# Thermohouse – Thermal Performance of 300 Standard Element

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23 October 2009

BRE report number 255996

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## Executive Summary


BRE has been commissioned by Thermohouse (part of MGC Group Ltd.) to undertake a three-dimensional thermal performance assessment of an ICF wall construction (Thermohouse 300). Two variations of the Thermohouse 300 ICF detail are modelled, with the thermal conductivity of the EPS at 0.035 W/m·K (higher conductivity) and 0.030 W/m·K (lower conductivity). Additionally, BRE has been asked to carry out calculations for a roof panel design.

Calculations have been carried out using the relevant standards BR497[Ref 1] and EN ISO 10211[Ref 2] and the following points are concluded:-

- The minimum surface temperatures for the ICF wall comply with the requirements in the BRE Information Paper IP 1/06[Ref 4]. The requirement given in the Information Paper, for walls and roofs of dwellings, is that the surface temperature factor should not fall below 0.75. The higher conductivity model produced a minimum surface temperature factor ($f_{Rsi}$) of 0.97 (0.967), the lower conductivity model produced a factor of 0.97 (0.974). The surface temperature factors therefore satisfy the requirements in IP 1/06.
- The U-value of the higher conductivity ICF model was found to be 0.23 W/m²K. As expected, the lower conductivity model produced an improved U-value of 0.20 W/m²K.
- The U-value was also calculated for the lower conductivity ICF model, but without taking into account the impact of the steel fixings. This resulted in a U-value of 0.18 W/m²K, meaning the steel fixings cause an increase to the U-value of 0.02 W/m²K.
- The U-value for the roof panel was found to be 0.15 W/m²K and its minimum surface temperature factor was found to be 0.98 (0.983).
- Although the surface temperature factors are satisfactory for the wall and roof designs it needs to be borne in mind that there are also requirements for wall-roof and wall-floor junctions which are not assessed in this report.

Details of the calculations are given in Appendix A of the report.

## Contents

## Introduction

BRE has been commissioned by Thermohouse, part of MGC Group Ltd, in order to provide an assessment of the thermal performance of an ICF wall construction design and of a roof panel design. Thermohouse have provided drawings and for clarity the drawings are reproduced in this report.

A U-value is a measure of the quantity of heat that will flow through unit area in unit time, per unit difference in temperature between the internal and external environment. It is expressed in W/m²K. A surface temperature factor ($f_{Rsi}$-factor) is an indication of the minimum temperature of an internal surface for a given set of internal and external conditions and this gives an indication of the risk of surface condensation.

Thermal performance requirements for buildings are set out in Part L of the Building Regulations[Ref 3]. The thermal performance of external elements may be calculated using EN ISO 10211[Ref 2] and this report sets out the results of 3-dimensional thermal performance calculations, using the methods in EN ISO 10211. The calculations were carried out using Physibel's Trisco software and this report presents the methodology, results and interpretation of the thermal performance calculations.

The minimum surface temperature factor (which is defined in BRE IP 1/06[Ref 4]) is a measure of the degree of thermal bridging and it gives an indication of the risk of surface condensation. A high $f_{Rsi}$-factor indicates a relatively low risk of inside surface condensation while a low $f_{Rsi}$-factor indicates a high risk. The risk of condensation also depends upon the type of building and the use to which it is put. For example, a swimming pool or data centre may incur a higher risk of condensation than an office or warehouse. The relevant Building Regulations should be referred to in order to determine the requirements as regards thermal bridging and risk of surface condensation.

The results of these calculations are presented in the following sections and are intended to serve as guidance for assessing compliance with Building Regulations.

# The wall and roof constructions

## The ICF wall construction

The U-values of the ICF wall construction variations were evaluated using the procedures in EN ISO 10211, which give relevant guidance on numerical modelling. The modelling takes account of the dimensions and thermal conductivities of the materials making up the ICF external wall construction. It also takes account of the surface effects according to current standards. The external wall designs which were assessed are described in Appendix A.

The U-value and minimum surface temperature factor ($f_{Rsi}$) were calculated and the results are shown in Table 1.

| | Higher Conductivity (EPS – 0.035 W/m·K) | Lower Conductivity (EPS – 0.030 W/m·K) |
|---|---|---|
| U-value (W/m²K) | 0.23 | 0.20 |
| Minimum surface temperature factor, $f_{Rsi}$ | 0.967 | 0.974 |

***Table 1 U-values and minimum surface temperature factors for Thermohouse 300 with two types of EPS insulation***

Note: The figures in Table 1 are applicable to walls and roofs, but not applicable to junctions such as roof-wall junctions or wall-floor junctions, which are not assessed in this report.

Note: The requirement given in the Information Paper, for walls and roofs of dwellings, is that the surface temperature factor should not fall below 0.75.

## The roof panel construction

The roof panel design consists of 235 mm expanded polystyrene (0.030 W/m·K) with 15 mm top ribs, with a 15 mm internal layer of gypsum plaster (thermal conductivity 0.26 W/m·K[1]). Steel channels penetrate the insulation to provide mechanical support. Immediately above the roof space is a set of battens and counterbattens and a breathable membrane with roof tiles above the membrane. Details of the roof panel are shown in Appendix B.

The U-value and minimum surface temperature factor ($f_{Rsi}$) were calculated and the results are shown in Table 2.

| | Roof panel (EPS – 0.030 W/m·K) |
|---|---|
| U-value (W/m²K) | 0.15 |
| Minimum surface temperature factor, $f_{Rsi}$ | 0.983 |

***Table 2 U-values and minimum surface temperature factors for the roof panel***

Note: The figures in Table 2 are applicable to walls and roofs, but not applicable to junctions such as roof-wall junctions or wall-floor junctions, which are not assessed in this report.

Note: The requirement given in the Information Paper, for walls and roofs of dwellings, is that the surface temperature factor should not fall below 0.75.

[1] The thermal conductivity value of 0.26 W/m·K was advised by the client on 8 September 2009

# Results

Results are given for both the ICF wall design and the roof panel construction.

## The ICF wall

The U-value and minimum surface temperature factors ($f_{Rsi}$) of the proposed ICF wall construction variations have been determined by numerical modelling and conclusions presented in this report. The following points are concluded:-

- The minimum surface temperatures are compliant with the requirements in the BRE Information Paper IP1/06. The minimum surface temperature factor ($f_{Rsi}$) was found to be well above the minimum requirements in IP 1/06. The higher conductivity model produced a minimum surface temperature factor of 0.967, the lower conductivity model produced a factor of 0.974.
- The U-value of the higher conductivity model ($\lambda$ = 0.035 W/m·K) was found to be 0.23 W/m²K. As expected, the lower conductivity model ($\lambda$ = 0.030 W/m·K) produced an improved U-value of 0.20 W/m²K.
- The U-value was also calculated for the lower conductivity model, but without taking into account the impact of the steel fixings. This resulted in a U-value of 0.18 W/m²K, meaning the steel fixings cause an increase to the U-value of 0.02 W/m²K

## The roof panel

The U-value and minimum surface temperature factors ($f_{Rsi}$) of the proposed roof panel construction have been determined by numerical modelling and conclusions presented in this report. The following points are concluded:-

- The minimum surface temperatures are compliant with the requirements in the BRE Information Paper IP1/06. The minimum surface temperature factor ($f_{Rsi}$) of 0.98 was found to be well above the minimum requirements in IP 1/06.
- The U-value of the roof panel was found to be 0.15 W/m²K.

## Note regarding junctions

- Although the surface temperature factors are satisfactory for the wall and roof designs it needs to be borne in mind that there are also requirements for wall-roof and wall-floor junctions which are not assessed in this report.

## References

[1] BR497 Conventions for calculating linear thermal transmittance and temperature factors, T Ward and C Sanders, IHS BRE Press 2007

[2] EN ISO 10211 Thermal bridges in building construction – Heat flows and surface temperatures

[3] Building Regulations 2008, Technical Guidance Document L, Conservation of Fuel and Energy, Department of the Environment, Heritage and Local Government

[4] Assessing the effects of thermal bridging at junctions and around openings. T Ward, *BRE Information Paper* IP 1/06. Garston, BRE Press, 2006.

## Appendix A: Technical Information regarding the ICF wall

Figure A.1.1 shows a cross-section of the external wall design and Figure A1.2 shows an overview.

The external wall variations were modelled in order to assess their thermal performance. The calculations were carried out with a notional internal temperature of 20°C and a notional external temperature of 0°C.

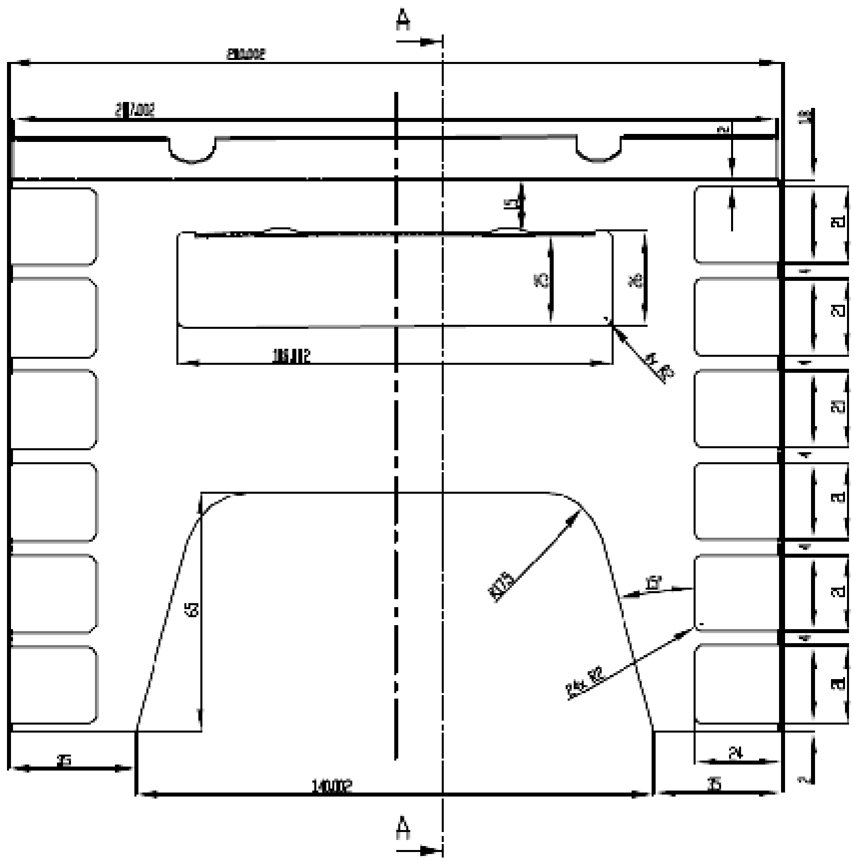



***Figure A.1.1 The ICF wall construction design as provided by MCG Group Ltd (note: there are three modifications. (A) An external render of 12.5mm has been included. (B) A 50mm cavity with 50x50mm timber studs at 400mm centres has been included. (C) An internal plasterboard finish of 12.5mm has been included.***

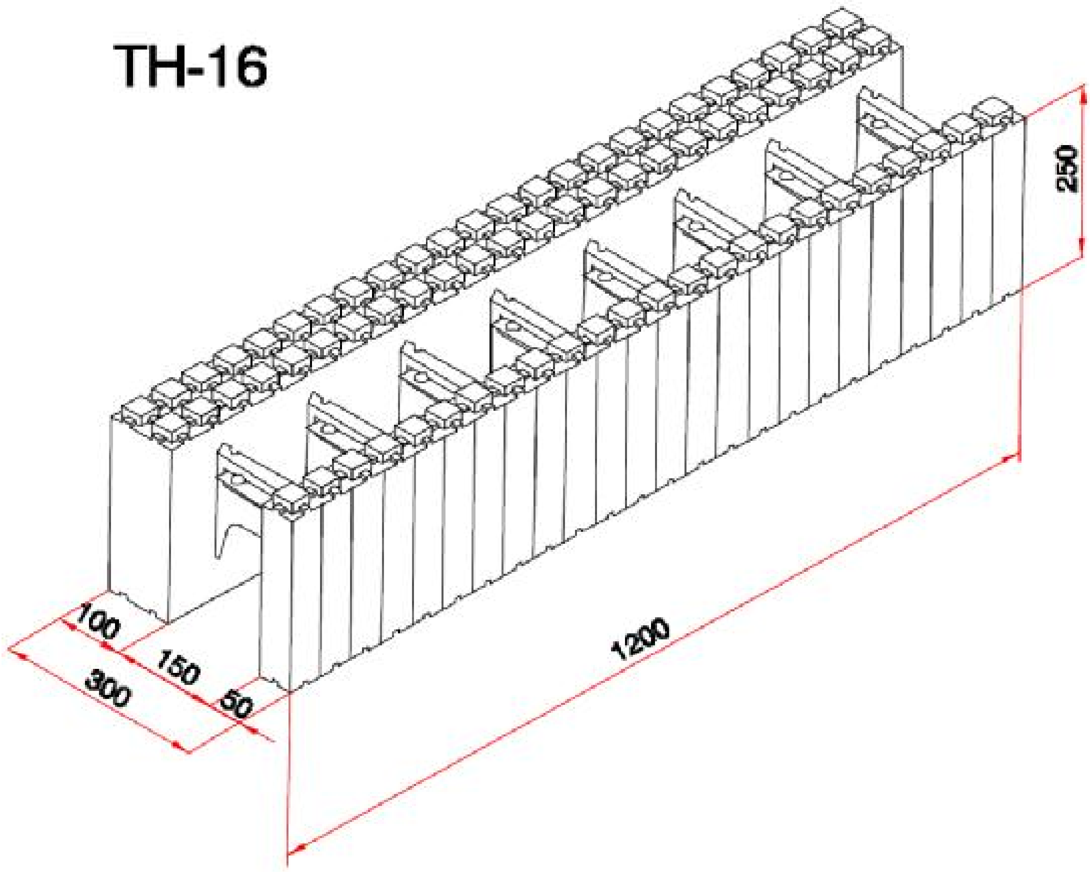



***Figure A.1.2 An overview of the wall system. The poured concrete is dense structural concrete with a typical density of 2400 kg/m³. Guidance is given in Technical Guidance Document L of the building regulations.***

Table A.2.1 shows the conductivities of the materials and air spaces used in the numerical modelling.

| Material | Thermal conductivity in W/m·K |
|---|---|
| Plasterboard | 0.21 |
| Cavity (50mm) | 0.277 |
| Timber (softwood) | 0.13 |
| EPS (Higher Conductivity) | 0.035 |
| EPS (Lower Conductivity) | 0.030 |
| Concrete (Density of 2400 kg/m$^3$) | 2.0 |
| Render | 0.26 |
| Steel | 50.0 |

***Table A.2.1 Thermal conductivities of the materials***

The layers for Thermohouse 300 are as in Tables A.2.2 and A.2.3.

| Outer extent of section | Inner extent of section | Thickness (mm) |
|---|---|---|
| Internal side of gypsum skim | Outer side of gypsum skim | 4 |
| Internal side of plasterboard | Outer side of plasterboard | 12.5 |
| Inner side of cavity | Outer side of cavity | 50 |
| Inner side of EPS | Outer side of EPS | 50 |
| Inner side of concrete | Outer side of concrete | 150 |
| Inner side of EPS | Outer side of EPS | 100 |
| Inner side of render | Outer side of render | 12.5 |

***Table A.2.2 Section dimensions used in the numerical modelling***

| Top of layer | Bottom of layer | Thickness (mm) |
|---|---|---|
| Adiabatic boundary | Top of upper section of construction | 50 |
| Top of upper section of construction | Top of steel fixing | 150 |
| Top of steel fixing | Top of lower section of construction | 50 |
| Top of lower section of construction | Adiabatic boundary | - |

***Table A.2.3 Layer dimensions used in the numerical modelling***

U-Value and minimum internal surface temperature factor calculations are in Tables A3.1, 3.2 and 3.3.

| **'Higher Conductivity' ICF Wall** | **Result** | **Unit** |
|---|---|---|
| Thickness of internal gypsum skim | 4 | mm |
| Total heat transfer, $\Phi$ | 1.35130 | W |
| Lateral dimension of model, $b_1$ (horizontal) | 1200 | mm |
| Lateral dimension of model, $b_2$ (vertical) | 250 | mm |
| Area of model in plane perpendicular to principal direction of heat transfer, $b_1$ x $b_2$ | 0.3 | m² |
| Internal environmental temperature, $T_i$ | 20 | °C |
| External environmental temperature, $T_e$ | 0 | °C |
| **U-value,** $\Phi$ / ( ($T_i$ – $T_e$) x ($b_1$ x $b_2$) ) | **0.225** | **W/m²K** |
| Minimum internal surface temperature | 19.39 | °C |
| **Minimum surface temperature factor, $f_{Rsi}$** | **0.97** | **-** |

***Table A3.1 A summary of the results of the numerical modelling calculations for the Higher Conductivity variation (EPS – 0.035 W/m•K)***

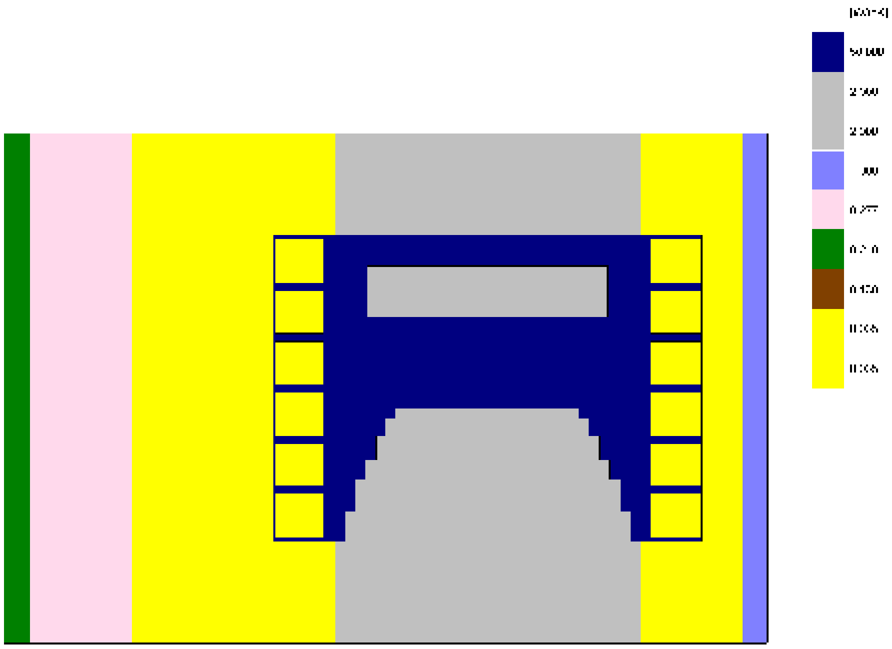
| **'Lower Conductivity'** | **Result** | **Unit** |
|---|---|---|
| Thickness of internal gypsum skim | 4 | mm |
| Total heat transfer, $\Phi$ | 1.1833 | W |
| Lateral dimension of model, $b_1$ (horizontal) | 1200 | mm |
| Lateral dimension of model, $b_2$ (vertical) | 250 | mm |
| Area of model in plane perpendicular to principal direction of heat transfer, $b_1$ x $b_2$ | 0.3 | m² |
| Internal environmental temperature, $T_i$ | 20 | °C |
| External environmental temperature, $T_e$ | 0 | °C |
| **U-value,** $\Phi$ / ( ($T_i$ – $T_e$) x ($b_1$ x $b_2$) ) | **0.197** | **W/m²K** |
| Minimum internal surface temperature | 19.47 | °C |
| **Minimum surface temperature factor, $f_{Rsi}$** | **0.974** | **-** |

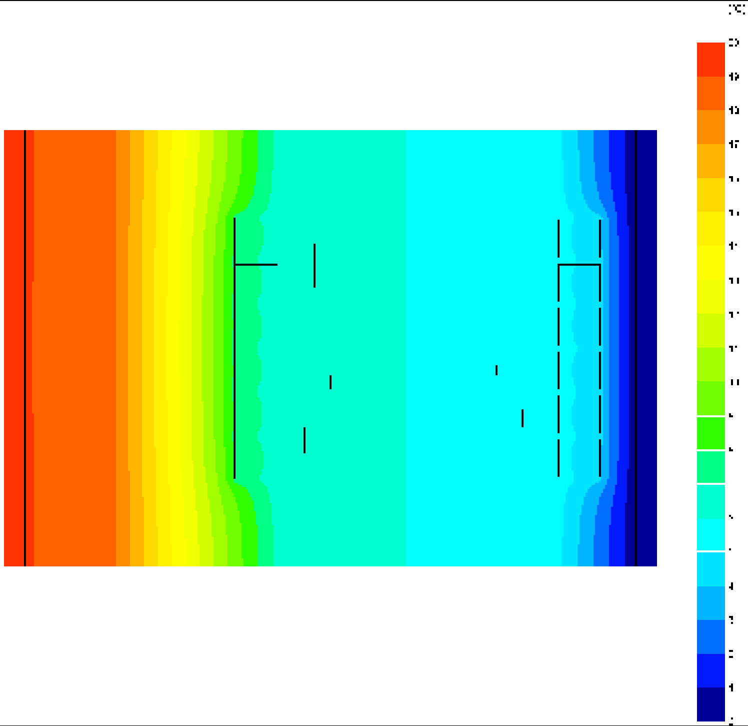
***Table A3.2 A summary of the results of the numerical modelling calculations for the Higher Conductivity variation (EPS – 0.030 W/m•K)***

| **'Lower Conductivity' with no steel fixings** | **Result** | **Unit** |
|---|---|---|
| Thickness of internal gypsum skim | 4 | mm |
| Total heat transfer, $\Phi$ | 1.08781 | W |
| Lateral dimension of model, $b_1$ (horizontal) | 1200 | mm |
| Lateral dimension of model, $b_2$ (vertical) | 250 | mm |
| Area of model in plane perpendicular to principal direction of heat transfer, $b_1$ x $b_2$ | 0.3 | m² |
| Internal environmental temperature, $T_i$ | 20 | °C |
| External environmental temperature, $T_e$ | 0 | °C |
| **U-value,** $\Phi$ / ( ($T_i$ – $T_e$) x ($b_1$ x $b_2$) ) | **0.181** | **W/m²K** |
| Minimum internal surface temperature | 19.52 | °C |
| **Minimum surface temperature factor, $f_{Rsi}$** | **0.976** | **-** |

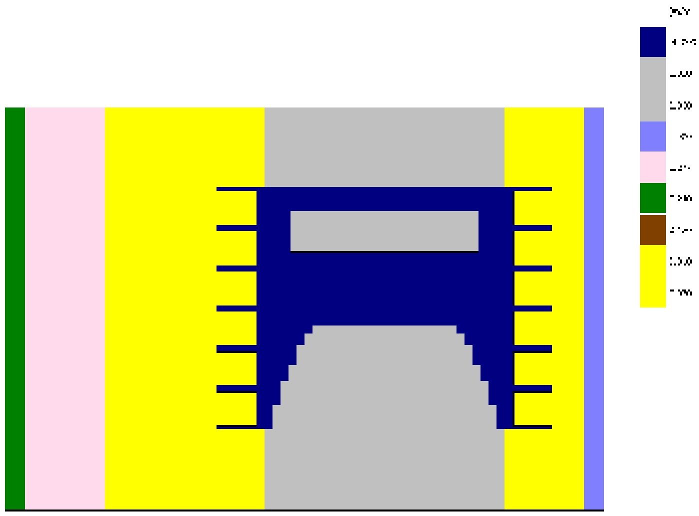
***Table A3.3 A summary of the results of the numerical modelling calculations for the Higher Conductivity variation (EPS – 0.030 W/m•K) with the steel fixings removed***

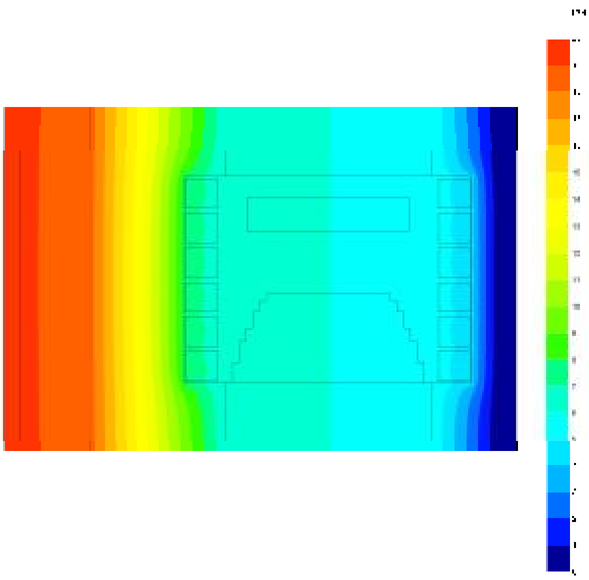
| V_1 | **Thermodeck 300**<br>**EPS thermal conductivity – 0.035 W/m·K** | $U_{wall}$ | $f$ |
|---|---|---|---|
| | ICF Wall Construction | 0.23 | 0.967 |





| | | | |
|---|---|---|---|
| V_2 | **Thermodeck 300**<br>**EPS thermal conductivity – 0.030 W/m·K** | $U_{wall}$ | $f$ |
| | ICF Wall Construction | 0.20 | 0.974 |





<table>
<tr><td rowspan="2">V_3</td><td>Thermodeck 300<br>EPS thermal conductivity – 0.03 W/m·K<br>No steel fixings</td><td>$U_{wall}$</td><td>$f$</td></tr>
<tr><td>ICF Wall Construction</td><td>0.18</td><td>0.976</td></tr>
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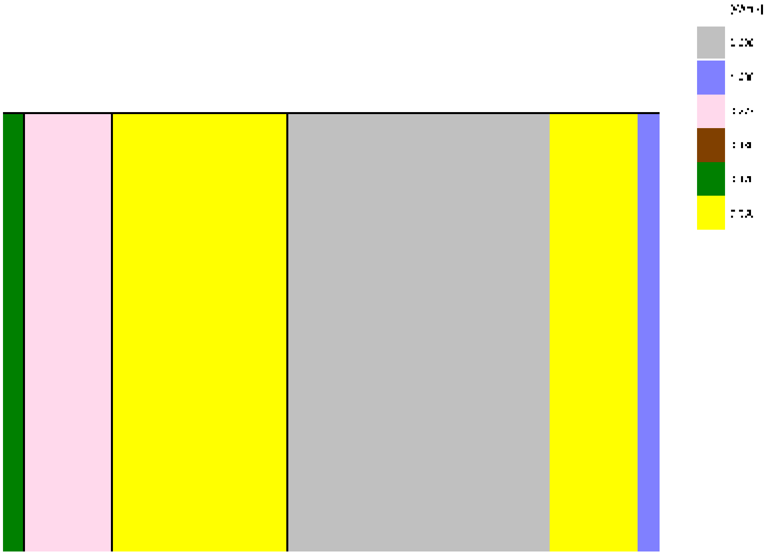

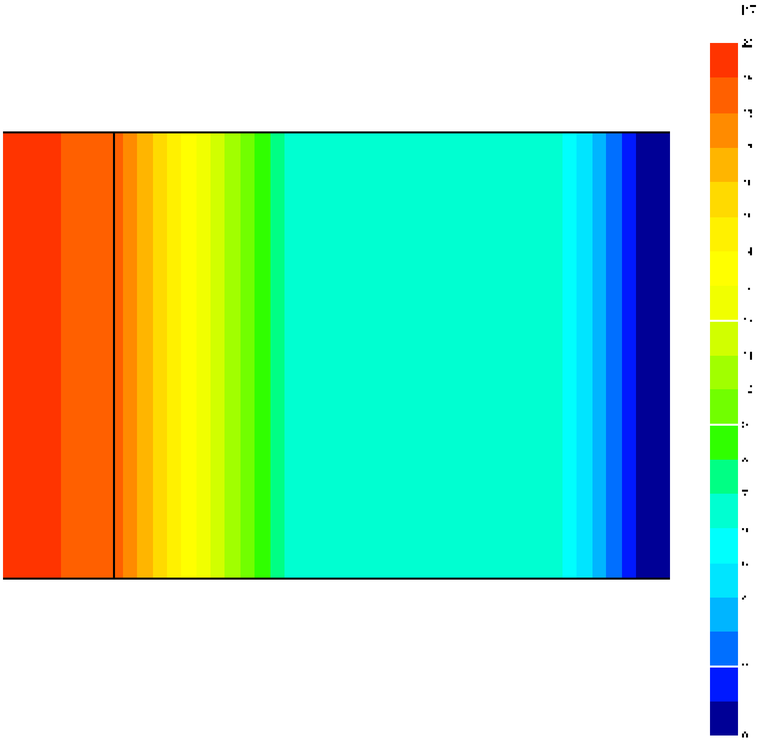

# Appendix B Technical information regarding the roof panel

Thermal modelling calculations were carried out on a roof panel design consisting of 235 mm thick expanded polystyrene (250 mm thick at the ribs) with a 15 mm internal layer of gypsum plaster (thermal conductivity 0.26 W/m·K). To the external side of the expanded polystyrene is a roof space with 50 mm × 50 mm timber counter battens, 50 mm × 38 mm timber roof battens, one layer of breathable membrane and roof tiles. 100 mm high steel channels penetrate the insulation to provide mechanical support. The centre-to-centre spacing of the steel channels is 255 mm.

Table B.1 summarises the dimensions and thermal conductivity values of the various parts of the thermal model of the roof panel.

| Description | Thermal Conductivity W/mK | Horizontal dimension mm | Vertical dimension mm | Minimum horizontal position mm | Maximum horizontal position mm | Minimum vertical position mm | Maximum vertical position mm |
|---|---|---|---|---|---|---|---|
| EPS | 0.03 | 255 | 235 | 0 | 255 | 115 | 350 |
| EPS | 0.03 | 45 | 15 | 105 | 150 | 350 | 365 |
| EPS | 0.03 | 25 | 15 | 0 | 25 | 350 | 365 |
| EPS | 0.03 | 25 | 15 | 230 | 255 | 350 | 365 |
| plaster | 0.260 | 255 | 15 | 0 | 255 | 100 | 115 |
| steel | 50.000 | 50 | 1.2 | 102.5 | 152.5 | 220 | 221.2 |
| steel | 50.000 | 50 | 1.2 | 102.5 | 152.5 | 318.7 | 320 |
| steel | 50.000 | 1.2 | 100 | 151.3 | 152.5 | 220 | 320 |

***Table B.1 The dimensions and thermal conductivities of the parts making up the model***

| Roof panel | Result | Unit |
|---|---|---|
| Lateral dimension of model, parallel to steel channels, $b_1$ | 1000 | mm |
| Lateral dimension of model, perpendicular to steel channels, $b_2$ | 255 | mm |
| Centre to centre spacing of the steel channels | 255 | mm |
| Thermal conductivity of the EPS roof insulation | 0.030 | W/m·K |
| Thermal conductivity of the 15 mm plaster | 0.26 | W/m·K |
| Thickness of steel channels | 1.2 | mm |
| Area through which heat passes | 0.255 | m² |
| Heat transfer through the roof panel section | 0.780 | W |
| Temperature at warm side of panel | 20 | °C |
| Temperature at cold side of panel | 0 | °C |
| **U-value of roof panel** | **0.15** | **W/m²K** |
| Minimum surface temperature | 19.66 | °C |
| **Minimum surface temperature factor** | **0.983** | **-** |

***Table B.2 A summary of the results of the numerical modelling calculations for roof panel***

| | Thermohouse Roof Panel | $U_{roof}$ | $f$ |
|---|---|---|---|
| | | 0.15 | 0.983 |