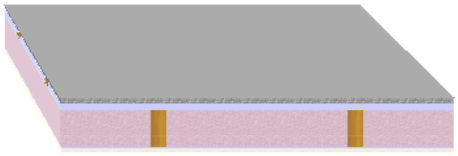
Source: **Lapolla Products - Pitched roofs**

Component: **Protec Pitched Roof - 0.19Wm2k 147mm Rafter**

OUTSIDE



This illustration of inhomogeneous layers is provided only to assist in visualising the arrangement.

On the basis of the given information about the inhomogeneous layers, it is not possible to estimate how and where bearing elements intersect each other. It was assumed that the layers intersect crosswise. The size of the areas was calculated corresponding to their percentage of the whole area.

INSIDE

Assignment: Pitched roof < 70°, with insulation between rafters

		Manufacturer	Name	Thickness [m], number	Lambda [W/(mK)]	Q	R [m²K/W]
		Rse					0.0400
☑	1	BS EN 12524	Tiles (roofing), concrete	0.0220	1.500	D	0.0147
☑	2	Inhomogeneous material layer	consisting of:	0.0250	ø 0.290		0.0862
	2a	BS EN ISO 6946	Slightly vent. air layer: 25 mm, upwards heat flow	87.50 %	0.313	D	-
	2b	BS EN 12524	Softwood Timber [500 kg/m³]	12.50 %	0.130	D	-
☑	3	TYVEK	Tyvek Supro Plus	0.0005	0.100	C	0.0045
☑	4	Inhomogeneous material layer	consisting of:	0.1400	ø 0.031		4.5692
	4a	Own catalogue Air gaps	Lapolla 4G Closed Cell Level 0: dU" = 0.00 W/(m²K)	92.00 %	0.022	E	-
	4b	BS EN 12524	Softwood Timber [500 kg/m³]	08.00 %	0.130	D	-
☑	5	BS EN ISO 6946	Unventilated air layer: 7 mm, upwards heat flow	0.0070	0.054	D	0.1296
☑	6	Lafarge Plasterboard Ltd	Lafarge Standard wallboard	0.0125	0.180	C	0.0694
		Rsi					0.1000
				0.2070			

$R_T = (R_T' + R_T'')/2 = 5.18$ m²K/W

Correction to U-value for	according to	delta U [W/(m²K)]
Air gaps	BS EN ISO 6946 Annex D	~~0.000~~ 0.000

$U = 1/R_T + \Sigma\Delta U = 0.19$ W/(m²K)

Q .. The physical values of the building materials has been graded by their level of quality. These 5 levels are the following
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B .. B: Data is entered and validated by the manufacturer or supplier. Data is certified by 3rd party
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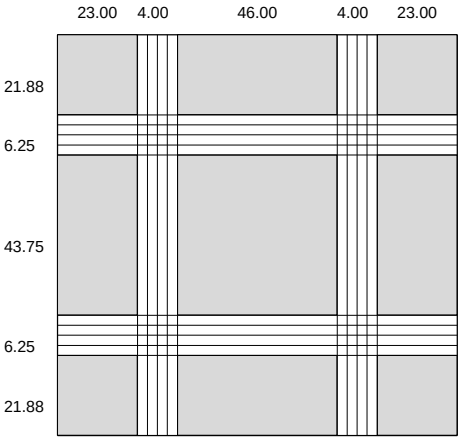
U = **0.19** W/(m²K) R_T= **5.18** m²K/W

Source: **Lapolla Products - Pitched roofs**
Component: **Protec Pitched Roof - 0.19Wm2k 147mm Rafter**

Draft of the component (portion in %):



The intersection of the inhomogeneous layers results in 4 Zones (A, B, C, D). Information given in %.

A	5.03 + 10.06 + 5.03 + 10.06 + 20.13 + 10.06 + 5.03 + 10.06 + 5.03 consisting of material layers: 1, 2a, 3, 4a, 5, 6	= 80.50%
B	0.88 + 1.75 + 0.88 + 0.88 + 1.75 + 0.88 consisting of material layers: 1, 2b, 3, 4a, 5, 6	= 7.00%
C	1.44 + 2.88 + 1.44 + 1.44 + 2.88 + 1.44 consisting of material layers: 1, 2a, 3, 4b, 5, 6	= 11.50%
D	0.25 + 0.25 + 0.25 + 0.25 consisting of material layers: 1, 2b, 3, 4b, 5, 6	= 1.00%

Upper limit of the thermal transfer resistance R

U_A [W/(m²K)] = $\frac{1}{(\sum R_{i,A}) + R_{si} + R_{se}}$ = $\frac{1}{6.66 + 0.1 + 0.04}$ = 0.15

U_B [W/(m²K)] = $\frac{1}{(\sum R_{i,B}) + R_{si} + R_{se}}$ = $\frac{1}{1.38 + 0.1 + 0.04}$ = 0.66

U_C [W/(m²K)] = $\frac{1}{(\sum R_{i,C}) + R_{si} + R_{se}}$ = $\frac{1}{6.77 + 0.1 + 0.04}$ = 0.14

U_D [W/(m²K)] = $\frac{1}{(\sum R_{i,D}) + R_{si} + R_{se}}$ = $\frac{1}{1.49 + 0.1 + 0.04}$ = 0.61

$$R_T' = \frac{1}{A * U_A + B * U_B + C * U_C + D * U_D} = 5.34\ m^2K/W$$

Lower limit of the thermal transfer resistance R

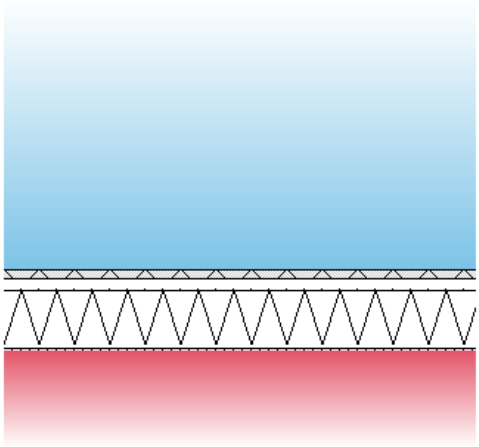
R_{se} [m²K/W]		= 0.04
R_1'' [m²K/W] = d_1/λ_1 =	0.0220 / 1.500	= 0.01
R_2'' [m²K/W] = $d_2/(\lambda_{2a} * (A + B) + \lambda_{2b} * (C + D))$ =	0.0250 /(0.313 * 87.50% + 0.130 * 12.50%)	= 0.09
R_3'' [m²K/W] = d_3/λ_3 =	0.0005 / 0.100	= 0.00
R_4'' [m²K/W] = $d_4/(\lambda_{4a} * (A + C) + \lambda_{4b} * (B + D))$ =	0.1400 /(0.022 * 92.00% + 0.130 * 8.00%)	= 4.57
R_5'' [m²K/W] = d_5/λ_5 =	0.0070 / 0.054	= 0.13
R_6'' [m²K/W] = d_6/λ_6 =	0.0125 / 0.180	= 0.07
R_{si} [m²K/W]		= 0.1

$$R_T'' = \sum R_i'' + R_{si} + R_{se} = 5.01\ m^2K/W$$

Source: **Lapolla Products - Pitched roofs**

Component: **Protec Pitched Roof - 0.19Wm2k 147mm Rafter**

OUTSIDE



INSIDE

The list of material layers shown below may differ from those in the U-value calculation printout. Only material layers which are used in the Condensation Risk Analysis are listed.

This calculation of the Condensation risk analysis according to BS EN ISO 13788:2002 has been performed on a construction containing inhomogeneous layers. This calculation is only valid through the selected section. It is advisable that you should also select the alternative position and recalculate the Condensation Risk Analysis for a more complete assessment of the construction.

The CRA calculation for pitched roofs can be very unreliable and caution should be used when interpreting these results. For further guidance the user is advised to follow the recommendation of BS 5250:202 (currently under review).

Assignment: Pitched roof < 70°, with insulation between rafters

Name	Thickn. [m]	lambda [W/(mK)]	Q	μ [-]	Q	sd [m]	R [m²K/W]
Tiles (roofing), concrete	0.0220	1.500	D	60.00	D	1.32	0.0147
Slightly vent. air layer: 25 mm, upwards heat flow	0.0250	0.313	D	1.00	D	0.03	0.0799
Tyvek Supro Plus	0.0005	0.100	C	89.00	C	0.04	0.0045
Lapolla 4G Closed Cell	0.1400	0.022	E	62.10	E	8.69	6.3636
Unventilated air layer: 7 mm, upwards heat flow	0.0070	0.054	D	1.00	D	0.01	0.1296
Lafarge Standard wallboard	0.0125	0.180	C	4.00	C	0.05	0.0694

Q .. The physical values of the building materials has been graded by their level of quality. These 5 levels are the following
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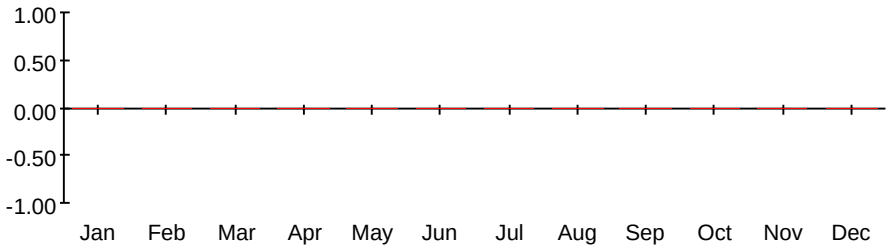
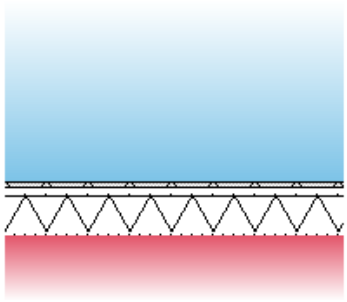
Condensation risk analysis - summary of main results
Calculation according BS EN ISO 13788

Surface temperature to avoid critical surface moisture:
No danger of mould growth is expected.

Interstitial condensation:
No condensation is predicted at any interface in any month.

Interstitial condensation and evaporation per month gc [g/m²]





Component, condensation range

CRA calculations according to BS EN ISO 13788:2002 are used as a guide in predicting interstitial condensation. This methodology uses some simplifications of the dynamic processes involved and subsequently does have some limitations. Further information can be found in Information Paper IP 2/05 'Modelling and controlling interstitial condensation in buildings'' Feb 2005.

The CRA calculation for pitched roofs can be very unreliable and caution should be used when interpreting these results. For further guidance the user is advised to follow the recommendation of BS 5250:202 (currently under review).

Surface temperature to avoid critical surface humidity
Calculation according BS EN ISO 13788

Location: Plymouth/Mountbatte; Humidity class according BS EN ISO 13788 annex A: Dwellings with low occupancy

		1	2	3	4	5	6	7	8	9	10	11	12
	Month	Te [°C]	phi_e ---	Ti [°C]	phi_i ---	pe [Pa]	delta p [Pa]	pi [Pa]	ps(Tsi) [Pa]	Tsi,min [°C]	fRsi ---	Tsi [°C]	Tse [°C]
I	January	6.6	0.840	20.0	0.606	818	597	1415	1769	15.6	0.670	19.5	6.7
	February	6.1	0.830	20.0	0.599	781	619	1400	1750	15.4	0.670	19.5	6.2
	March	7.4	0.810	20.0	0.597	834	561	1395	1744	15.4	0.631	19.5	7.5
	April	8.8	0.760	20.0	0.582	860	499	1359	1699	15.0	0.549	19.6	8.9
	May	11.7	0.770	20.0	0.611	1058	370	1428	1785	15.7	0.484	19.7	11.7
	June	14.4	0.780	20.0	0.654	1279	249	1528	1911	16.8	0.426	19.8	14.4
	July	16.4	0.790	20.0	0.699	1473	160	1633	2041	17.8	0.398	19.9	16.4
	August	16.3	0.810	20.0	0.713	1500	165	1665	2082	18.1	0.498	19.9	16.3
	September	14.4	0.820	20.0	0.682	1345	249	1594	1993	17.4	0.545	19.8	14.4
	October	11.9	0.830	20.0	0.649	1156	361	1517	1896	16.7	0.588	19.7	11.9
	November	9.1	0.840	20.0	0.623	970	486	1456	1820	16.0	0.635	19.6	9.2
	December	7.7	0.840	20.0	0.612	882	548	1430	1788	15.7	0.654	19.6	7.8

- The critical month is January with $f_{Rsi,max}$ = 0.670
  f_{Rsi} = 0.964

$f_{Rsi} > f_{Rsi,max}$, the component complies.

Nr Explanation

1 External temperature
2 External rel. humidity
3 Internal temperature
4 Internal relative humidity
5 External partial pressure $p_e = \phi_e * p_{sat}(T_e)$; $p_{sat}(T_e)$ according formula E.7 and E.8 of BS EN ISO 13788
6 Partial pressure difference. The security factor of 1.10 according to BS EN ISO 13788, ch.4.2.4 is already included.
7 Internal partial pressure $p_i = \phi_i * p_{sat}(T_i)$; $p_{sat}(T_i)$ according formula E.7 and E.8 of BS EN ISO 13788
8 Minimum saturation pressure on the surface obtained by $p_{sat}(T_{si}) = p_i / \phi_{si}$,
where ϕ_{si} = 0.8 (critical surface humidity)
9 Minimum surface temperature as function of $p_{sat}(T_{si})$, formula E.9 and E.10 of BS EN ISO 13788
10 Design temperature factor according 3.1.2 of BS EN ISO 13788
11 Internal surface temperature, obtained from $T_{si} = T_i - R_{si} * U * (T_i - T_e)$
12 External surface temperature, obtained from $T_{se} = T_e + R_{se} * U * (T_i - T_e)$

Interstitial condensation - main results
Calculation according BS EN ISO 13788

No condensation is predicted at any interface in any month.

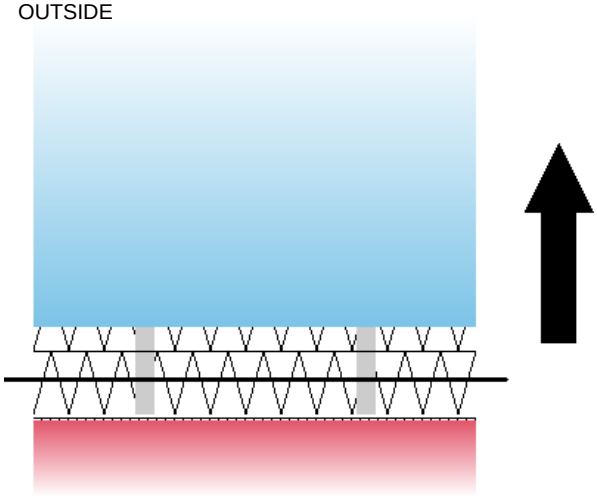
Climcatic conditions
Location: Plymouth/Mountbatte; Humidity class according BS EN ISO 13788 annex A: Dwellings with low occupancy

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Internal temperature [°C]	Ti	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Internal rel. humidity [%]	phi_i	60.6	59.9	59.7	58.2	61.1	65.4	69.9	71.3	68.2	64.9	62.3	61.2
External temperature [°C]	Te	6.6	6.1	7.4	8.8	11.7	14.4	16.4	16.3	14.4	11.9	9.1	7.7
External rel. humidity [%]	phi_e	84.0	83.0	81.0	76.0	77.0	78.0	79.0	81.0	82.0	83.0	84.0	84.0

Source: **Lapolla Products - Pitched roofs**

Component: **Protec Pitched Roof - 0.19Wm2k 147mm Rafter**

OUTSIDE



INSIDE

The list of materials shown below may differ from those in the U-value calculation printout. Only material layers which are used in the heat capacity calculation are listed.

Single material layers shown in the U-value calculation printout may be separated to meet the exclusion criteria:

A .. The total thickness of the layers exceed 0.1 m.
B .. The mid point in the construction is reached.

For insulation layers the following criteria applies:

C .. An insulating layer is reached (defined as lambda <= 0.08 W/(mK)).

	Name	Thickness [m]	lambda [W/(mK)]	Q	Thermal capacity [kJ/(kgK)]	Q	Density [kg/m³]	Q	Thermal mass kJ/(m²K)	Criteria Exclusion
	End of calculation - Cold									
1	Tiles (roofing), concrete	0.0220	1.500	D	1.00	D	2100.0	D	~~46.2~~	A, -, C
2	Inhomogeneous material layer consisting of:	0.0250							~~2.5~~	A, -, -
2a	Slightly vent. air layer: 25 mm, upwards heat flow	87.50%	0.313	D	1.01	D	1.2	D	~~0.0~~	A, -, C
2b	Softwood Timber [500 kg/m³]	12.50%	0.130	D	1.60	D	500.0	D	~~2.5~~	A, -, -
3	Tyvek Supro Plus	0.0005	0.100	C	1.70	C	322.0	C	~~0.2~~	A, -, C
4	Inhomogeneous material layer consisting of:	0.0595							~~3.8~~	A, -, -
4a	Lapolla 4G Closed Cell	92.00%	0.022	E	1.40	E	30.0	E	~~2.3~~	A, -, C
4b	Softwood Timber [500 kg/m³]	08.00%	0.130	D	1.60	D	500.0	D	~~3.8~~	A, -, -
4	Inhomogeneous material layer consisting of:	0.0805							5.2	-, -, -
4a	Lapolla 4G Closed Cell	92.00%	0.022	E	1.40	E	30.0	E	~~3.1~~	-, -, C
4b	Softwood Timber [500 kg/m³]	08.00%	0.130	D	1.60	D	500.0	D	5.2	-, -, -
5	Unventilated air layer: 7 mm, upwards heat flow	0.0070	0.054	D	1.01	D	1.2	D	~~0.0~~	-, -, C
6	Lafarge Standard wallboard	0.0125	0.180	C	1.00	C	680.0	C	8.5	-, -, -
	Start of calculation - Warm									
		0.2070							**13.7**	

Heat capacity = 13.7 kJ/(m²K)

The following exclusion criteria apply:
A .. The total thickness of the layers exceed 0.1 m.
C .. An insulating layer is reached (defined as lambda <= 0.08 W/(mK)).

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