Report for Insultrak CC. on the thermal performance of Insultrak® composite polymer thermal break in an over-purlin roof installation with Starlite® white foil faced fibre-glass roof insulation.

Scope of project

InsultrakCC. have required of SP Energy:

1. That a finite element analysis is performed in order to estimate the thermal resistance of the Insultrak thermal break system
2. That a heat flow meter as per ISO/SANS8301 is used to measure the thermal resistance of an Insultrak thermal break
3. That the installed thickness of 100mm white foil faced Starlite fibreglass thermal insulation with the Insultrak thermal break is measured
4. That the thermal transmission of the Starlite fibreglass thermal insulation with Insultrak is compared with an installation without the thermal break system

Addendum: The results of 3 above are extended to other thicknesses and assuming the same caternary effect as measured for 100mm.

Concluding comments are provided.

Introduction

Insultrak is a thermal breaker hollow 40mm x 40mm XHDPE square profile extrusion with a wall thickness of approximately 6mm.

It is intended to be installed above and in contact with a compressed flexible thermal insulation on the upper side of metal purlins and below a profiled roof sheet.

The flexible insulation is a fibre-glass layer of density 12kg/m3 and typically between 50 and 135mm thick depending on the thermal resistance requirements of the building and its occupancy.

The roof sheeting may be fixed through the high point of the metal profile through the Insultrak and the flexible insulation and into the steel purlin.

The measurement of the thermal resistance of the thermal insulation system can be by way of an ASTM 1363 hot-box using a representative section of steel roof, purlins and insulation system with thermal breaks or spacers. Such testing is reported in ASHRAE handbook at various thicknesses and is extracted below in Annexure A.

The objective of this report is to summarise prior work and report realistic and achievable R-values for flexible fibre-glass thermal insulation in conjunction with the Insultrak spacer.

1. Finite element analysis

Therm software is used to estimate the thermal transmission of the Insultrak thermal break spacer:

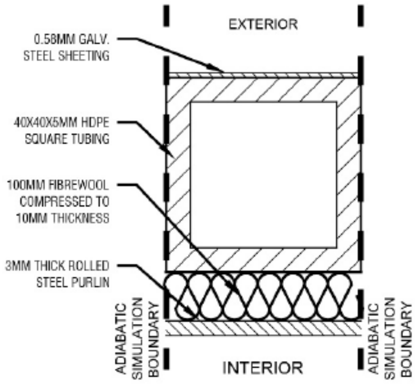
Thermal Analysis of HDPE Square Section in Roof Construction

MATERIAL PROPERTIES

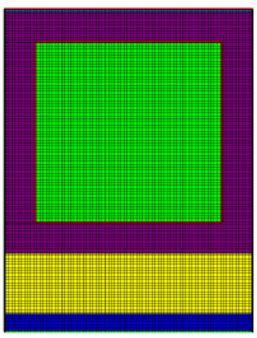
MATERIAL	K-VALUE (W/m.K)	EMISSIVITY
Galvanised Steel Sheeting	62	0.2
Polyethylene (High Density)	0.47	0.9
Fibrewool (Compressed)	0.15	0.9
Rolled Steel	50	0.6

BOUNDARY CONDITIONS & AIR FILMS

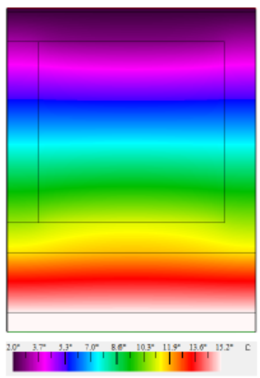
BOUNDARY	U-VALUE (W/m².K)	TEMP. (°C)
NFRC Exterior	26	-18
NFRC Interior	3.29	21
ISO 10077 Exterior	25	0
ISO 10077 Interior	7.7	20



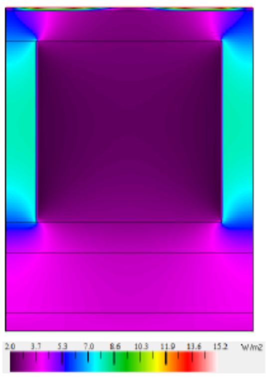
ANNOTATED SECTION



SIMULATED MESH



INFRARED VISUALISATION



THERMAL FLUX VISUALISATION

Infrared and thermal flux visualisations are shown according to ISO simulated conditions.

SIMULATED RESULTS

SIMULATION	R-VALUE (m².K/W)	U-VALUE (W/m².K)	ERROR ENERGY NORM
NFRC Simulation Conditions	0.4409	2.2680	0.42%
ISO Simulation Conditions	0.3493	2.8627	0.62%

Simulations have been performed according to conditions and methods laid out in corresponding NFRC guidelines and ANSI/ASHRAE 140 and Addendum B for NFRC Simulation conditions and ISO 10077 and ISO 52016 for ISO Simulation conditions.

PROJECT :	HDPE Analysis
CLIENT :	Insultrak
DATE :	2021-02-14
DRAWN BY :	F Matheson
CHECKED BY :	H Harris

in association with SP ENERGY

The ISO simulation conditions are more akin to RSA conditions for resultant R-value of 0.35m2K/W for the 40 x40mm Insultrak.

2. Heat Flow Meter testing to determine the thermal resistance of the Insultrak

The objective of the test is to measure the thermal transmission of the Insultrak from which the thermal resistance can be calculated. The ISO8301 Heat Flow Meter equipment is not intended for measuring products which are not in flat format and able to contact two parallel heat transfer plates. Therefore the Thermal Transmittance is measured as per the so-called dummy sample technique developed in Annexure E of EN16012/Draft ISO22097 Thermal Transmittance of Reflective Thermal insulation products which is extracted below for reference in Annexure D. Thermal Resistance of the Insultrak is the inverse of the Thermal Transmittance.

The steel roof-sheet above and the steel purlin below the Insultrak both constitute a relative infinite heat sink, and the insulation is recovering in thickness on either side of compression zone of the Insultrak, but the performance or thermal contribution from these side elements are imponderables and it is considered that we should not try to calculate these influences in the performance of the Insultrak itself. The test method adopted does not make the mistake of introducing roof sheets or purlins or tapering insulation into the testing of the Insultrak. The effects of these elements it is submitted are minor in relation to the thermal transmission of the Insultrak itself.

The heat flow meter test principle incorporates a hot plate and cold plate with edge effect controls in place and aims to set up parallel heat flow paths through the test sample(s). The presence of air-spaces adjacent to and between the plates creates inaccuracies and radiation effects which need to be avoided.

Good contact between the test sample and the plates is important in ISO8301 in achieving an accurate test result.

Adaptation of the Dummy test method

A sandwich of three layers of EPX is constructed: One inner and one outer layer each of 10mm thickness and a centre layer of 40mm.
The reference thermal transmittance is established with the testing of the combined 60mm of three layers of EPS. A steady state must be reached. The heat flow is measured and recorded.
A strip of Insultrak is cut to a precise length and inserted in a slot which is cut in the 40mm centre layer of EPS. Care is taken to ensure the fit is tight and that there is at least minimum 40mm EPS surround to the Insultrak.

A steady state is reached and the heat flow measured and recorded.

The result of the experiment is the difference between the above two measurements: R= 0.22m2K/W
The calculation is set out in Annexure C.

3. Measurement of the average thickness of fibre-glass flexible insulation:

The objective of the testing is to determine the caternary effect of suspending a flexible insulation between purlins on wires spaced at 300mm centres, and the influence of the Insultrak profile on the average thickness.

The 100mm nominal thickness fibreglass is fixed in situ in accordance with the manufacturer's instructions on tensioned wires under a profiled metal roof sheet, all being supported by 75mm wide lipped-channel purlins set at 1.735m apart. The Insultrak is fixed on top of the fibreglass over the purlins.

Measurements were taken in a sampling grid at the following distances from the purlin edge: 100mm, 390mm, 830mm, 1170mm, 1485mm, 1585mm.

The calculation of a 70mm average thickness is provided below.

Estimated installed thickness of Foil-faced fibreglass with Insultrack thermal break									
Thickness measurements at mid span and on wires									
									Total area
Grid distances from outside of purlin	0-75	175	490	905	1245	1560	1660		
Grid differences	75	100	315	415	415	315	100	1735	0.5205
Thickness measured									
On-wire	5	56	70	75	67	56	5		
Between wire	5	64	81	90	82	64	5		
Average thickness	5	60	75.5	82.5	74.5	60	5		
Mean thickness on zone mm	5	32.5	67.75	79	78.5	67.25	32.5		
Area of zone (meters)	0.0225	0.03	0.0945	0.1245	0.1245	0.0945	0.03		0.5205
Weighted average thickness (mm)	0.216138	1.873199	12.30043	18.89625	18.77666	12.20965	1.873199		66
includes the insulation over the purlins									
Average thickness between purlins mm									69
Note: The technique of measurement was via the insertion of a thin metal probe through the foil.									
The drag of the probe on the foil resulted in a consistent error of aproximately one millimeter.									
The 1.0mm will need to be added to the above two average calculations.									

4. Calculation of the thermal resistance of Insultrak as installed in a system with 100mm white faced flexible fibre-glass insulation

Methodology employed and rationale

The finite element analysis was performed in order to quantify the isolated influence of the Insultrak. The result obtained in the finite element analysis needs adjustment for the contribution of the surface effects plus the assumed contribution of the compressed fibre insulation layer and the heat flows around the Insultrak.

The ASHRAE Zone method is a series/parallel calculation of heat flows and incorporates an edge effect zone that approximates the tendency for heat to enter and leave highly conductive elements which might intrude through a system[1]. The calculation of width of the edge effect is in accordance with guidance given in ISO6946.

Description of the ASHRAE Zone Method for thermal resistance calculation

The ASHRAE Zone method is a series/parallel calculation of heat flows and incorporates an edge effect zone that approximates the tendency for heat to enter and leave highly conductive elements which might intrude through a system[1]. The calculation of width of edge effect is in accordance with guidance given in ISO6946.

Results

The detailed calculation results of a comparative ASHRAE ZONE Method calculation of the thermal resistance of 100mm flexible fibre-glass insulation with and without the Insultrak thermal break is set out in Annexure C.

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[1] ASHRAE Fundamentals handbook 2009, vol 27.5.

Comments on results

The thermal resistance value obtained by ASHRAE Zone Method for the 100mm fibre insulation without thermal break spacer or wires is 1.33m2K/W. This correlates fairly well with results of Hot-box testing of installed 101.6mm (4 inch) fibre published[1]. This table is reproduced as Annexure A to this report.

This calculated thermal resistance assuming a net average 60mm of effective thickness of fibre as a result of the caternary effect and the compression of the fibres by the purlins and supporting wires is calculated at 1.05m2K/W.

The average effective thickness of fibre with the Insultrak is measured at 70mm. This is the major reason for the improvement in thermal resistance with the spacer.

The contribution of the Insultrak is minor as the thermal conductivity is 4.5 times that of the fibre insulation which it displaces.

The thermal resistance obtained by ISO8301 test result for the Insultrak is 0.22m2K/W, and this translates into a thermal conductivity of 0.18W/mK. The thermal conductivity result obtained by finite element analysis is 0.115 W/mK. The more conservative value is used in this report.

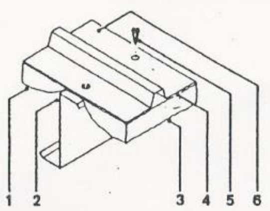
The results may be summarised in absolute terms or as a percentage reduction relative to an installed thickness of fibre insulation:

Thermal Resistance (R-values in m^2K/W):
100mm Fibre insulation installed over-purlin under roof sheet without Insultrak
1.05
100mm Fibre Insulation installed over-purlin under roof-sheet with Insultrak
1.82
Percentage increase in R-value 77

Annexure A; The ASHRAE position

Without a thermal break the flexble fibre-glass installed over-purlin is credited with the following performance in the ASHRAE Handbook.[2]

Table 5C Tested Coefficients of Transmission (U) for Pre-Engineered Metal Buildings
$W/m^2 \cdot K$ between the air on the two sides



Construction Details		Blanket insulation thickness, mm[a] 50.8	76.2	101.6
Construction 1				
Roof Section				
Winter Conditions, Upward Flow				
1. Inside surface (still air)		0.11	0.11	0.11
2. Structural support (purlin)				
3. Blanket insulation				
4. Corrugated metal panel	Tested R^b (= 1/C) =	0.74	1.12	1.39
5. Panel fastener				
6. Outside surface (6.7 m/s wind)		0.030	0.030	0.030
Thermal resistance (R)		0.88	1.26	1.53
($U = 1/R_T$)		1.14	0.79	0.65

Thus the base case of 100mm flexible fibre insulation installed over steel purlins

2

Annexure B – Tested thermal transmittance & resistance of Insultrak

Calculation of R-value of XPE 40 x 40mm spacer

Dimensions of test samples:	Input		
Thickness of base case	60	mm	
Length of base case	300	mm	
Width of base case	300	mm	
Length of spacer	220	mm	
Width of spacer	40	mm	
k-value results of base case test	0.03450	W/mK	
k-value result of case with spacer	0.05240	W/mK	
Temperature difference	26.00000	K	ΔT
Base case heat flow	2.01825	W	[Q=Area x U-value x ΔT]
Spacer case heat flow	3.06540	W	[Q=Area x U-value x ΔT]
Additional heat flow via spacer	1.04715	W	Difference is ΔQ
Cross-sectional area of spacer	0.00880	m2	Area A
Heat flow via spacer per spacer area	118.99432	W/m2	[H=ΔQ/A]
Thermal conductance	4.57670	W/m2K	[U=H/ΔT]
Thermal Resistance	0.218498	m2K/W	R=1/U

Annexure C – ASHRAE Zone Method calculation

Table of calculations

(i) Base case

CALCULATION OF AREA CONDUCTANCE and EFFECTIVE THERMAL RESISTANCE OF SYSTEM										
ZONE A								THERMAL BREAKER		ZONE B
ELEMENT	AREA OF	CONDUCTANCE		THICKNESS			CONDUCTANCE	RESISTANCE/AREA		THERMAL
Heat flow downward	ELEMENT	OR MATERIAL		OF			AREA PRODUCT		DEGC/W	RESISTANCE
	OR ZONE	THERMAL		MATERIAL			W/DEGC			
	M2	CONDUCTIVITY		M			M			M2DEGC/W
Outside Air	0.1285	20			0.0000	Air film of negligible thickness	2.5700E+00		3.8911E-01	0.0500
0.8mm Steel Roofing	0.1285		53		0.0008		8.5131E+03		1.1747E-04	0.0000
Fibreglass insulation/air av thick below	0.0525		0.04		0.0125		1.6800E-01	|		
Steel purlin	0.0760		53		0.0030		1.3427E+03	|	7.4469E-04	
Fibreglass Zone B wires & caternary effect			0.04		0.0600					1.5000
Purlin surface	0.0760	6.8		Heat flow dov	0.0000	Air film of negligible thickness	5.1680E-01		9.6749E-01	
Insulation surface	0.0525	6.8		Heat flow dov	0.0000	Air film of negligible thickness	3.5700E-01			0.1471
					Thermal Resistance Zone B					1.6971
					Total R/A	Zone A			1.357	
					A/R	Zone A			0.737	
					Area Transmittance Zone B				0.985	
					Transmittance over combined area				1.722	
					Thermal Transmission per m2				0.956	W/m2DegC
RESULTANT U-VALUE CALCULATED FOR SYSTEM ie					R-value of system				1.05	

(ii) With Insultrak breaker

CALCULATION OF WIDTH OF ZONE A	Horizontal	
Widest portion of conductive element m	0.0760	Purlin width
Recommended margin either side is half the thickness	0.0263	Heat transfer zone outside of purlin
Zone Width	0.1285	
This is the width of the zone around the conductive element to be used		
If the fixing method has no transverse members the length is considered as one meter ie zone width equals area		
CALCULATION OF WIDTH OF ZONE B		
The purlin spacing module determines the width of the two combined zones		
Width of zone B is the purlin span less Zone A predominant	1.6715	

CALCULATION OF AREA CONDUCTANCE and EFFECTIVE THERMAL RESISTANCE OF SYSTEM										
ZONE A								THERMAL BREAKER		ZONE B
ELEMENT	AREA OF	CONDUCTANCE		THICKNESS			CONDUCTANCE	RESISTANCE/AREA		THERMAL
Heat flow downward	ELEMENT	OR MATERIAL		OF			AREA PRODUCT		DEGC/W	RESISTANCE
	OR ZONE	THERMAL		MATERIAL			W/DEGC			
	M2	CONDUCTIVITY		M			M			M2DEGC/W
Outside Air	0.1285	20			0.0000	Air film of negligible thickness	2.5700E+00		3.8911E-01	0.0500
0.8mm Steel Roofing	0.1285		53		0.0008		8.5131E+03		1.1747E-04	0.0000
Fibreglass insulation/air av thick above	0.0885		0.04		0.0400		8.8500E-02	|	3.7244E+00	
Thermal break	0.0400		0.18		0.0400		1.8000E-01	|		
Fibreglass insulation compressed	0.0760		0.04		0.0125		2.1280E-01	|		
Fibreglass insulation/air av thick below	0.0525		0.04		0.0125		1.6800E-01	|	2.6261E+00	
Steel purlin	0.0760		53		0.0030		1.3427E+03		7.4479E-04	
Fibreglass Zone B wires & caternary effect			0.04		0.0700					1.7500
Purlin surface	0.0760	6.8		Heat flow dov	0.0000	Air film of negligible thickness	5.1680E-01		9.6749E-01	
Insulation surface	0.0525	6.8		Heat flow dov	0.0000	Air film of negligible thickness	3.5700E-01			0.1471
					Thermal Resistance Zone B					1.9471
					Total R/A	Zone A			7.708	
					A/R	Zone A			0.130	
					Area Transmittance Zone B				0.858	
					Transmittance over combined area				0.988	
					Thermal Transmission per m2				0.549	W/m2DegC
RESULTANT U-VALUE CALCULATED FOR SYSTEM ie					R-value of system				1.82	

Annexure D

“Dummy specimen” technique for the heat flow meter apparatus

Principle

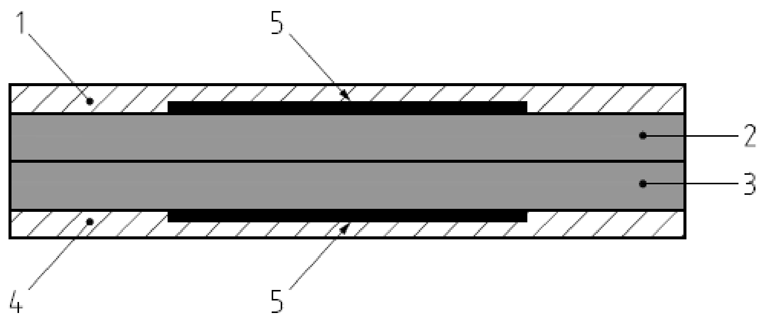
Heat flow meter apparatus needs to be calibrated with reference materials having similar thermal performance to the materials being tested. As most heat flow meter apparatus will not have been calibrated with thin reference materials (< 20 mm thick), a method is given in this annex to ensure that thermal resistance measurements made on such thin materials, in a heat flow meter apparatus, conform to ISO 8301. This method is referred to as the “dummy specimens” method.

Procedure

In this method, a pair of “dummy specimens” each not less than 10 mm thick shall be used to make a composite specimen of a thickness that is covered by the reference samples used to calibrate the heat flow meter apparatus. The dummy specimen may, for example, be EPS (white or grey) with a density above 20 kg/m^3 to avoid infrared influence on the measurement. Two measurements shall be made using the specimen arrangements illustrated in Figure E.1 and Figure E.2:

a) using only the two dummy specimens, to determine their combined thermal resistance;
b) with the specimen under test sandwiched between the two dummy specimens;
c) the thickness of the test specimen shall be maintained by the use of suitable low conductivity spacers set to the measured thickness of the test specimen and placed between the dummy specimens outside the metering area.

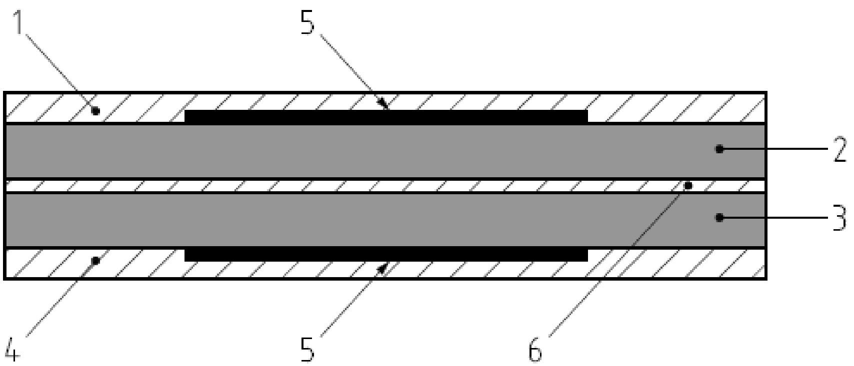
The thermal resistance of the material under test shall then be derived from the results of these two measurements as the difference in thermal resistance between the second test and the first test.



Key

1	cold plate
2	dummy specimen 1
3	dummy specimen 2
4	hot plate
5	Heat Flux Transducer

Figure E.1 — Schematic diagram of dummy specimen arrangement



Key

1	cold plate
2	dummy specimen 1
3	dummy specimen 2
4	hot plate
5	Heat Flux Transducer
6	thin specimen being tested

Figure E.2 — Schematic diagram of dummy specimen arrangement with specimen under test

E.3 Specimens of low thermal resistance

In the case where the test specimen (excluding the dummy specimens) is expected to have a thermal resistance of less than 0,5 $m^2.K/W$, surface thermocouples shall also still be used.

E.4 Calibration

To achieve a 10 K temperature difference across the test specimen requires a temperature difference of approximately 50 K across the whole stack. This requires a separate calibration file to be established with this temperature difference across the reference specimen.

Recommended adaptation of this test procedure for determination of the Thermal Transmittance of Insultrak:

Introduction

Insultrak is a hollow 40mm x 40mm XHDPE square profile extrusion with a wall thickness of approximately 6mm.

As is intended to be installed it is in contact with a compressed flexible thermal insulation above a metal purlin and above it a profiled roof sheet. The roof sheet is fixed through the high point of the metal profile through the Insultrak and the flexible insulation and into the steel purlin.

The base case reference thermal transmittance is established with the testing of the combined 60mm of three layers of EPS. A steady state must be reached. The heat flow is measured and recorded.

A strip of Insultrak is cut to a precise length and inserted in a slot which is cut in the 40mm centre layer of EPS. Care should be taken to ensure the fit is tight and that there is at least minimum 40mm EPS surround to the Insultrak. A steady state must be reached and the heat flow remeasured and recorded.

The result of the experiment is the difference between the above two measurements.

Addendum

If the assumption of a 70% loss of thickness attributable to the caternary effect of supporting wires is valid then the following results might hold:

Nominal FG thickness	70%/average thickness	ASHRAE Zone Method R-value (m^2K/W)
50mm	35mm	1.05
75mm	52.5mm	1.44
100mm	70mm	1.82
135mm	94.5mm	2.34