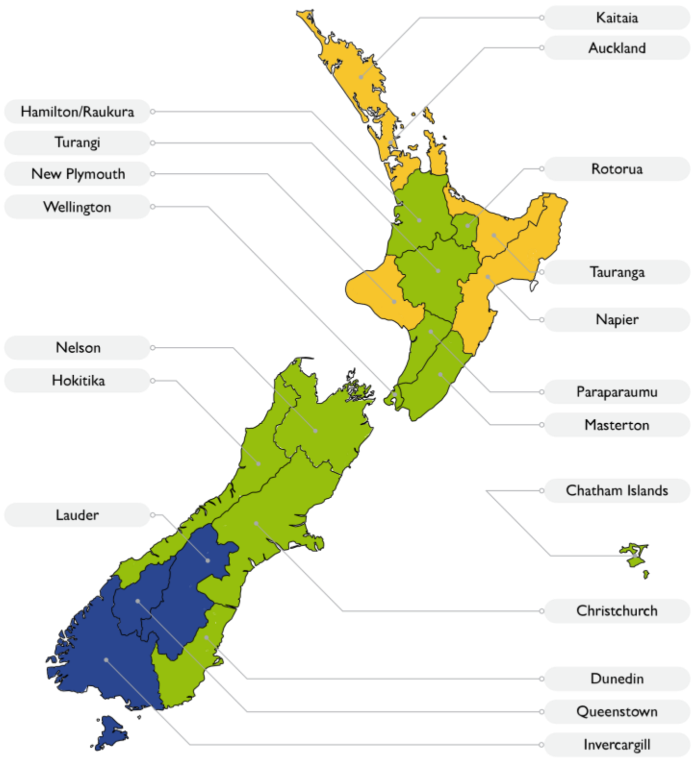


Both examples for 90mm stud + 10mm gypsum wall board or 100mm wall.

PASSIVE HOUSE Ψ AND FRSI

Slab Passive House calculations of Ψ are in accordance with ISO10211:2017 with Passive House Institute (PHI) modifications and fRSI criteria. These use EXTERNAL DIMENSIONS and the heat loss at the sill plate (which should not be neglected) is included in this Ψ calculation. NZBC has no official requirements for a particular fRSI value but NZGBC Homestar V5 does have requirements Intended to parallel the Passive House requirements. In PHPP10 these will be calculated via a moisture balance for each specific building to allow lower fRSI values to be used as less conservative criteria are appropriate with more detailed knowledge of the building ventilation rates, loads, and heating setpoints.

FRSI REQUIREMENTS FOR NZ REGIONS FOR PASSIVE HOUSE



Climate zone	Minimum Temperature Factor fRSI = 0.25 m²K/W
Arctic	0.80
Cold	0.75
Cool-temperate	0.70
Warm-temperate	0.65
Warm	0.55
Hot	-
Very hot	-

Figure 1: This map shows the three different fRSI zones at the weather station altitudes. The climate zone and thus the fRSI requirements also vary with altitude as the average temperatures typically drop by 0.6C per 100m of elevation gain. In general these zones can be used without considering the elevation change. Illustration: Sustainable Engineering Ltd. fRSI requirements from [PHI Passive House Standard Building Criteria](#).