ASH & LACY

Thermal Modelling Report

Cape Town

Mega Park Unit MP58
Cnr Peter Barlow Drive & Mill Road
Belville South
7530
T: 021 9511036 | M: 083 215 1782
dion.marsh@ashandlacy.com

ISO 9001

UKAS QUALITY MANAGEMENT

TIPSASA THERMAL INSULATION PRODUCTS & SYSTEMS ASSOCIATION SA

SGS

SAMCRA SOUTH AFRICAN METAL CLADDING AND ROOFING ASSOCIATION

Index

1.0 Report

Subject: Thermal Simulation Tests of Typical Roof Assemblies Incorporating Bulk Insulation Blankets

Introduction

The prescriptive route of compliance in SANS10400-XA stipulates that a prescribed total minimum R-Value be achieved in roof assemblies based on the building classification and geographical location. It is widely accepted that the most efficient location for insulation is over purlin. A continuous layer of insulation is achieved, and if installed correctly almost entirely eliminates thermal bridging. Bulk insulation blankets or quilts provide a cost effective and flexible solution in achieving these prescribed R-Values. The insulation however needs to maintain its thickness and position throughout the building envelope assembly in order to achieve its designed thermal resistance. Compression of insulation will proportionately lower the thermal resistance of the material, resulting in a reduced thermal performance.

It is still common practice for a glass fibre blanket or quilt to be installed over purlin below a single steel roof assembly without the use of a roof spacer system. The insulation is supported by basic straining wire and draped between purlins to allow for some recovery in the materials loft. Variations of this detail utilising continuous XPS or timber packers are sometimes employed to improve loft recovery, but these methods still result in varying degrees of compression.

A recent series of independent compression tests were carried out by Oxford Brookes University in the UK to establish the effect of compression on the thermal conductivity and thermal resistance of a Glass Fibre Quilt with a density of 12kg/m3 under these particular site assembly conditions. The tests revealed that when fixed directly below a steel roof sheet and/or packer a 155mm Glass fibre quilt with a density of 12 kg/m3 is compressed at the purlin to a thickness of less than 5.0 mm resulting in a density of 328.6kg/m3. The thermal conductivity of the compressed insulation increased marginally from 0.038W/mK to 0.046W/mK whilst the thermal resistance decreased dramatically from 4.079m2K/W to 0.109m2K/W. South African Building Standards stipulate that an overall minimum R-Value has to be achieved by building envelopes but allows for insulation to cross purlin lines provided that a thermal break of 0.2m2K/W is introduced. The Oxford Brookes University test results confirmed that a compressed 155mm 12kg/m3 glass fibre quilt between a single skin steel weather sheet and purlin does not achieve this required thermal break requirement.

These roof assembly details have been the topic of discussion at both TIPSASA and SAMCRA technical committee meetings and have come under increased scrutiny as to whether the current construction details and methods being used are achieving the prescribed minimum requirements stipulated in the National Building Standards. The lack of available data was the eventual catalyst that prompted Ash & Lacy South Africa to produce an accurate thermal study of these assemblies.

The aim of the study is to produce a comprehensive set of accurate and definitive thermal performance data for commonly used insulated roof assemblies by means of thermal modelling software utilising data obtained from practical field mock-up's, case studies, accredited third party test results and published material properties.

Data Sources

1. Mock-Up Study: Ash & Lacy South Africa (Pty) Ltd and Safintra Roofing (Pty) Ltd. Dion Marsh & Marnitz Benecke, 28/08/13 (Addendum A)

2. Mock-Up Study: Ash & Lacy Building Systems Ltd (UK). Dr Yisheng Tian, 16/05/16

3. Accredited Third Party Laboratory Tests: Oxford Brookes University. Christopher Kendrick, 13/05/16 (Addendum B)

4. THERM 7.4.3.0 09-21-2015 NFRC Thermal Simulation Software Materials Library: Lawrence Berkeley National Laboratory

5. Products Data Sheets:

i. Factorylite: Isover St Gobain

ii. Insultrak: D&D Roof Insulation

iii. Saflok 700: Safintra Roofing

iv. AshGrid: Ash & Lacy South Africa

v. AshFix: Ash & Lacy South Africa

Materials/Data	**Thermal Conductivity**	**Density**	**Emissivity**
Steel Purlins 2.0mm	50.000 W/m-K	8050.00 kg/m^3	0.6
Glass Fibre Insulation (Uncompressed)	0.038 W/m-K	12.00 kg/m^3	0.9
Glass Fibre Insulation (Compressed)	0.046 W/m-K	313.20 kg/m^3	0.9
XPS Packer	0.024 W/m-K	32.00 kg/m^3	0.9
Air Gap (Partially Ventilated)	Complex	NA	Complex
Carbon Steel Fastener	50.000 W/m-K	7850.00 kg/m^3	0.9
AshGrid Brackets	50.000 W/m-K	7850.00 kg/m132	0.2
AshGrid Bars	50.000 W/m-K	7850.00 kg/m133	0.2

Boundary Condition Data	**Film Coefficient (1)**	**Film Coefficient (2)**	**Temperature °c**	**Relative Humdidity**
Exterior Boundary Condition	20.000 W/m^2-K	0.050 m^2-K/W	25	50%
Interior Boundary Condition	6.800 W/m^2-K	0.0147 m^2-K/W	19	50%

Software

1 .THERM 7.4.3.0 09-21-2015 NFRC Thermal Simulation Software developed at Lawrence Berkeley National Laboratory

2. SketchUp Pro 2014

3. Blender V2. 77 3D

Software Utilised

THERM 7.4.3.0 09-21-2015 NFRC Thermal Simulation Software developed at Lawrence Berkeley National Laboratory (LBNL) with the support of the US department of energy for use by building component manufacturers, engineers, educators, students, architects and others interested in heat transfer.
THERM Models two dimensional heat transfer effects in building components such as windows, walls, foundations, roofs and doors; appliances; and other products where thermal bridges are of concern. THERM's heat transfer analysis allows you to evaluate products energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage and structural integrity.
THERM's two dimensional conduction heat transfer analysis based on the finite element method, which can model the complicated geometries of building products with the ability to accurately calculate total R-Values of assemblies. THERM is utilised by the British Board of Agrement (BBA) for thermal simulations in accordance with EN ISO 10077-2. The BBA utilises THERM to carry out thermal simulations and also to verify calculations carried out by others in order to meet UK Building Regulations

Methodology

1. Collated and utilised data from mock-up and case studies to create accurate 2D & 3D drawing of three (3) theoretical roof assembly with a continuous uncompressed layer of insulation with no thermal bridges.
2. Collated and utilised data from mock-up and case studies to create accurate 2D & 3D drawings of nine (9) common roof assemblies.

3. Transposed the 2D .dxf files into THERM 7.4.3 to create accurate cross sectional models of the various roof assemblies.

4. Applied material properties data, internal & external temperatures, relative humidity and boundary conditions to models.

5. Ran THERM 7.4.3 Thermal Simulation software to produce a set of results for each roof assembly type: An active database of the twelve (12) roof assemblies modelled and simulated with THERM 7.4.3.0 is available on request and can be viewed in conjunction with the downloadable THERM software. The results of the simulations include the following:

i. Roof assembly R-value
ii. Isotherms
iii. Flux Vectors
iv. Flux Magnitude
v. Min/Max Temperatures
vi. Collated and summarised results

Test Results

1. A total of twelve (12) roof assemblies were modelled and simulated. Nine (9) of these assemblies were based on actual assemblies commonly used in South Africa whilst three (3) models were based on theoretical assemblies with a continuous uncompressed layer of insulation with no thermal bridges. The simulation results of the actual assemblies were compared to the theoretical assemblies to show the percentage of total R-value loss.
2. The percentage in R-value loss varied dramatically ranging between ± 2% - 72% depending on the assembly, presence of a spacer system, the type of spacer system and the extent of compression incurred by the insulation.
3. The simulated flux vectors and isotherms revealed that a significant amount of thermal movement (bridging) occurs at the purlin lines when the insulation is compressed directly below a roof sheet.
4. A similar pattern in flux vector movement occurs in assemblies where the insulation is compressed below the XPS packer/spacer. Although the XPS packers have an excellent thermal resistance the compressed insulation that exits from below the packer on either side of the purlin is only 4-5mm thick with a thermal resistance of between 0,086m2.K/W - 0,108 m2.K/W. A significant amount of thermal bridging occurs at these lines. The flux vector movements in the simulation are concentrated in these areas. Another significant result of the simulation was the flux vector paths at mid purlin. These vectors that would have ordinarily had a more vertical path tend to travel more horizontally within the insulation directly below the steel roof sheet in a path that gravitates towards the air gaps and compressed insulation at and adjacent to the purlin lines. This increased thermal movement gravitating towards the purlin lines also results in thermal movement diagonally through the sides of the XPS packers where their thickness is only a percentage of their overall depth.

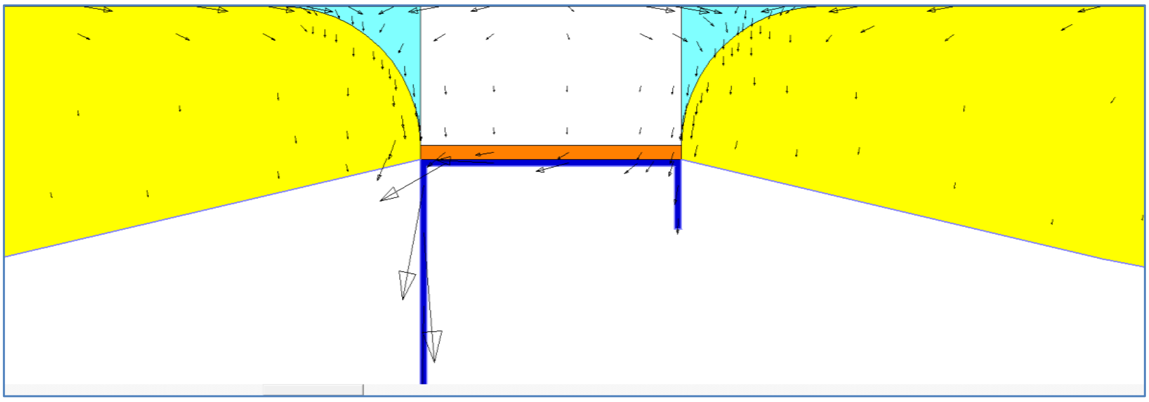
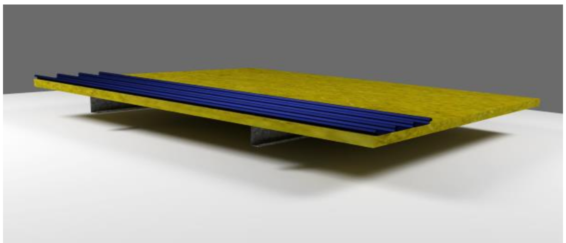
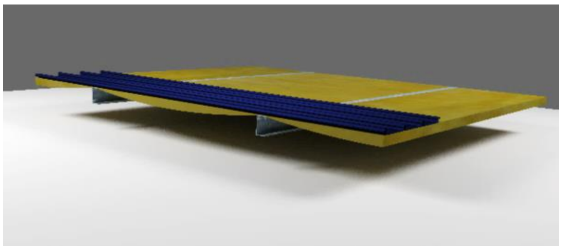
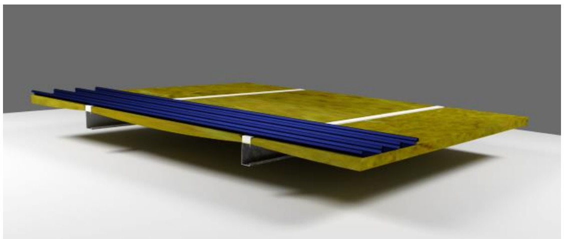
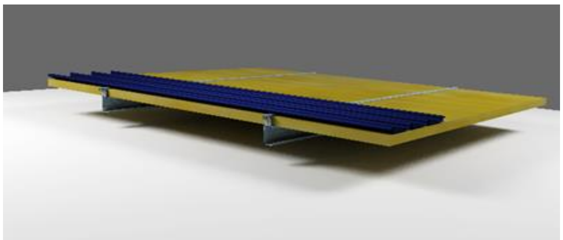
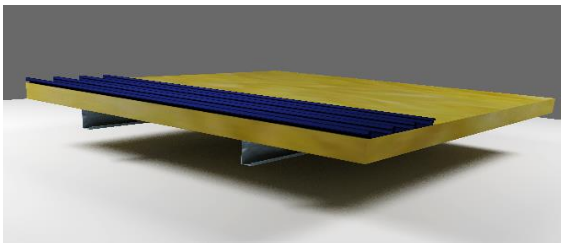
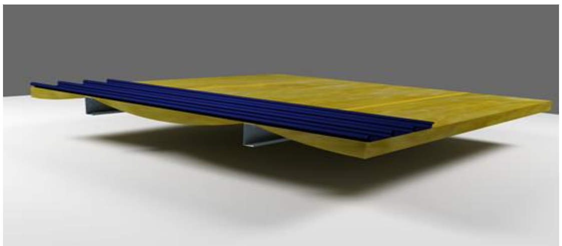
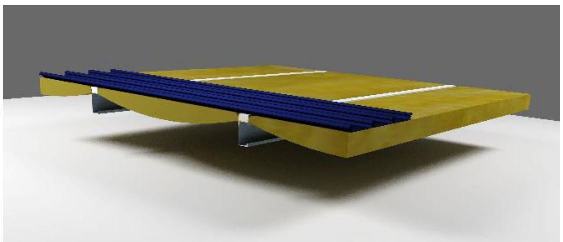
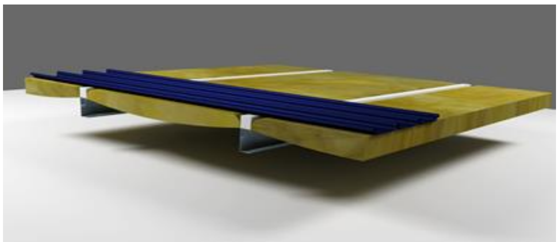
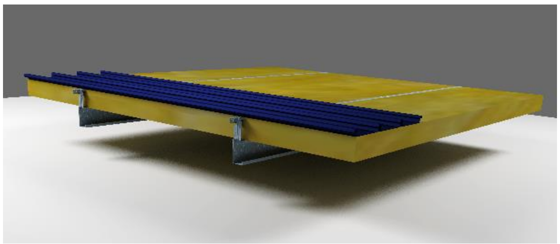
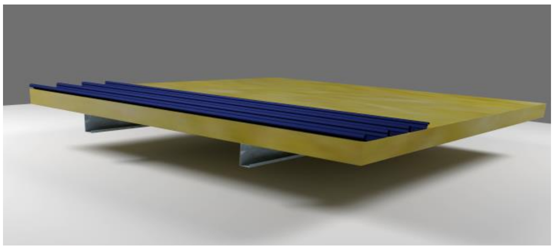
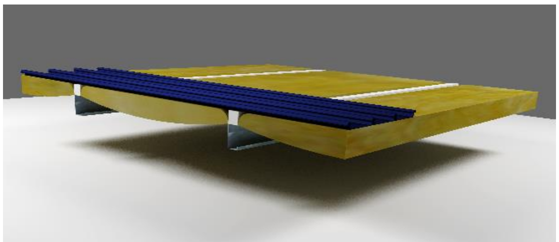
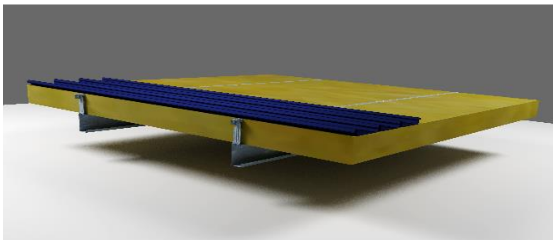


Figure 1 - Example of Flux Vector Paths at Purlin Lines

5. Only three (3) of the nine (9) typical assemblies achieved an R-value percentage loss of less than 5%. These were the assemblies that utilised a bar and bracket type mechanical spacer system which do not cause compression of the insulation at purlin lines. The fractional R-value losses incurred by these assemblies were attributed to small airgaps below the profiled bars and a thermal bridging percentage of approximately 0.1% at the bracket positions.

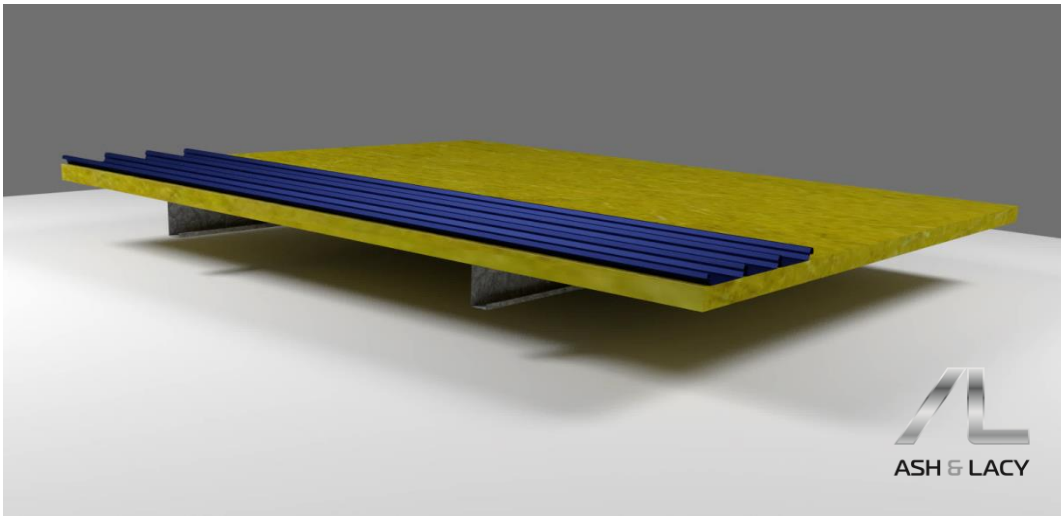
Summary of Simulation Results Continued

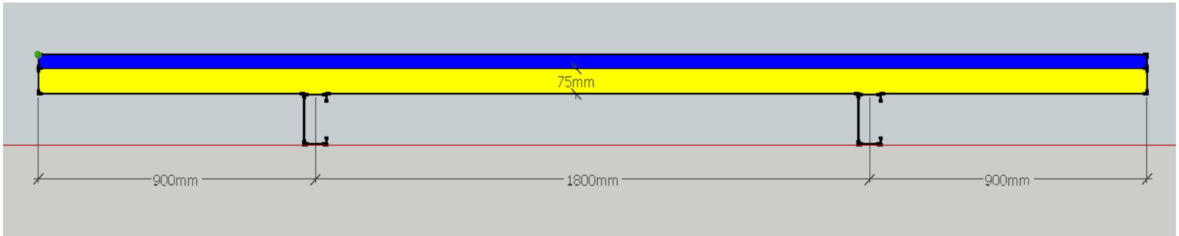
DESCRIPTION OF ROOF ASSEMBLY	IMAGE OF ROOF ASSEMBLY	TOTAL R-VALUE (ACTUAL) m2.K/W	R-VALUE PERCENTAGE LOSS %
75mm Glass Fibre 12 kg/m3, Over Purlin 1800mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet		2.1451	0% LOSS
75mm Glass Fibre 12 kgm3 Over Purlin, 1800mm Centres , Concealed Fix Weather Sheet		1.0043	53% LOSS
75mm Glass Fibre 12 kgm3 Over Purlin 1800mm Centres, 40mm XPS Spacer, Concealed Fix Weather Sheet		1.8114	16% LOSS
75mm Glass Fibre 12 kgm3 Over Purlin 1800mm Centres, 85mm Ashgrid Spacer, 10mm Airgap, Concealed Fix Weather Sheet		2.1165	1% LOSS
135mm Glass Fibre 12 kg/m3, Over Purlin 1500mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet		3.7435	0% LOSS
135mm Glass Fibre 12 kgm3, Over Purlin 1500mm Centres, No Spacer, Concealed Fix Weather Sheet		1.0341	72% LOSS

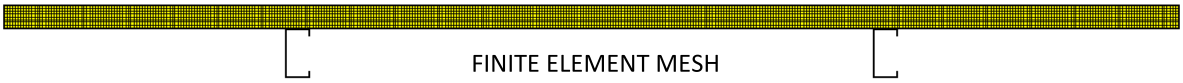
DESCRIPTION OF ROOF ASSEMBLY	IMAGE OF ROOF ASSEMBLY	TOTAL R-VALUE (ACTUAL) m2.K/W	R-VALUE PERCENTAGE LOSS %
135mm Glass Fibre 12 kgm3 Over Purlin 1500mm Centres, 40mm XPS Spacer, Concealed Fix Weather Sheet		2.6077	30% LOSS
135mm Glass Fibre 12 kgm3 Over Purlin 1500mm Centres, 75mm XPS Spacer, Concealed Fix Weather Sheet		3.1181	17% LOSS
135mm Glass Fibre 12 kgm3 Over Purlin 1500mm Centres, 135mm Ashgrid Spacer, Concealed Fix Weather Sheet		3.6425	3% LOSS
150mm Glass Fibre 12 kg/m3, Over Purlin 1500mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet		4.0972	0% LOSS
150mm Glass Fibre 12 kgm3 Over Purlin 1500mm Centres, 75mm XPS Spacer, Concealed Fix Weather Sheet		3.3288	19% LOSS
150mm Glass Fibre 12 kgm3 Over Purlin 1500mm Centres, 150mm Ashgrid Spacer, Concealed Fix Weather Sheet		4.0343	2% LOSS

Assembly A

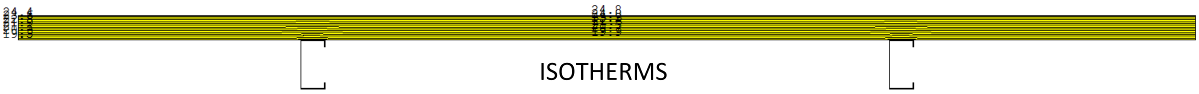
Description - 75mm Glass Fibre 12kg/m³ Over Purlin 1800mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet



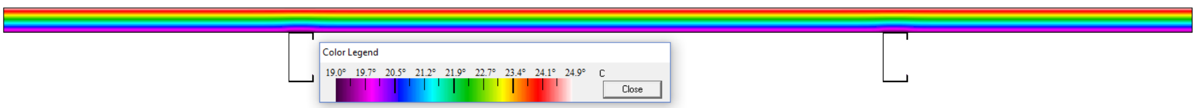




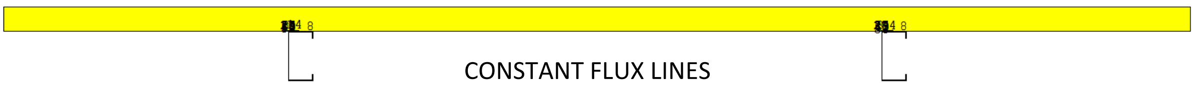
FINITE ELEMENT MESH



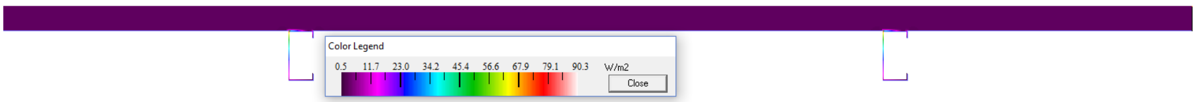
ISOTHERMS



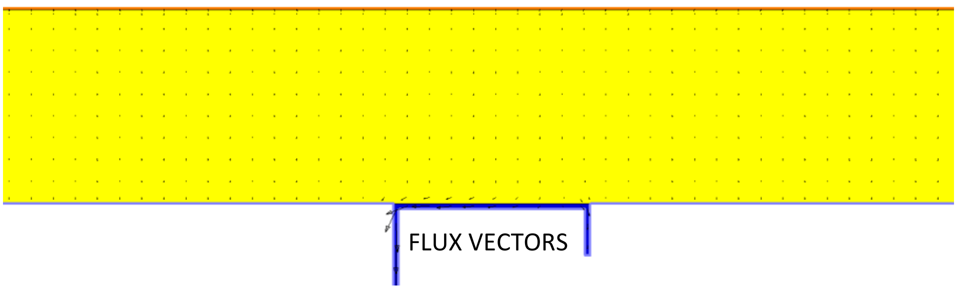
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly A

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m^2-K)
Roof Assembly	3600	Projected X	0.4662

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) $12kg/m^3$	0.04	0.9

Standard Boundary Conditions

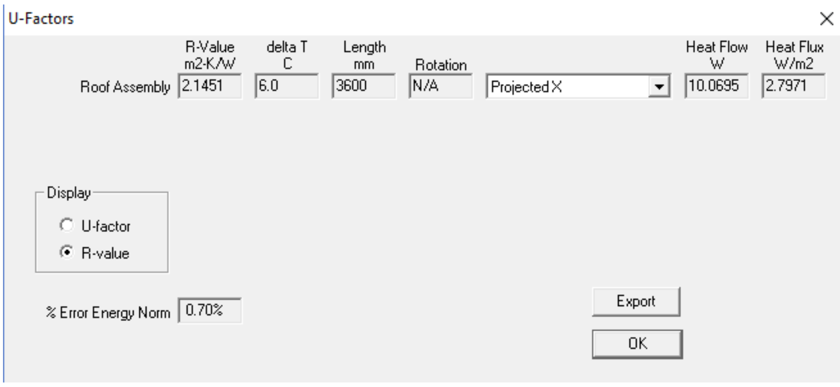
Name	Temperature °c	Film Coefficient W/m^2-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

Calculation Specifications

Mesh Parameter: 10

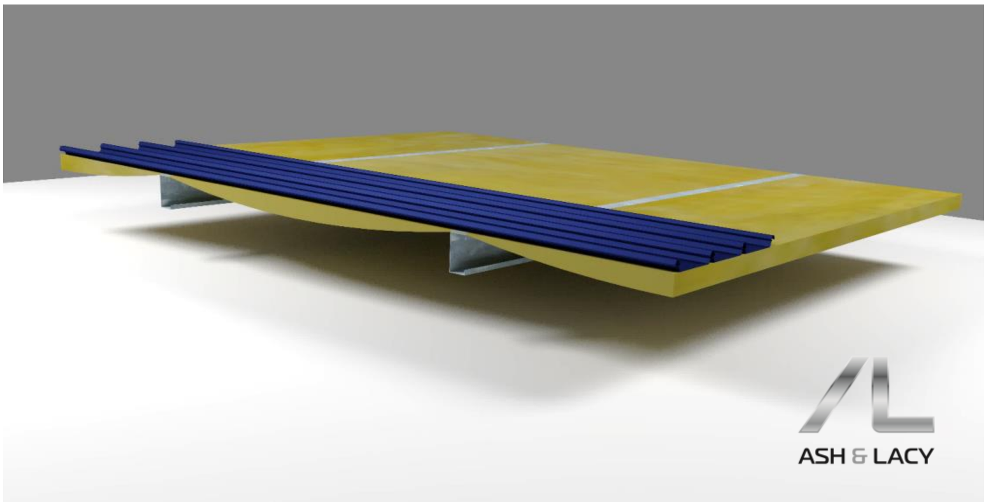
Estimated Error: 0.7%

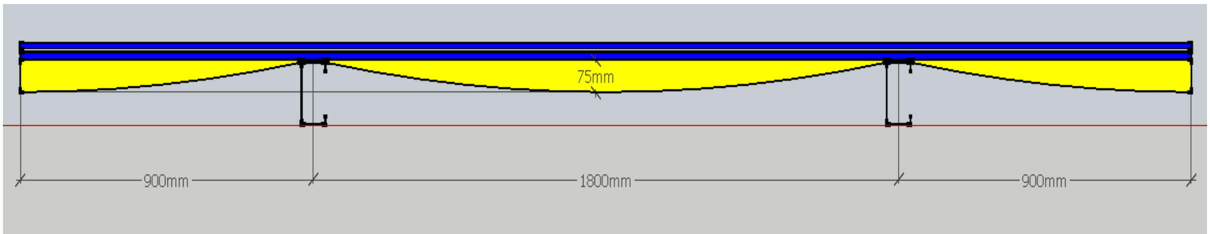
Calculations done in THERM 7.4.3.0

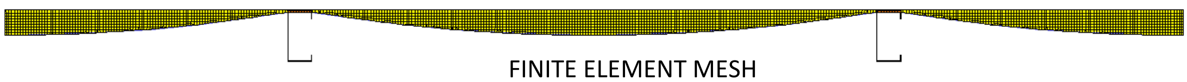


Assembly B

Description - 75mm Glass Fibre 12kg/m³ Over Purlin, 1800mm Centres, Concealed Fix Weather Sheet

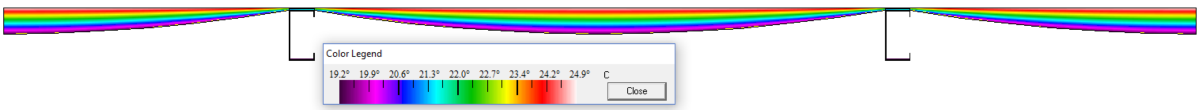






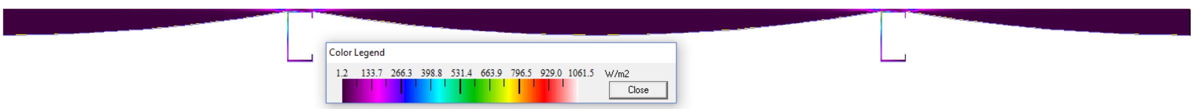
FINITE ELEMENT MESH

ISOTHERMS

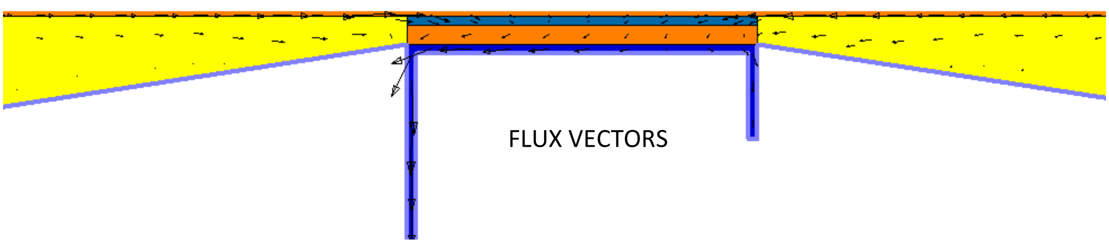


COLOUR INFRARED WITH LEGEND

CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly B

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3600	Projected X	0.9957

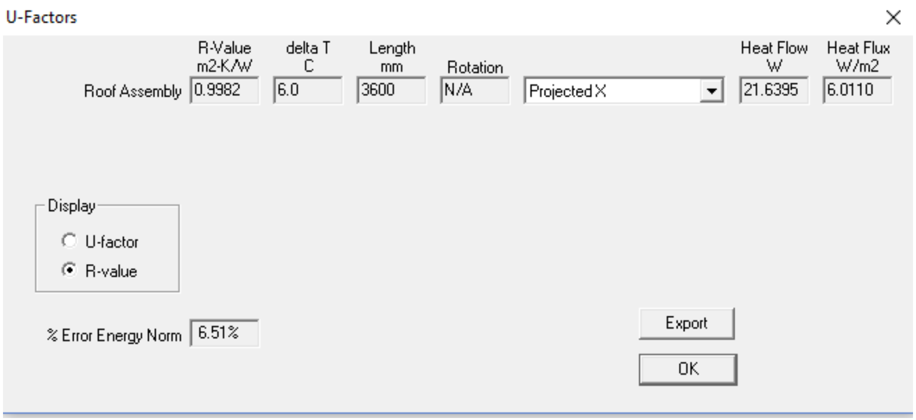
Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
Glass Fibre Compressed (SA) 326kg/m²	0.05	0.9
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9

Standard Boundary Conditions

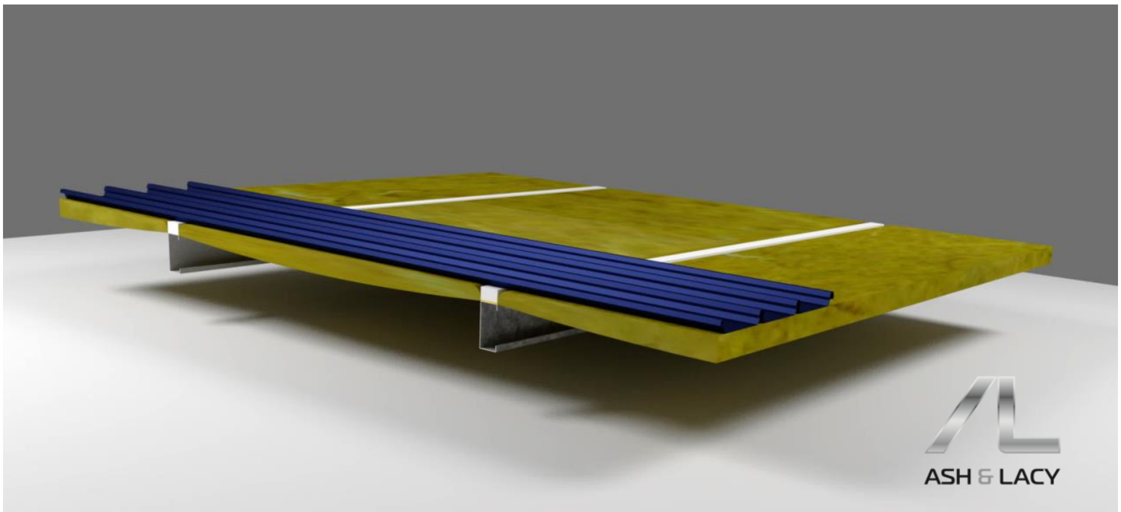
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

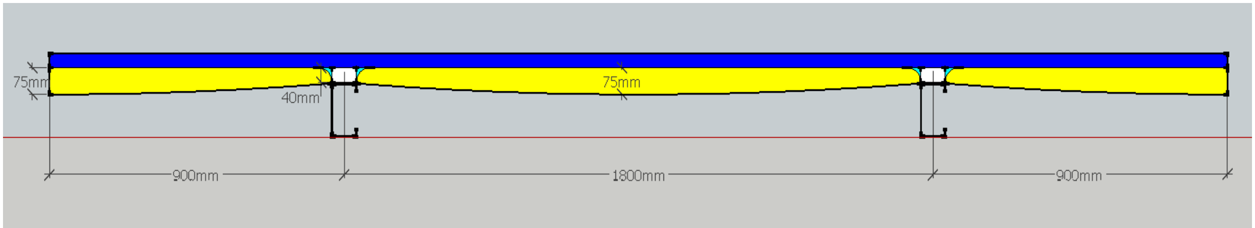
Calculation Specifications
Mesh Parameter: 10
Estimated Error: 6.5%
Calculations done in THERM 7.4.3.0



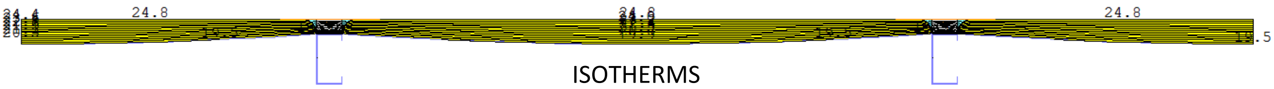
Assembly C

Description - 75mm Glass Fibre 12kg/m³ Over Purlin 1800mm Centres, 40mm XPS Spacer, Concealed Fix Weather Sheet

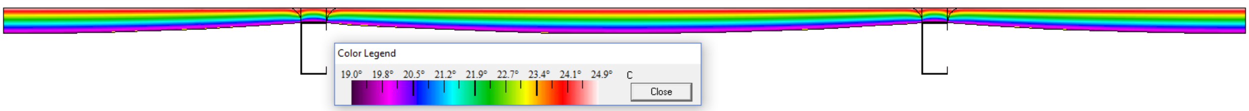




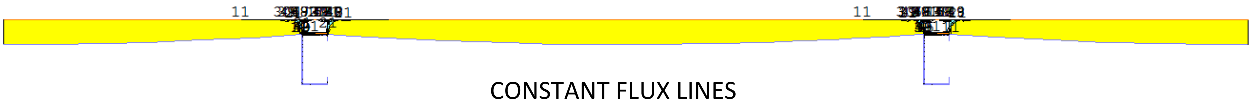
FINITE ELEMENT MESH



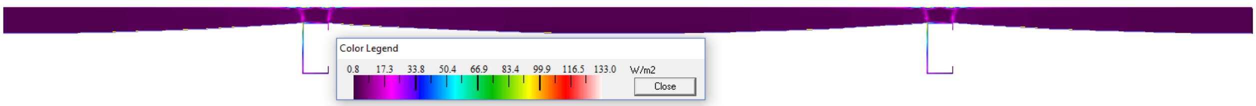
ISOTHERMS



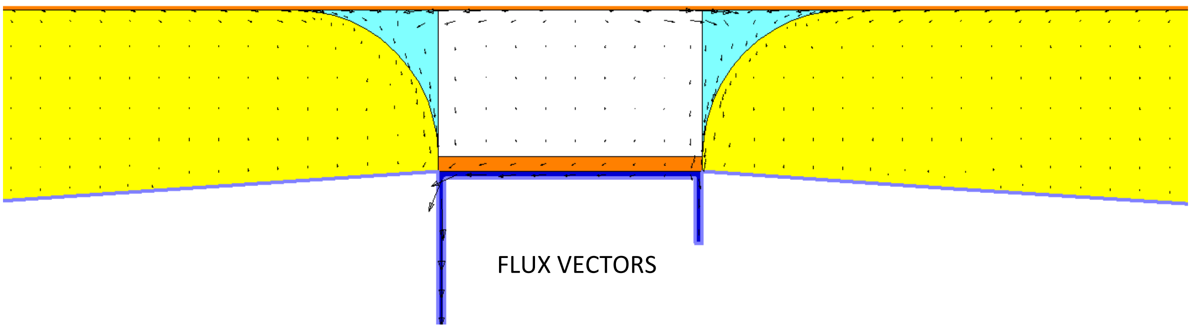
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly C

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3600	Projected X	0.552

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
Glass Fibre Compressed (SA) 326kg/m²	0.05	0.9
XPS Spacer 32kg/m³	0.02	0.9
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9

Cavities

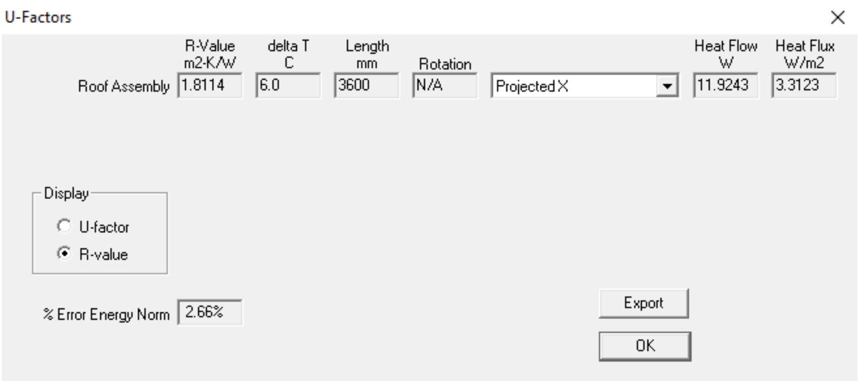
Name: Air Gap
Gas Fill: Air
Convection Model: CEN Ventilated
Radiation Model: Standard

Poly	Heat Flow	Side 1		Side 2		Dimension		NU	Keff	Cavity Height
ID	Dir	Temp °c	Kmis	Temp °c	Kmis	Horz.	Vert.	#	W/m-K	mm
11		22.92	0.90	22.51	0.90	18.53	18.74	NA	0.1833	NA
12		22.94	0.90	22.53	0.90	18.61	18.65	NA	0.1837	NA
13		22.93	0.90	22.51	0.90	18.54	18.73	NA	0.1834	NA
14		22.93	0.90	22.55	0.90	18.49	18.78	NA	0.1831	NA

Standard Boundary Conditions

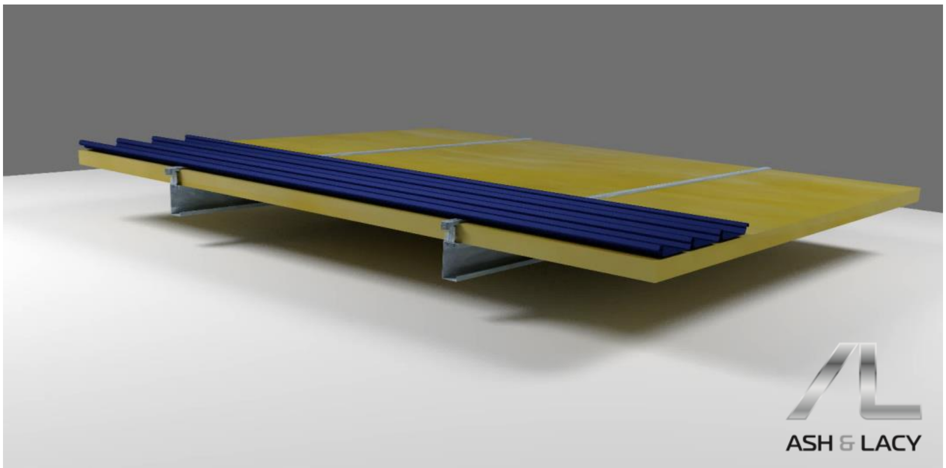
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

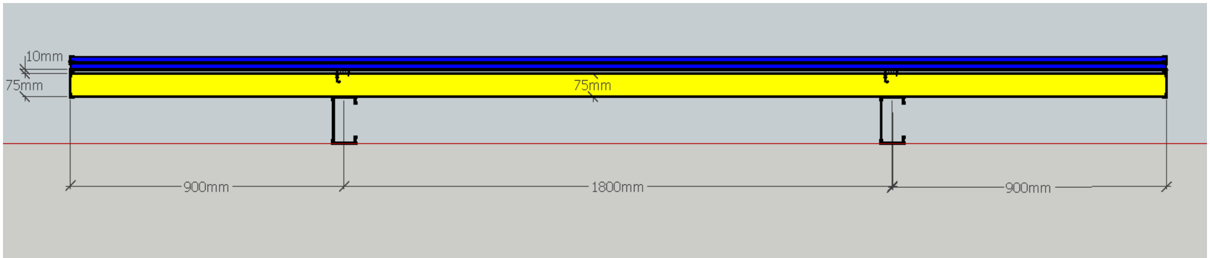
Calculation Specifications
Mesh Parameter: 10
Estimated Error: 2.7%
Calculations done in THERM 7.4.3.0

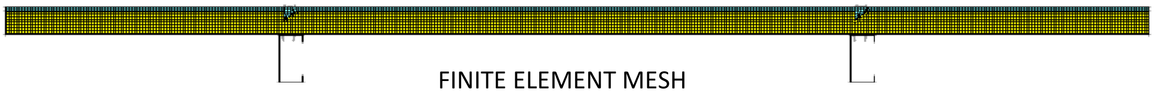


Assembly D

Description - 75mm Glass Fibre 12kg/m³ Over Purlin 1800mm Centres, 85mm AshGrid Spacer, 10mm Airgap, Concealed Fix Weather Sheet

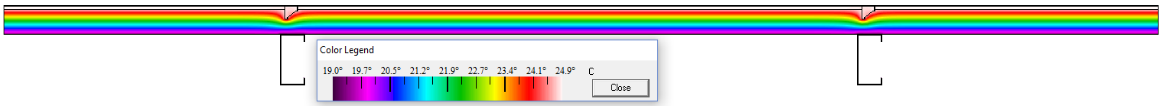




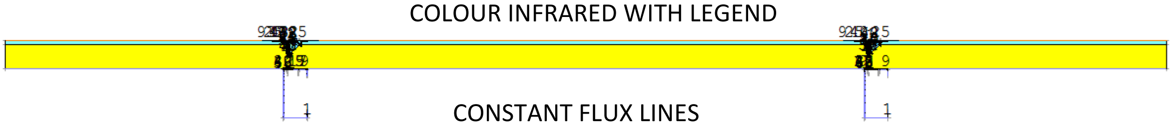


FINITE ELEMENT MESH

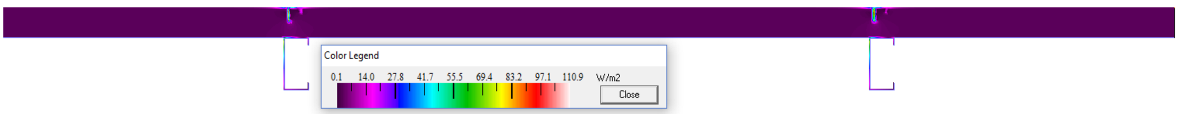
ISOTHERMS



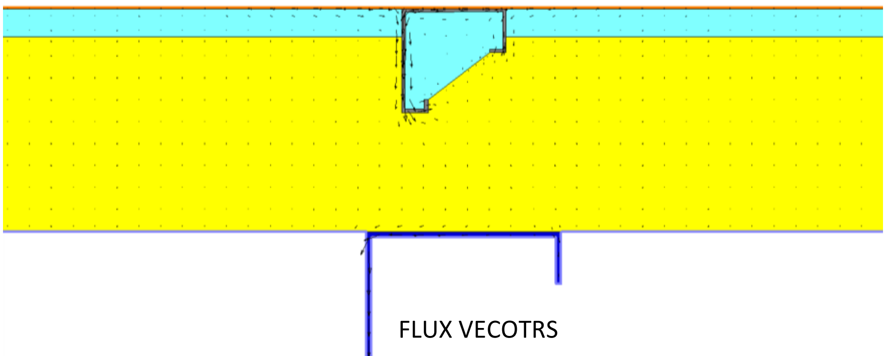
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECOTRS

Assembly D

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3600	Projected X	0.4725

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
AshGrid Spacer	50	0.2
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9

Cavities

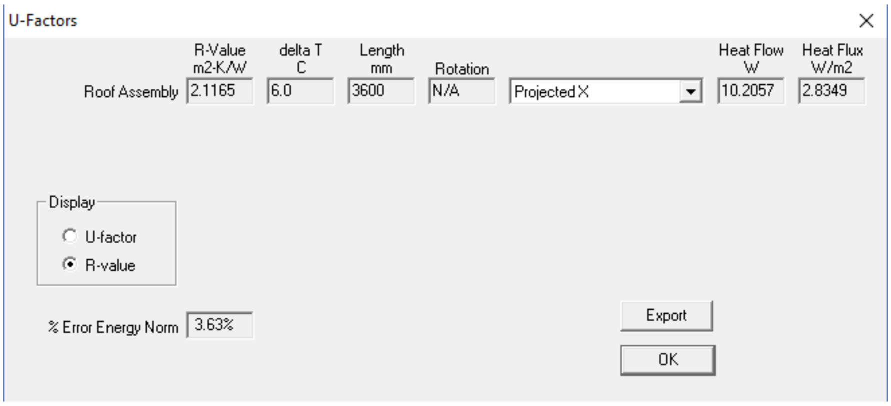
Name: Air Gap
Gas Fill: Air
Convection Model: CEN Ventilated
Radiation Model: Standard

Poly	Heat Flow	Side 1		Side 2		Dimension		NU	Keff	Cavity Height
ID	Dir	Temp °c	Kmis	Temp °c	Kmis	Horz.	Vert.	#	W/m-K	mm
6	Horizontal	24.86	0.90	24.83	0.50	883.75	10.85	NA	3.8065	NA
8	Horizontal	24.83	0.20	24.81	0.20	1759.93	10.85	NA	2.8841	NA
9	Horizontal	24.85	0.90	24.80	0.20	876.18	10.85	NA	2.2077	NA
11	Down	24.66	0.68	24.83	0.20	31.35	31.30	NA	0.1137	NA
14	Down	24.67	0.68	24.83	0.20	30.96	30.91	NA	0.1131	NA

Standard Boundary Conditions

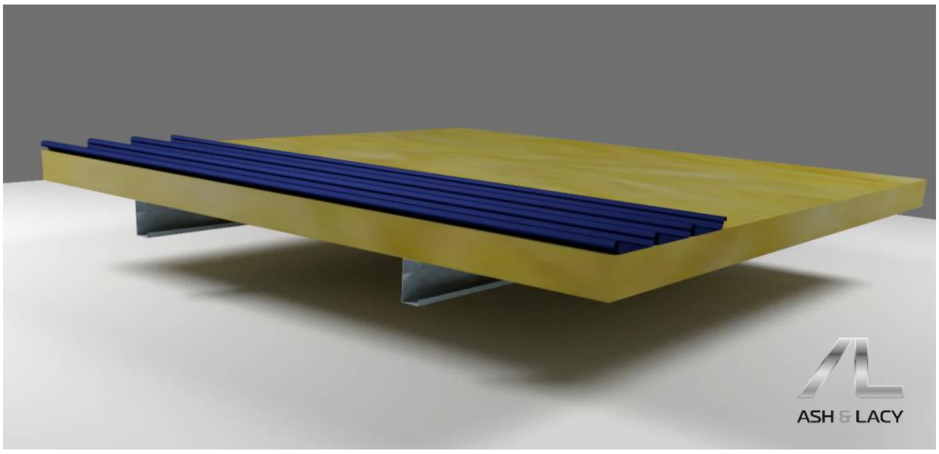
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

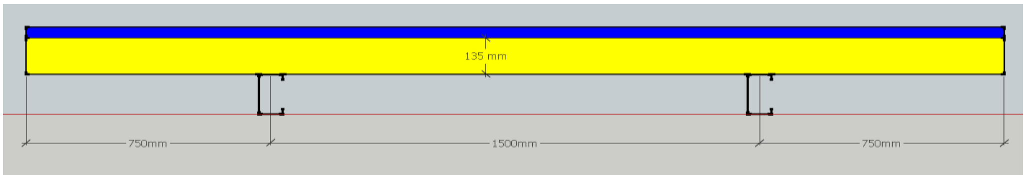
Calculation Specifications
Mesh Parameter: 10
Estimated Error: 3.6%
Calculations done in THERM 7.4.3.0

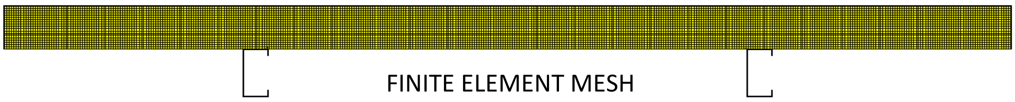


Assembly E

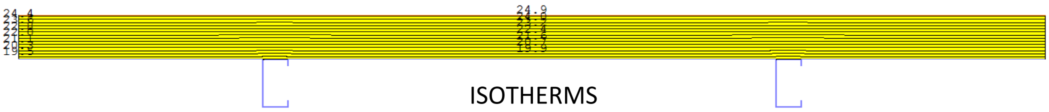
Description - 135mm Glass Fibre 12kg/m³ Over Purlin, 1500mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet



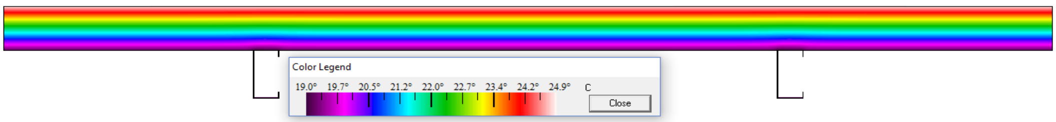




FINITE ELEMENT MESH

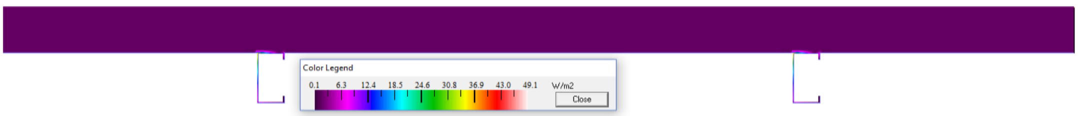


ISOTHERMS

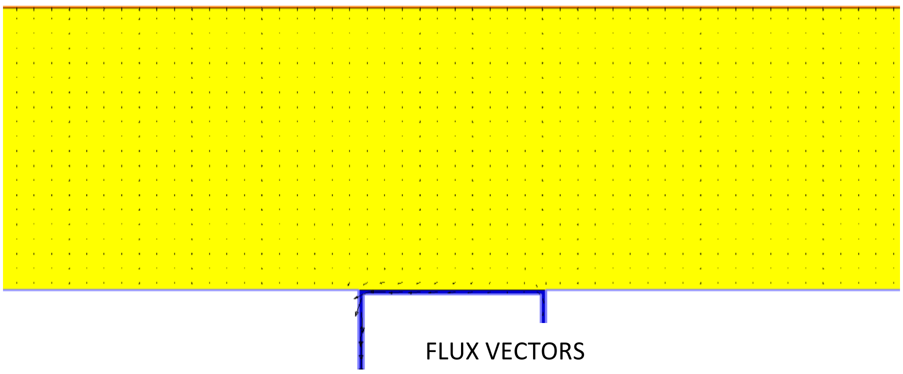


COLOUR INFRARED WITH LEGEND

CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly E

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3000	Projected X	0.2671

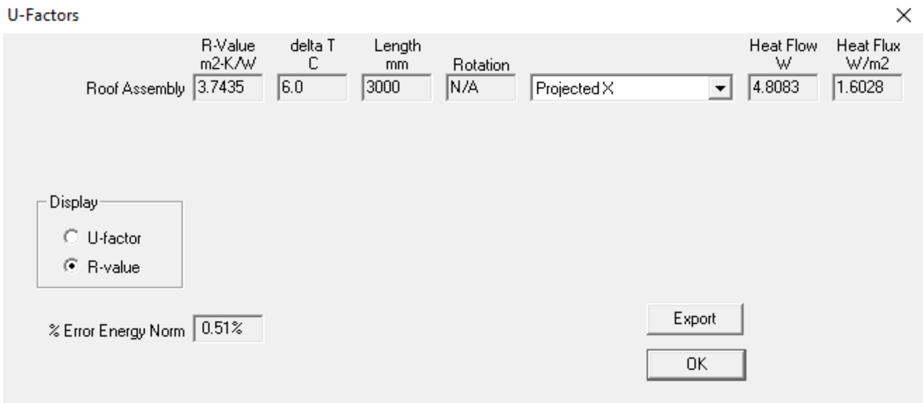
Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9

Standard Boundary Conditions

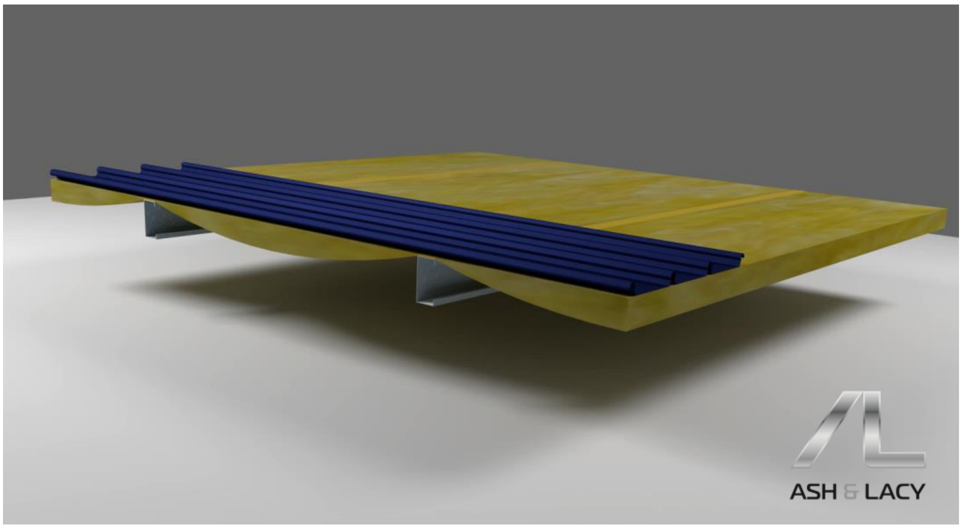
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

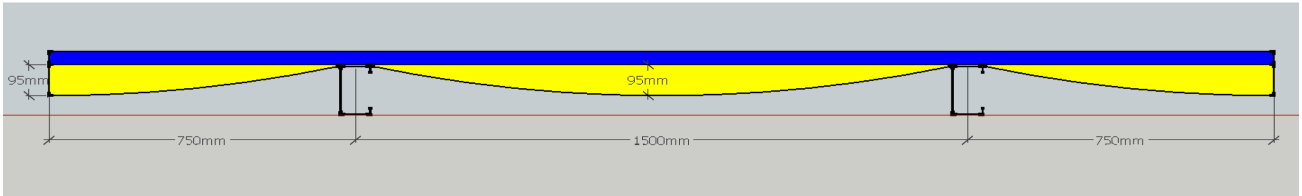
Calculation Specifications
Mesh Parameter: 10
Estimated Error: 0.51%
Calculations done in THERM 7.4.3.0

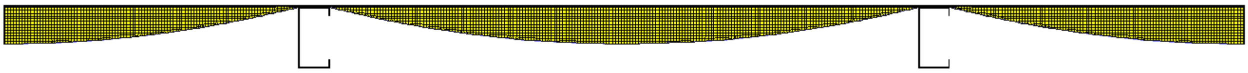


Assembly F

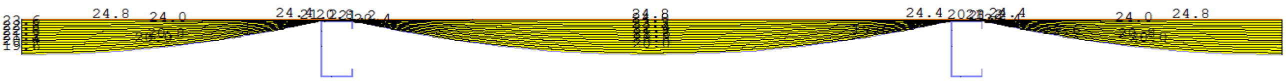
Description - 135mm Glass Fibre 12kg/m³ Over Purlin 1500mm Centres, No Spacer, Concealed Fix Weather Sheet



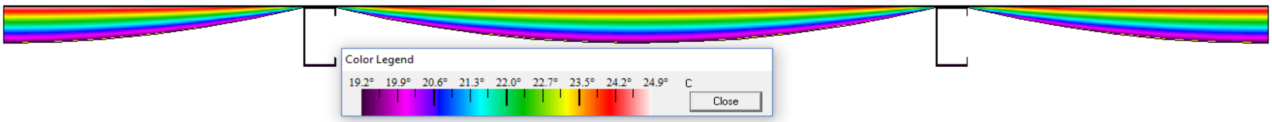




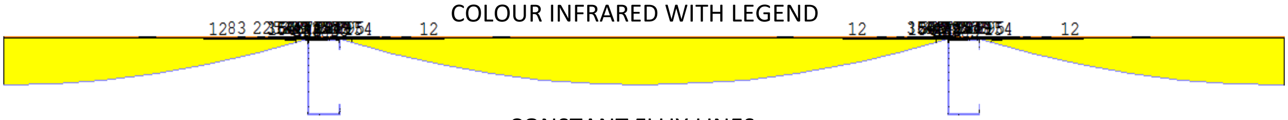
FINITE ELEMENT MESH



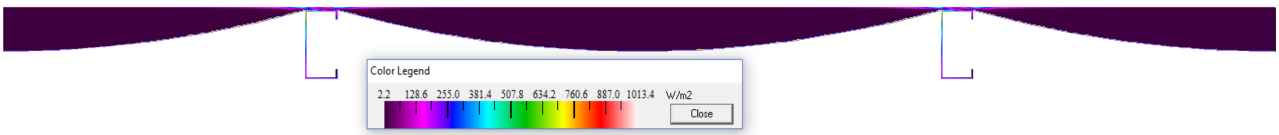
ISOTHERMS



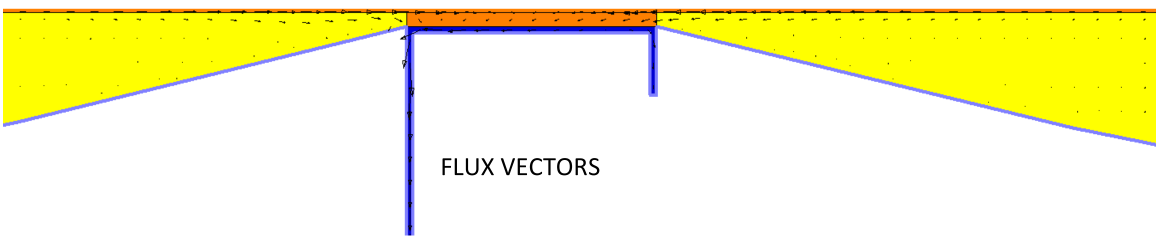
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly F

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3000	Projected X	0.967

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9
Glass Fibre Compressed (SA) 328kg/m³	0.05	0.9

Standard Boundary Conditions

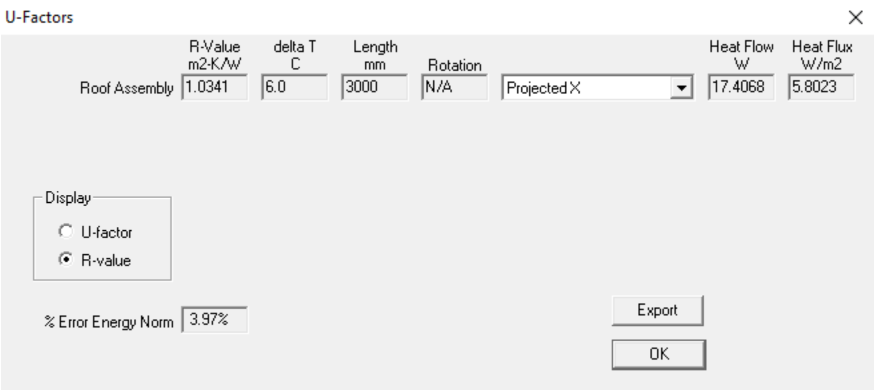
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

Calculation Specifications

Mesh Parameter: 10

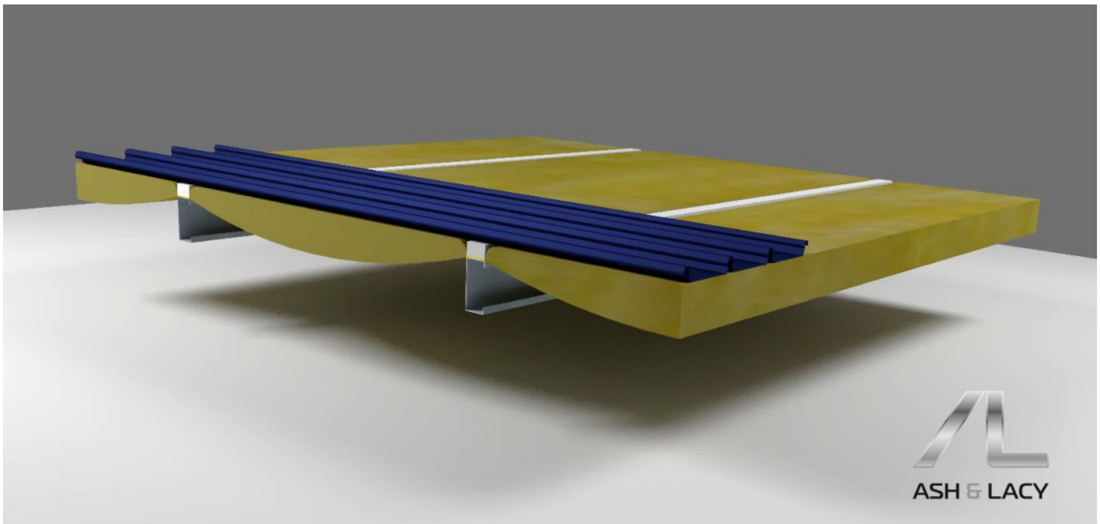
Estimated Error: 4%

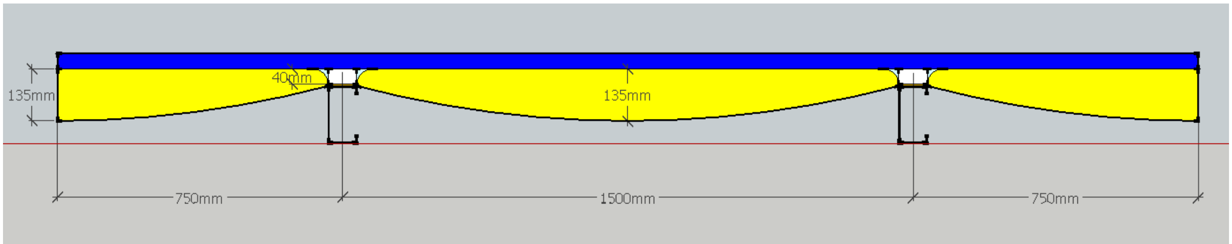
Calculations done in THERM 7.4.3.0

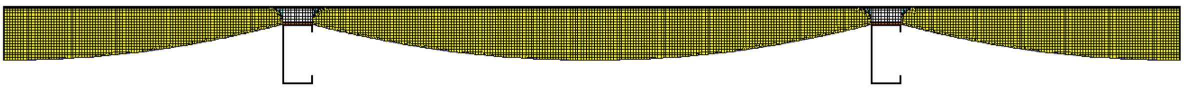


Assembly G

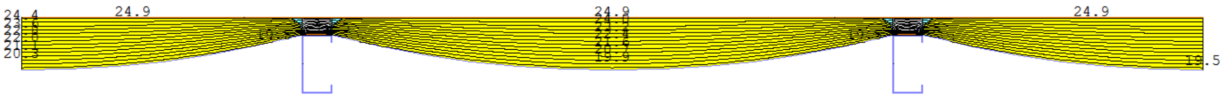
Description - 135mm Glass Fibre 12kg/m³ Over Purlin 1500mm Centres, 40mm XPS Spacer, Concealed Fix Weather Sheet



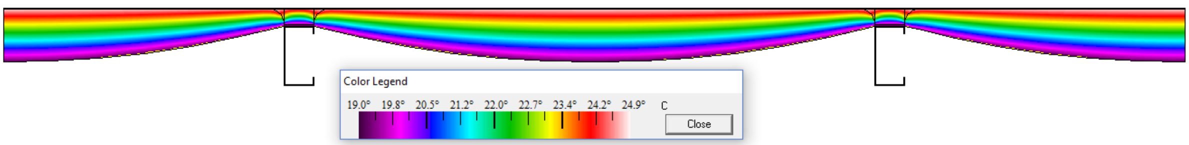




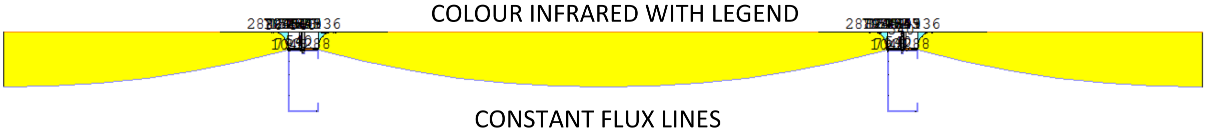
FINITE ELEMENT MESH



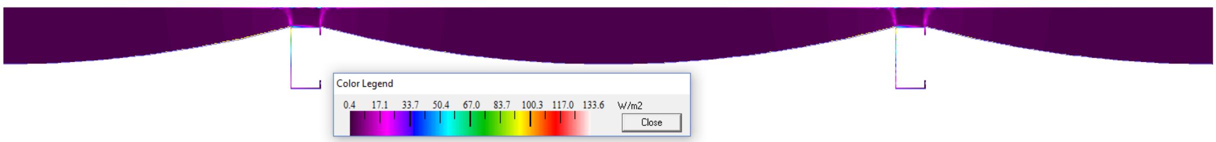
ISOTHERMS



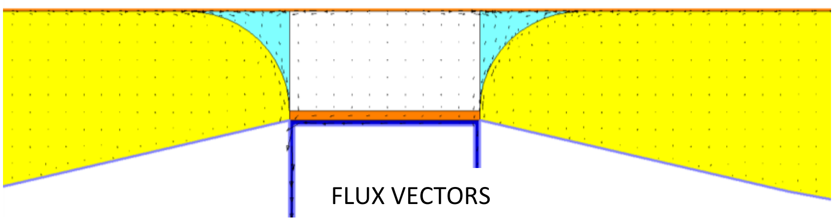
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly G

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3600	Projected X	0.3835

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
XPS Spacer (32kg/m³)	0.02	0.9
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9
Glass Fibre Compressed (SA) 328kg/m³	0.05	0.9

Cavities

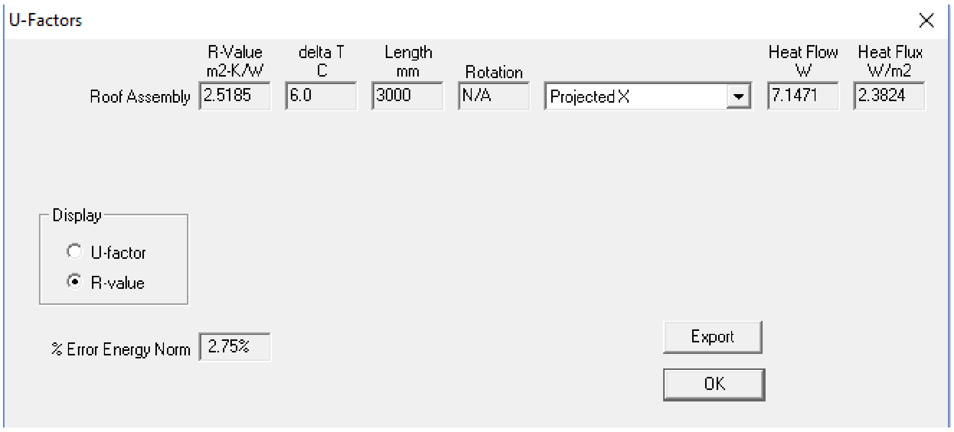
Name: Air Gap
Gas Fill: Air
Convection Model: CEN Ventilated
Radiation Model: Standard

Poly	Heat Flow	Side 1		Side 2		Dimension		NU	Keff	Cavity Height
ID	Dir	Temp °c	Kmis	Temp °c	Kmis	Horz.	Vert.	#	W/m-K	mm
12	Horizontal	22.48	0.90	21.93	0.90	18.59	18.67	NA	0.1828	NA
13	Horizontal	22.51	0.90	21.97	0.90	18.63	18.63	NA	0.1831	NA
14	Horizontal	22.50	0.90	21.96	0.90	18.54	18.71	NA	0.1827	NA
15	Horizontal	22.49	0.90	21.94	0.90	18.63	18.63	NA	0.183	NA

Standard Boundary Conditions

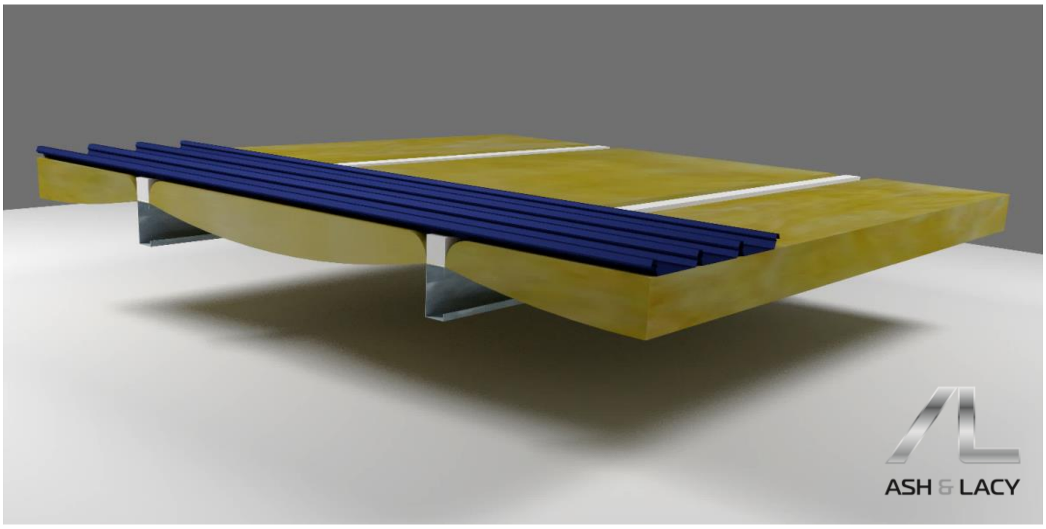
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

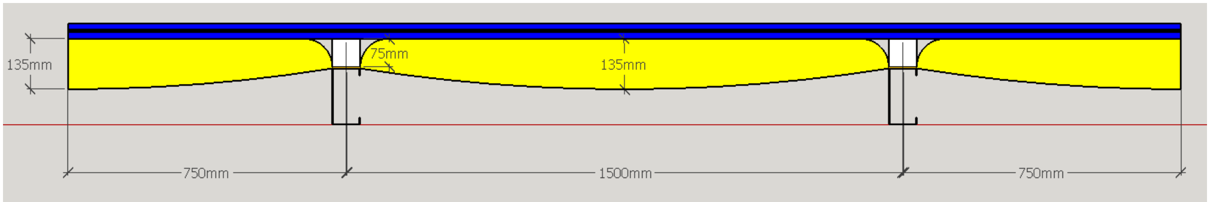
Calculation Specifications
Mesh Parameter: 5
Estimated Error: 5%
Calculations done in THERM 7.4.3.0

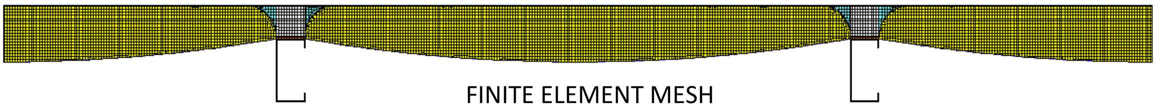


Assembly H

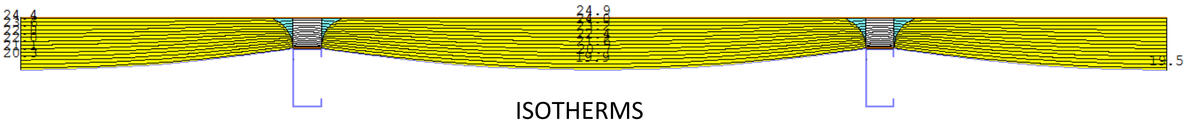
Description - 135mm Glass Fibre 12kg/m³ Over Purlin 1500mm Centres, 75mm Spacer, Concealed Fix Weather Sheet



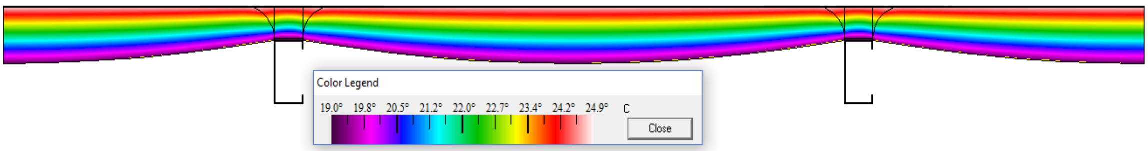




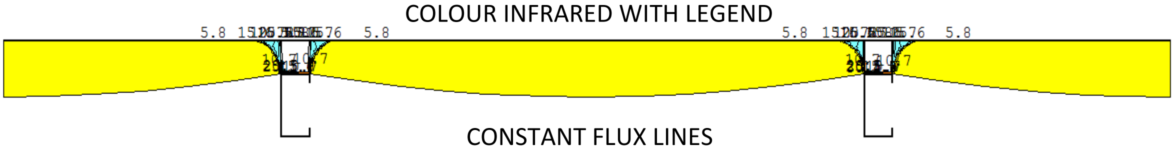
FINITE ELEMENT MESH



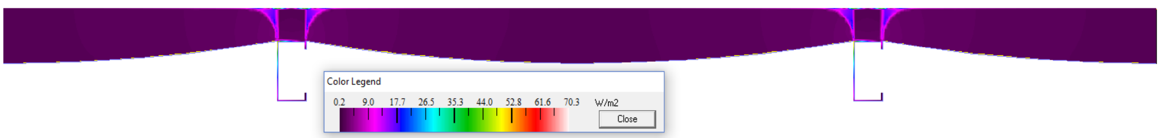
ISOTHERMS



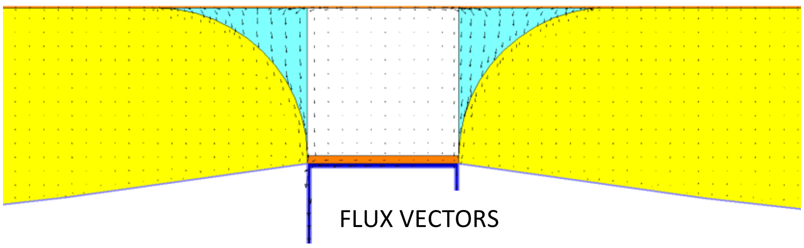
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly H

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3000	Projected X	0.3207

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
XPS Spacer (32kg/m³)	0.02	0.9
Glass Fibre (SA) 12kg/m³	0.04	0.9
Glass Fibre Compressed (SA) 328kg/m³	0.05	0.9

Cavities

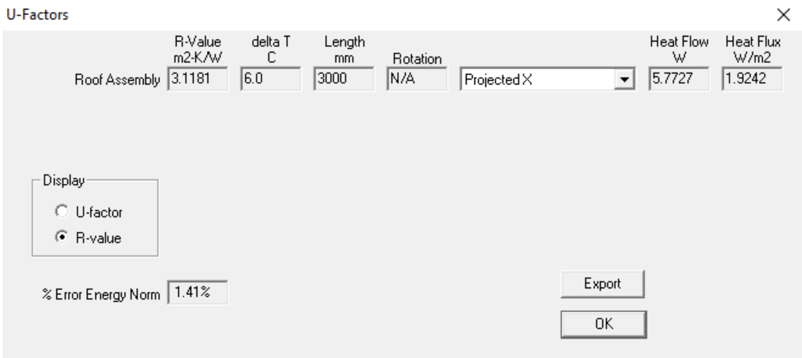
Name: Air Gap
Gas Fill: Air
Convection Model: CEN Ventilated
Radiation Model: Standard

Poly	Heat Flow	Side 1		Side 2		Dimension		NU	Keff	Cavity Height
ID	Dir	Temp °c	Kmis	Temp °c	Kmis	Horz.	Vert.	#	W/m-K	mm
63	Horizontal	22.45	0.90	21.89	0.90	34.92	34.92	NA	0.2993	NA
64	Horizontal	22.45	0.90	21.90	0.90	32.96	36.42	NA	0.2895	NA
65	Horizontal	22.45	0.90	21.89	0.90	33.49	36.06	NA	0.2923	NA
66	Horizontal	22.46	0.90	21.89	0.90	34.87	35.03	NA	0.2992	NA

Standard Boundary Conditions

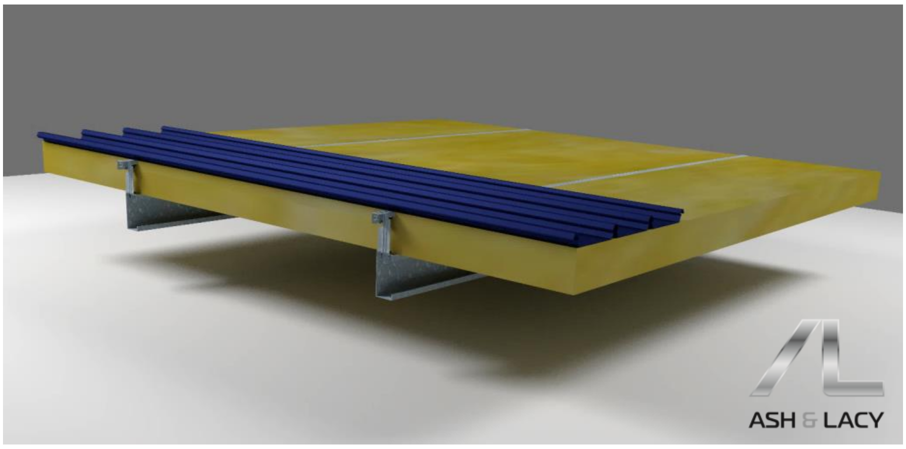
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

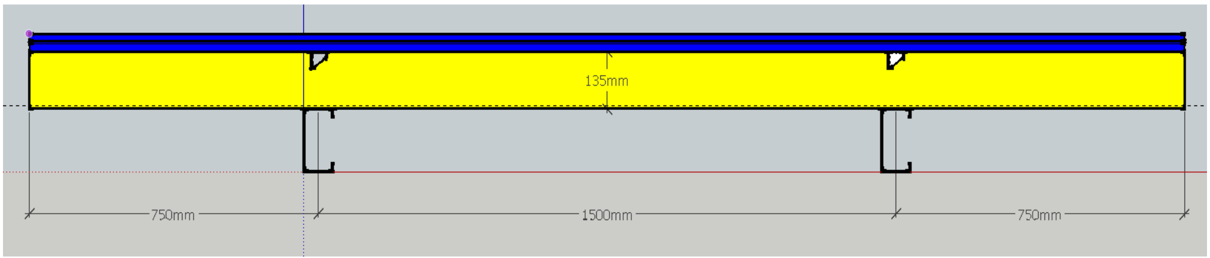
Calculation Specifications
Mesh Parameter: 10
Estimated Error: 1.4%
Calculations done in THERM 7.4.3.0

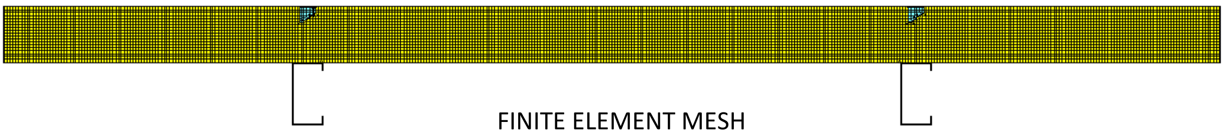


Assembly I

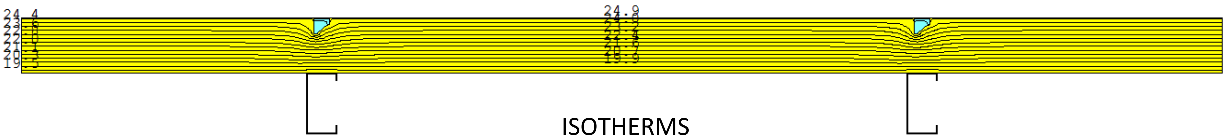
Description - 135mm Glass Fibre 12kg/m³ Over Purlin 1500mm Centres, 135mm AshGrid Spacer, Concealed Fix Weather Sheet



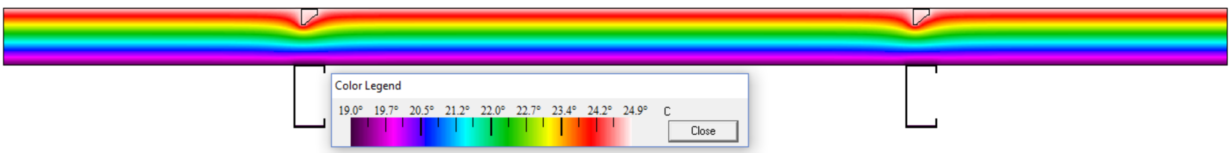




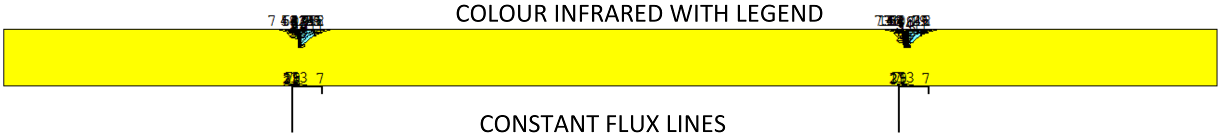
FINITE ELEMENT MESH



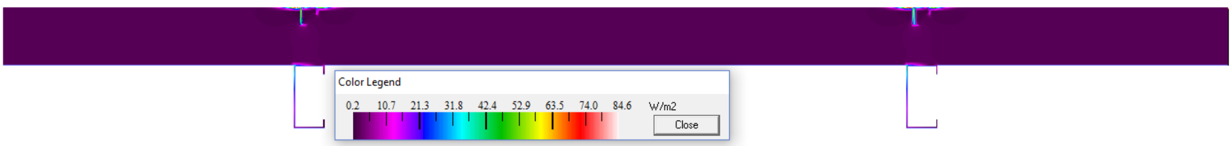
ISOTHERMS



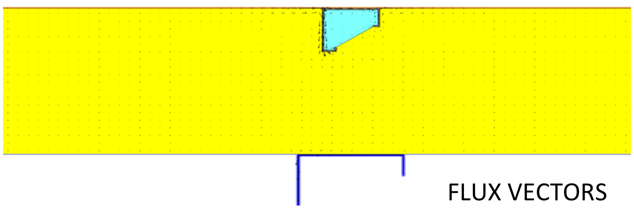
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly I

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3000	Projected X	0.2745

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
AshGrid Spacer	50	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9
Steel - Galvanised Sheet (%C)*	0.05	0.2

Cavities

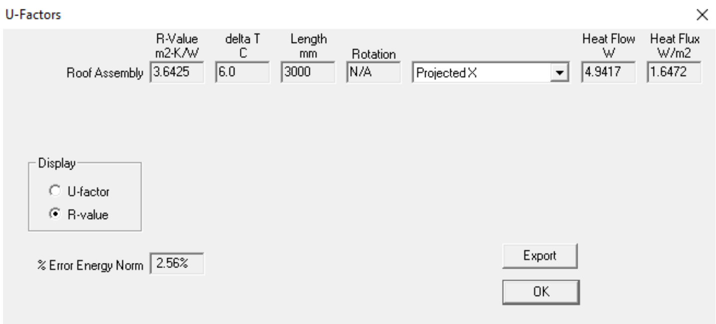
Name: Air Gap
Gas Fill: Air
Convection Model: CEN Ventilated
Radiation Model: Standard

Poly	Heat Flow	Side 1		Side 2		Dimension		NU	Keff	Cavity Height
ID	Dir	Temp °c	Kmis	Temp °c	Kmis	Horz.	Vert.	#	W/m-K	mm
9	Down	24.76	0.70	24.89	0.20	31.83	31.83	NA	0.1155	NA
10	Down	24.76	0.70	24.89	0.20	31.83	31.83	NA	0.1155	NA

Standard Boundary Conditions

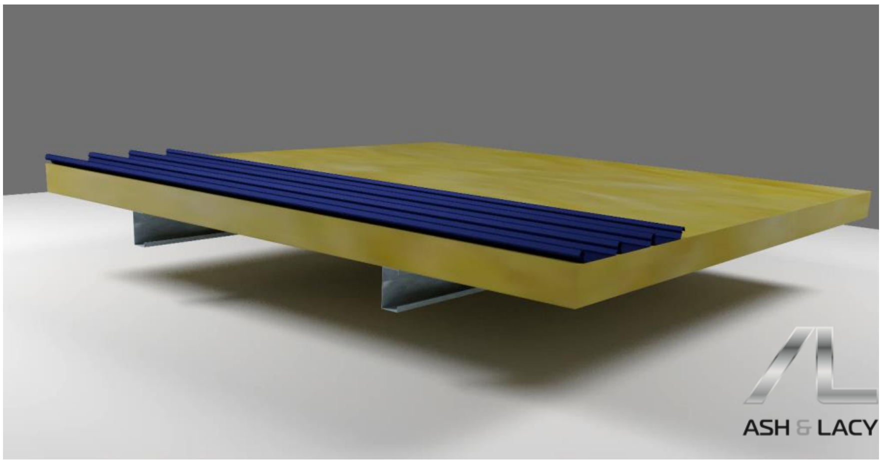
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

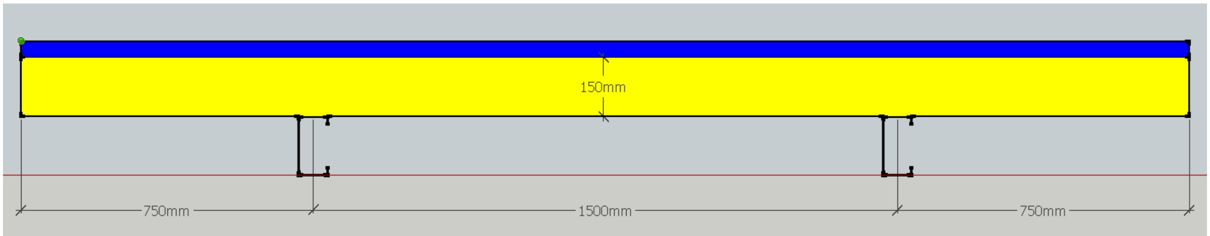
Calculation Specifications
Mesh Parameter: 10
Estimated Error: 2.6%
Calculations done in THERM 7.4.3.0

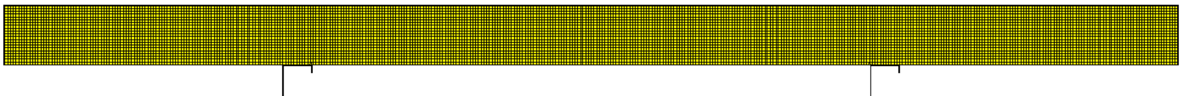


Assembly J

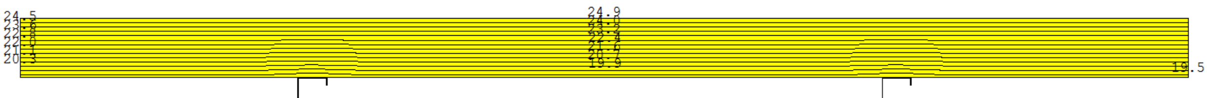
Description - 150mm Glass Fibre 12kg/m³ Over Purlin 1500mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet



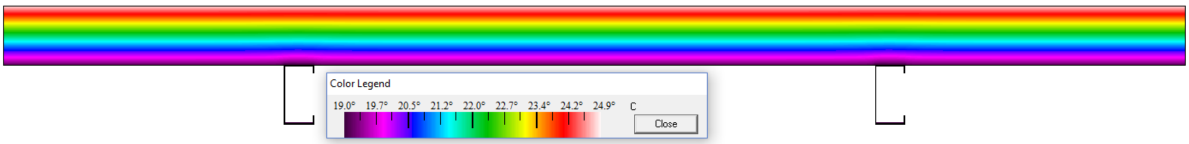




FINITE ELEMENT MESH

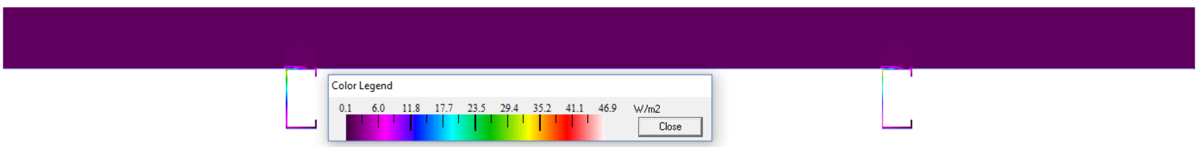


ISOTHERMS

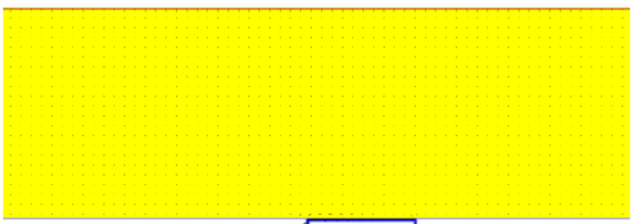


COLOUR INFRARED WITH LEGEND

CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly J

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3000	Projected X	0.2441

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9

Standard Boundary Conditions

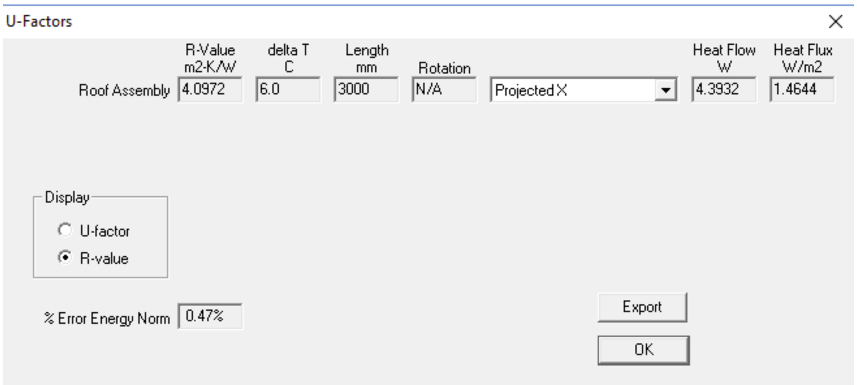
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

Calculation Specifications

Mesh Parameter: 10

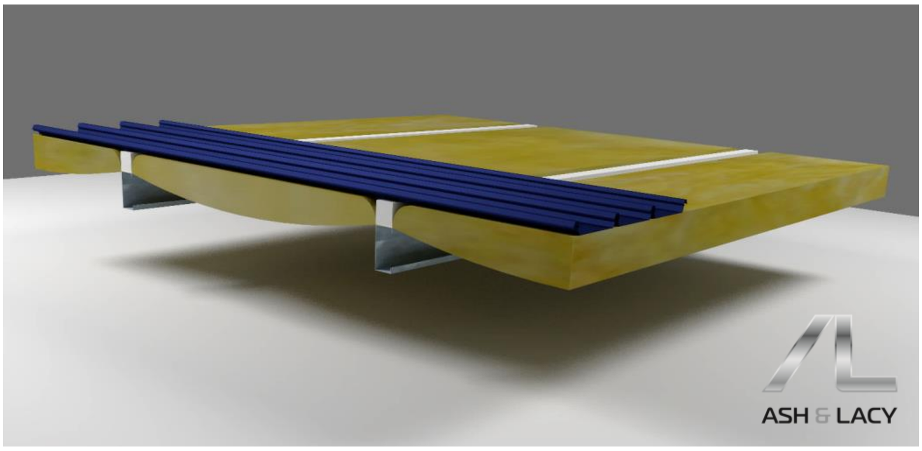
Estimated Error: 0.47%

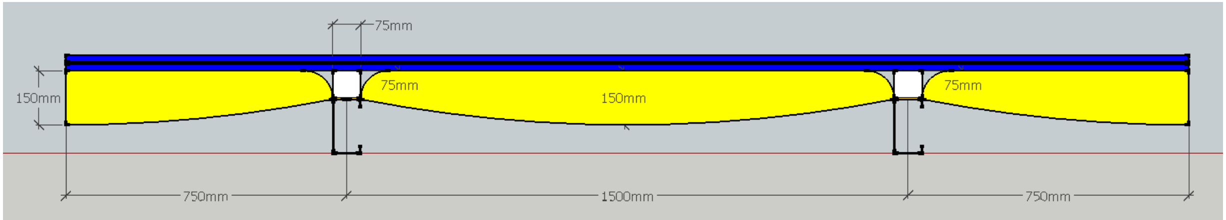
Calculations done in THERM 7.4.3.0

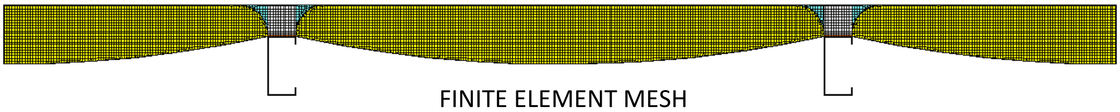


Assembly K

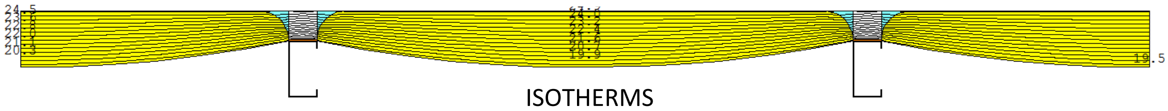
Description - 150mm Glass Fibre 12kg/m³ Over Purlin 1500mm Centres, 75mm XPS Spacer, Concealed Fix Weather Sheet



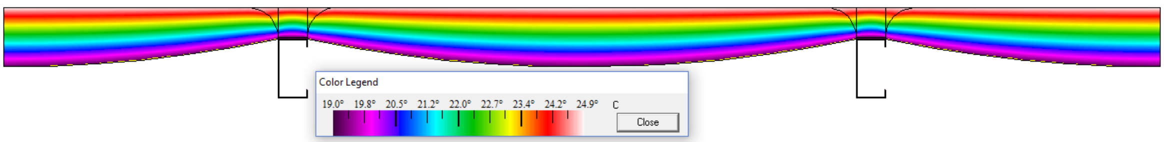




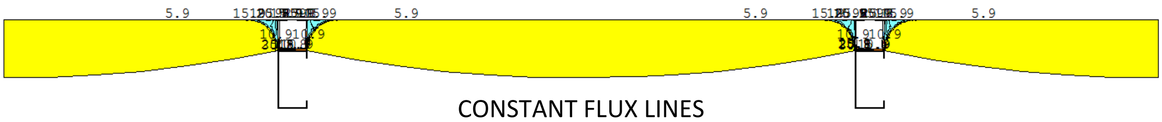
FINITE ELEMENT MESH



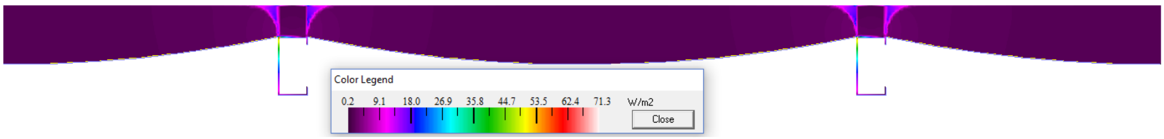
ISOTHERMS



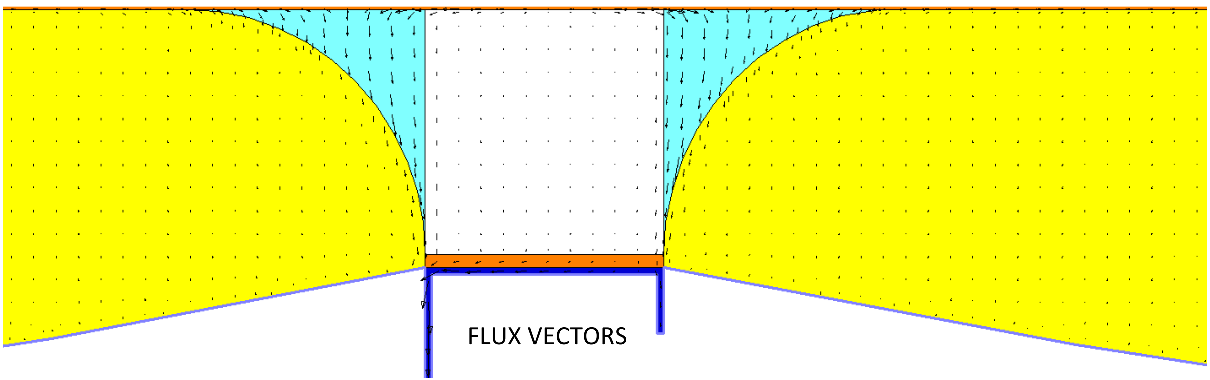
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly K

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3000	Projected X	0.3004

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
XPS Spacer (32kg/m³)	0.02	0.9
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9
Glass Fibre Compressed (SA) 328kg/m³	0.05	0.9

Cavities

Name: Air Gap
Gas Fill: Air
Convection Model: CEN Ventilated
Radiation Model: Standard

Poly	Heat Flow	Side 1		Side 2		Dimension		NU	Keff	Cavity Height
ID	Dir	Temp °c	Kmis	Temp °c	Kmis	Horz.	Vert.	#	W/m-K	mm
13	Horizontal	22.47	0.90	21.91	0.90	34.92	34.92	NA	0.2994	NA
14	Horizontal	22.47	0.91	21.91	0.91	34.98	36.44	NA	0.2897	NA
15	Horizontal	22.47	0.92	21.91	0.92	33.16	36.44	NA	0.2908	NA
16	Horizontal	22.47	0.93	21.91	0.93	34.58	35.26	NA	0.2978	NA

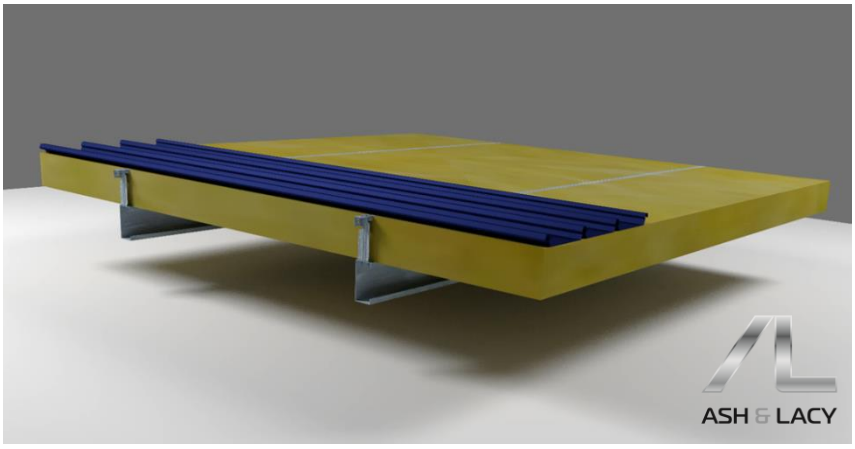
Standard Boundary Conditions

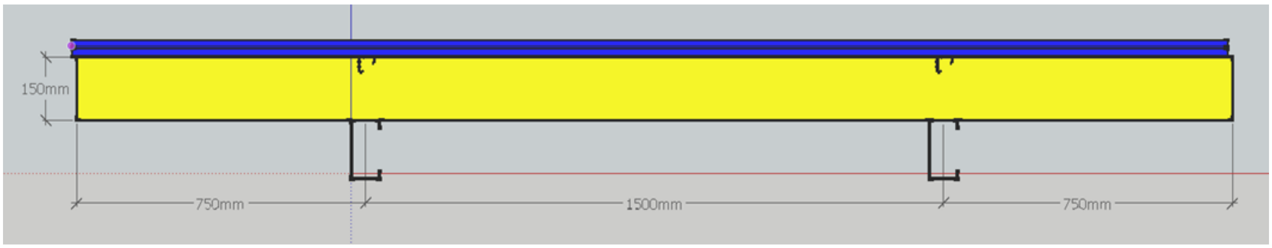
Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

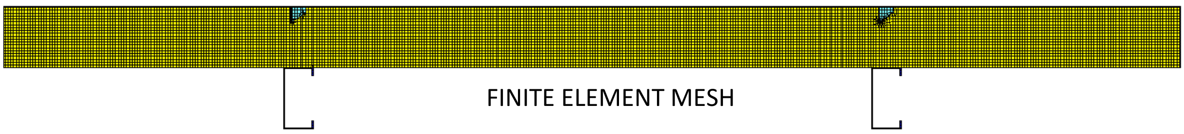
Calculation Specifications
Mesh Parameter: 10
Estimated Error: 1.4%
Calculations done in THERM 7.4.3.0

Assembly L

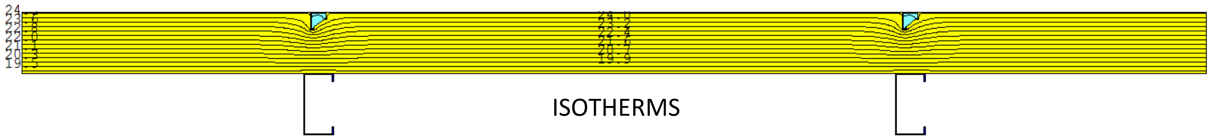
Description - 150mm Glass Fibre 12kg/m³ Over Purlin 1500mm Centres, 150mm AshGrid Spacer, Concealed Fix Weather Sheet



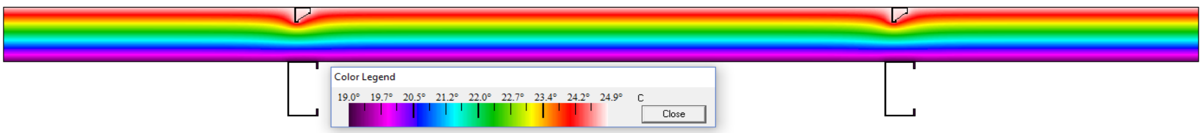




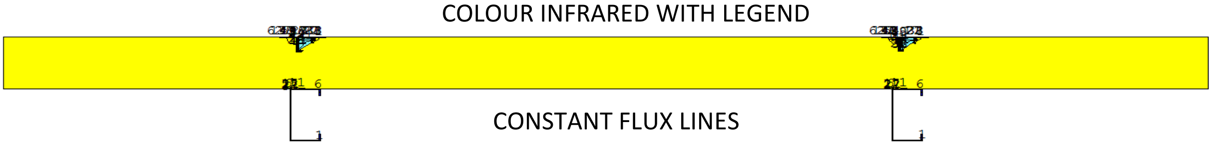
FINITE ELEMENT MESH



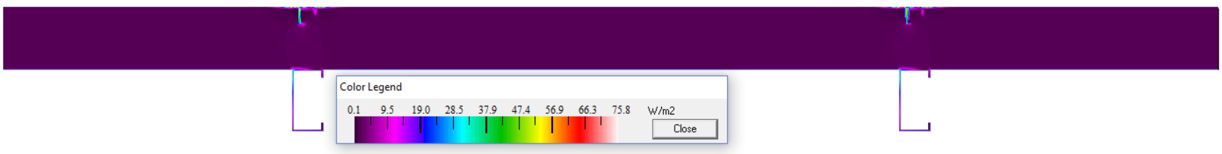
ISOTHERMS



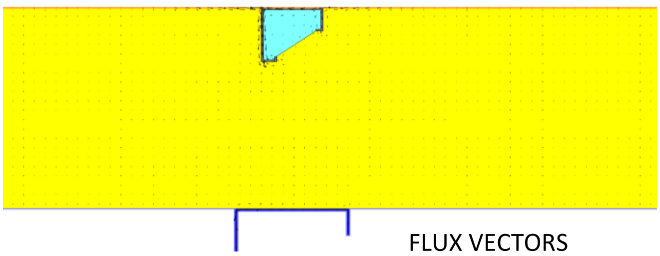
COLOUR INFRARED WITH LEGEND



CONSTANT FLUX LINES



COLOUR FLUX MAGNITUDE



FLUX VECTORS

Assembly L

U-Factors

Name	Length (mm)	Basis	U-Factor (W/m²-K)
Roof Assembly	3000	Projected X	0.2479

Solid Materials

Name	Conductivity W/m-K	Emissivity
Steel (Rolled, Ground)*	50	0.6
AshGrid Spacer	50	0.2
Steel - Galvanised Sheet (0.14 %C)*	62	0.2
Glass Fibre (SA) 12kg/m³	0.04	0.9

Cavities

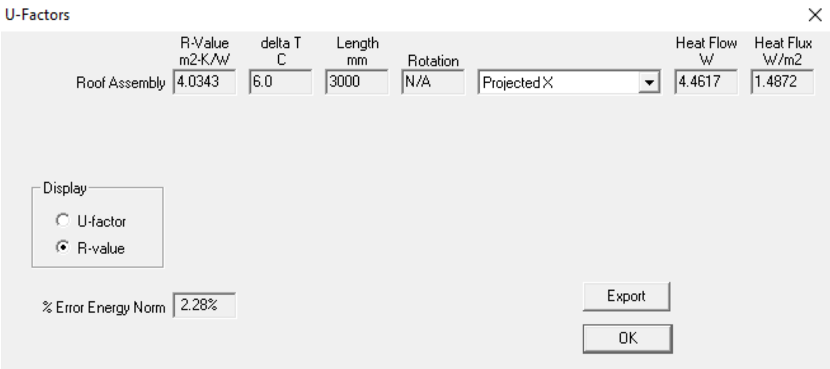
Name: Air Gap
Gas Fill: Air
Convection Model: CEN Ventilated
Radiation Model: Standard

Poly	Heat Flow	Side 1		Side 2		Dimension		NU	Keff	Cavity Height
ID	Dir	Temp °c	Kmis	Temp °c	Kmis	Horz.	Vert.	#	W/m-K	mm
8	Down	24.79	0.70	24.90	0.20	31.82	31.82	NA	0.1155	NA
9	Down	24.79	0.71	24.90	0.21	31.58	31.59	NA	0.115	NA

Standard Boundary Conditions

Name	Temperature °c	Film Coefficient W/m²-K
Interior South Africa	19	6.8
Exterior South Africa	25	20

Calculation Specifications
Mesh Parameter: 10
Estimated Error: 2.3%
Calculations done in THERM 7.4.3.0



Addendum A

DATE:	28th August 2013
LOCATION:	Safintra, Boksburg
CASE STUDY:	135mm Fibreglass blanket 12kg/m3 installed over purlin below concealed fix roof sheet.
PARTICIPANTS:	Ashgrid South Africa & Safintra
AIM:	(1) Establish performance of Saflok 700 concealed fix roof sheet installed over 135mm fibreglass blanket insulation without spacer system. (2) Establish performance of Saflok 700 concealed fix roof sheet installed over 135mm fibreglass blanket insulation with spacer system. (3) Establish how compression of 135mm fibreglass blanket affects the overall energy efficiency of the product.
METHODOLOGIES:	(1) Install 135mm Factorylite over purlin below Saflok 700 concealed fix roof sheet (No Spacer). (2) Install of 135mm Factorylite over purlin below Saflok 700 concealed fix roof sheet (With 135mm Ashgrid Spacer System).
PRODUCTS USED:	135mm Isover Foil Faced Factorylite 12kg/m3 0.53mm Colorplus Saflok 700 Corroshield Roofing Fasteners PVC Coated Straining Wire 130mm Ashgrid Spacer System

Insulation:	Isover Factorylite
Design Thickness:	135mm
Density:	12kg/m3
Roll Size:	1200mm x 10m
Thermal Conductivity:	0.040 W/(m.k.)
Design r-Value:	3.375 m2.K/W

The Factorylite is supplied pressure packed to reduce overall volume for transportation and handling on site.

In the pressure packed form the Factorylite is reduced to approximately 20-25mm in thickness.

Once unwrapped the Factorylite is designed to recover to it's full design depth within 24-48 hours.
The adjacent image shows the recovered depth immediately after removing from pressure packaging. The material recovered to an average depth of 110mm.

A test bed of cold rolled steel purlins and rafters was used:

Purlin Width:	50mm
Purlin Height:	150mm
Purlin Spacings:	1650mm CTC

Holes were drilled in the top and bottom purlins at 300mm centres to tie off the PVC coated straining wire to support the new insulation blanket.

PVC Coated straining wires were installed at 300mm centres allowing as much slack in the wires as practically possible to allow for the insulation to maintain it's natural loft between purlins.

Straining wire centres: 300mm

Factorylite installed over purlin and supported by PVC coated straining wire.

Factorylite installed over purlin and supported by PVC coated straining wire. The insulation maintains a constant loft of 110mm at this stage of installation.
(Recovery after 1 hr: 110mm)
(Recovery after 48 hrs: 125mm)

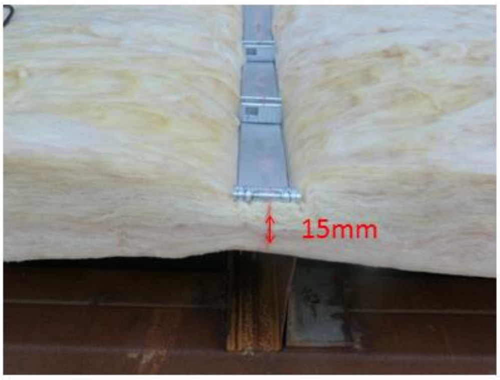
The side flap joints of the Factorylite were stapled together as per the manufacturers instructions.

The side flap joints of the Factorylite were stapled together as per the manufacturers instructions.

METHODOLOGY 1:

Saflok 700 concealed fix starter clips were installed directly to the steel purlins by means of 22mm Class 3 Corroshield square drive self-drilling wafer head fasteners.
The Factorylite insulation was compressed between the clip and purlin to a thickness of 15mm.

The compressed insulation visibly imposed forces on the Saflok 700 clip. Care needed to be taken to ensure that the clip wasn't installed out of horizontal alignment.



The Factorylite was compressed to 15mm between the clip and the purlin. The insulation appears thicker in the adjacent image as it is bulked over the end of the purlin. The image below better depicts how much compression occurs at the purlin when the roof sheet is installed without a spacer system.

The final Saflok 700 starter clip being installed.

The first Saflok 700 roof sheet was successfully installed to the starter clips achieving an impressive positive clipping action considering the compression of the underlying insulation. There was no deflection of the pan of the roof sheet..

The subsequent self-aligning Saflok 700 clips were then installed as per the manufacturers specifications. A second Saflok 700 roof sheet was then successfully installed once again achieving an impressive positive clipping action. There was no deflection of the pan of the roof sheet and the side-laps of the sheets were fully engaged over the length of the roof sheet.

It was noted at this point of the installation that although the insulation blanket had been allowed to drape between purlins within practical limits there was still considerable resultant compression of the material.

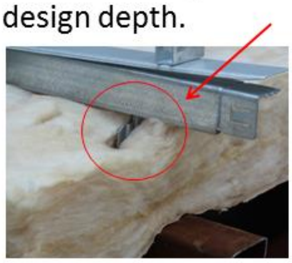
The Factorylite managed to recover to a depth of 85mm between purlins but this depth tapered uniformly downwards to 15mm at the purlins.

This overall compression results in a significantly reduced overall r-value. Please refer to accurate r-value calculations on page 18.

METHODOLOGY 2:

The 130mm pre-assembled Ashgrid bracket & bar spacer system was installed directly to the steel purlins with 25mm Class 3 self-drilling fasteners (2/no per bracket).

The fibres of the Factorylite blanket were easily parted without damaging the foil facing. The brackets were fixed directly to the steel purlins and the insulation blanket naturally bulked back around the bracket whilst allowing the insulation to maintain it's design depth.



Saflok 700 concealed fix starter clips were installed directly to the Ashgrid bars by means of 22mm Class 3 Corroshield square drive self-drilling wafer head fasteners.

The first Saflok 700 roof sheet was successfully installed to the starter clips achieving an impressive positive clipping without any resultant compression of the underlying insulation.

It was noted at this point of the installation that no resultant compression of the insulation material had occurred.

The Factorylite maintained a uniform depth of 120-125mm throughout the roof area.

INSULATION INSTALLED WITHOUT SPACER SYSTEM		INSULATION INSTALLED WITH SPACER SYSTEM	
Maximum depth achieved:	85mm	Maximum depth achieved:	125mm
Minimum depth achieved:	15mm	Minimum depth achieved:	110mm
Average depth achieved:	65mm	Average depth achieved:	120mm

COMPARATIVE DEPTHS

R-Value Calculations of compressed Insulation

The varying compression of the Factorylite insulation in methodology 1 resulted in a considerable reduction of the overall r-value of the roof

Width (mm)	Compressed Thickness (mm)	Original Design Thickness (mm)	Compression Factor	Percentage of Compression	Original Density kg/m3 (Before Compression)	Original k-Value W/(m.k) (Before Compression)	Original r-Value m2.K/W (Before Compression)	Resultant Density after compression kg/m3	Resultant k-Value W/(m.k) (After compression)	Resultant r-Value m2.K/W (After compression)	Area (m2)	Weighted Average Factors	Weighted Average r-Value per m2 m2.K/W
50	15.0	135	9.00	88.89%	12.00	0.04	3.375	108.00	0.04	0.375	0.050	0.02	0.003
100	27.5	135	4.91	79.63%	12.00	0.04	3.375	58.91	0.04	0.688	0.100	0.07	0.018
100	50.0	135	2.70	62.96%	12.00	0.04	3.375	32.40	0.04	1.250	0.100	0.13	0.058
100	62.5	135	2.16	53.70%	12.00	0.04	3.375	25.92	0.04	1.563	0.100	0.16	0.090
100	70.0	135	1.93	48.15%	12.00	0.04	3.375	23.14	0.04	1.750	0.100	0.18	0.113
100	77.5	135	1.74	42.59%	12.00	0.04	3.375	20.90	0.04	1.938	0.100	0.19	0.139
100	82.5	135	1.64	38.89%	12.00	0.04	3.375	19.64	0.04	2.063	0.100	0.21	0.158
100	85.0	135	1.59	37.04%	12.00	0.04	3.375	19.06	0.04	2.125	0.100	0.21	0.167
100	85.0	135	1.59	37.04%	12.00	0.04	3.375	19.06	0.04	2.125	0.100	0.21	0.167
100	85.0	135	1.59	37.04%	12.00	0.04	3.375	19.06	0.04	2.125	0.100	0.21	0.167
100	82.5	135	1.64	38.89%	12.00	0.04	3.375	19.64	0.04	2.063	0.100	0.21	0.158
100	77.5	135	1.74	42.59%	12.00	0.04	3.375	20.90	0.04	1.938	0.100	0.19	0.139
100	72.5	135	1.86	46.30%	12.00	0.04	3.375	22.34	0.04	1.813	0.100	0.18	0.122
100	67.5	135	2.00	50.00%	12.00	0.04	3.375	24.00	0.04	1.688	0.100	0.17	0.105
100	62.5	135	2.16	53.70%	12.00	0.04	3.375	25.92	0.04	1.563	0.100	0.16	0.090
100	50.0	135	2.70	62.96%	12.00	0.04	3.375	32.40	0.04	1.250	0.100	0.13	0.058
100	27.5	135	4.91	79.63%	12.00	0.04	3.375	58.91	0.04	0.688	0.100	0.07	0.018
50	15.0	135	9.00	88.89%	12.00	0.04	3.375	108.00	0.04	0.375	0.050	0.02	0.003
									0.040	1.521	1.700	2.70	1.772

r-Value

* The insulation was inspected again 72 hours after installation and it was found to have recovered to it's full design depth thus achieving an r-value of 3.375.	135mm INSULATION WITHOUT ASHGRID SPACER SYSTEM	135mm INSULATION WITH ASHGRID SPACER SYSTEM
Design thickness	135mm	135mm
Design r-Value m2.K/W	3.375	3.375
Design Thermal conductivity W/(m.k)	0.04	0.04
Maximum depth achieved (mm)	85mm	125mm
Minimum depth achieved (mm)	15mm	110mm
Average depth achieved (mm)	65mm	120mm
Actual r-Value m2.K/W	**1.772**	**3.0***

Addendum B

Report 160719ASH

MEASUREMENT OF THERMAL CONDUCTIVITY OF GLASSWOOL AT DIFFERENT DENSITIES

Client: Ash and Lacy

Date : 19th July 2016

Author: Christopher Kendrick

OISD, School of Architecture, Oxford Brookes University,
Headington Campus, Gipsy Lane, Oxford OX30BP

Phone: +44 (0) 1865 483208, Fax +44 (0) 1865 483298,
Email architectural-engineering@brookes.ac.uk

www.oisd.brookes.ac.uk/

OISD Technology

Oxford Institute for Sustainable Development

Modern methods of construction and prefabrication

Sustainable building design

Construction and life cycle costing

Steel, concrete, timber, masonry and glass construction

Construction design guidance and regulation

Building physics including: thermal, acoustic, structural and airtightness testing and analysis

Building envelope systems

Product and systems development

CAD and computer modeling

Contact:

Prof. Ray Ogden

Summary

A sample of Isover Glasswool was tested within a highly insulated chamber to determine thermal conductivity (λ) at different levels of compression. The results showed an increase in thermal conductivity from 0.038W/mK in the natural (uncompressed) state of 150mm to 0.046W/mK when highly compressed to 5mm using mechanical fasteners. This is an increase in thermal conductivity of 21% for a thirty-fold increase in material density.

1.Introduction

It was required to investigate the thermal conductivity of Isover Cladding roll 40 glasswool insulation at various levels of compression so as to accurately model thermal performance of retro-fitted insulation solutions. The data can be used in conduction modelling at a later stage in the work to assess U-values and extent of thermal bridging.

2. Method

Thermal conductivity can be calculated from measurements of heat flux through a known thickness of material subjected to a known temperature differential. The material sample must extremely well-insulated so as to ensure that the heat flux is as close to one-dimensional as possible, i.e. from hot to cold side without flowing laterally. Thermal conductivity is calculated using the expression below:

$$\lambda = Q \times L/\Delta T$$

Where Q = heat flux (W/m^2)
L = thickness of insulation (m)
ΔT = Temperature differential across sample (K)

In these tests, because a polyurethane 'plate' was used to enable compression of the insulation, the thermal resistance of this was measured separately. Thermal conductivity was calculated as below:

$$R_{glasswool} = R_{total} - R_{polyurethane}$$

$$= T/Q_{total} - 1.509$$

$$\lambda_{glasswool} = L/R_{glasswool}$$

Where R = thermal Resistance (m^2K/W)

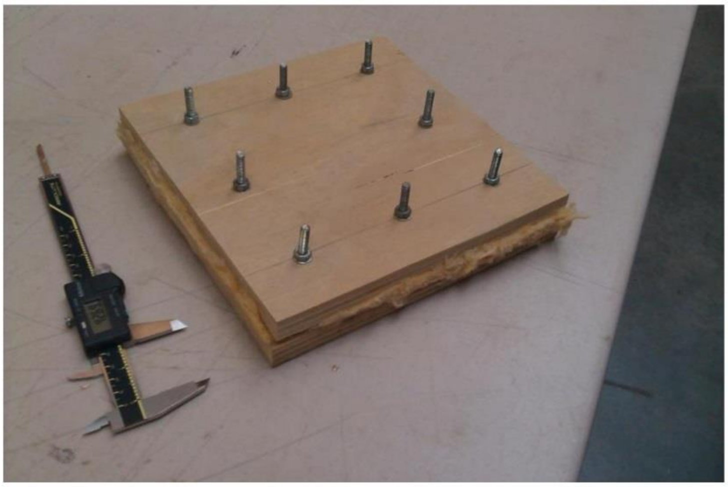
For the case when the insulation was highly compressed, a plywood compression arrangement was made, sandwiching the insulation between two 18mm plywood boards tightened together with coach bolts. See Figure 2. The compression boards were tested when empty of insulation, and the thermal resistance subtracted from the total resistance as described above.

The tests were run overnight to reduce disturbances from unexpected heat sources and to ensure the laboratory temperature was stable. Normally, four hours was allowed for the apparatus to reach steady state, followed by a period of at least ten hours data logging to obtain enough steady data to determine the average heat flux and temperature over this time.

Testing was carried out following the procedures and methods laid out in BS EN ISO 12667:2001[1].

Figure 1. Glasswool inside the test chamber

Figure 2. Glasswool in the compression plates, ready for testing



3. Equipment

[1] BS EN ISO 12667:2001 Thermal Performance of building materials and products – determination of thermal resistance by means of guarded hot plate and heat flow meter methods

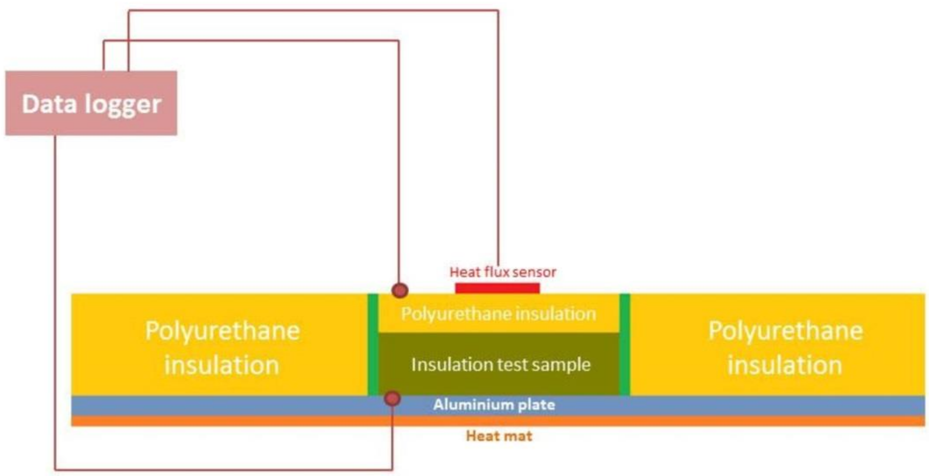
The equipment consists of an electric resistance heating mat, controlled using a proprietary electronic thermostat, covered by an aluminium heat spreader plate upon which the insulated chamber is placed. The plastic-sided chamber (240mm square) is surrounded by 180mm of polyurethane foam insulation (λ = 0.025W/mK) to a thickness of 200mm. Temperatures of the surfaces are measured using K-type (copper-constantan) thermocouples, calibrated in the laboratory using a calibrated platinum resistance thermometer (PRT). Insulation is placed in the chamber and covered with a 40mm thick sheet of polyurethane foam.

Heat flux is measured using factory-calibrated Hukseflux HFP01 thermopile heat flux sensors, which output a micro-voltage proportional to the heat flux.

Measurement of sensor voltages and logging of data is carried out using a Keithley 2700 data logger, linked by RS232 cable to a laptop computer running the Keithley ExceLinx data acquisition Excel plugin.

The entire apparatus is housed within a lightweight low emissivity enclosure to avoid spurious radiative heat fluxes within the laboratory (such as from overhead lighting) from distorting the results. See Figure 3.

Figure 3. Schematic of test equipment



4. Results

Table 1: Thermal conductivity

Insulation thickness mm	Density kg/m^3	λ W/mK
5	313.20	0.0462
35	44.74	0.0443
55	28.47	0.0438
75	20.88	0.0407
95	16.48	0.0405
115	13.62	0.0401
135	11.60	0.0386
155	10.44	0.0384

Figure 4. Thermal conductivity against insulation thickness in test chamber

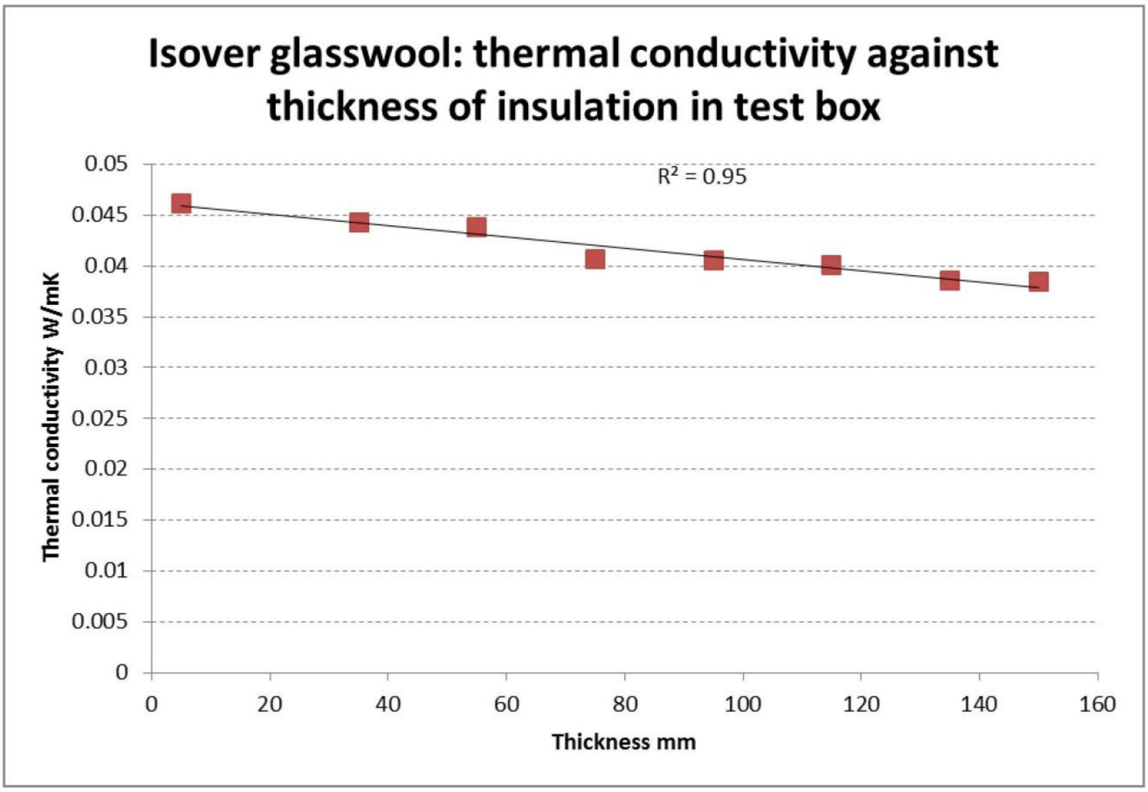
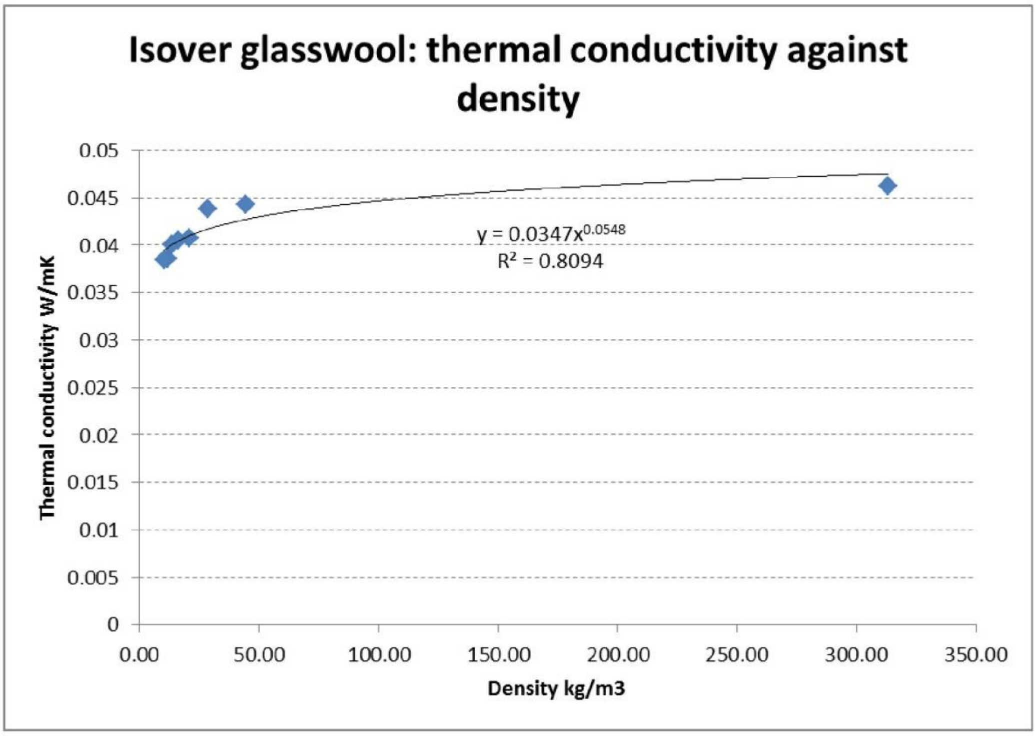


Figure 5. Thermal conductivity against insulation density



5. Conclusions

- The thermal conductivity of glasswool has been measured at various densities.
- Thermal conductivity rises with density, but the increase flattens out as maximum density is approached.
- Thermal conductivity rises by 21% from 0.038W/mK to 0.046W/mK when compressed from 155mm to 5mm (representing an increase in density by a factor of thirty)
- The results can be used with thermal modelling to more accurately determine the thermal performance of retrofit insulation solutions for single skin roofs in which portions of the insulation are compressed.