U-Value Competency

Elmhurst Energy

1

Introductions

Session format
Breaks
Q & A

Contact details for any further questions
Ocdea-support@Elmhurstenergy.co.uk
01455 883 236

2

Using Teams

- Keep Cameras on please.
- Please keep your microphones off unless you have a question.
- Use the chat facility to also ask questions.
- Please confirm after breaks you have access.

3

Agenda

- Why are u values important?
- The Competency scheme
- The Elmhurst U-Value Calculator / Online
- Group U Value
- Heat Transfer Methods + Group Workshop 1
- U-Value Calculation Methods
  - Simple / Combined / Dynamic
- BR443 U-Value Conventions
  - Thermal Properties of materials
- Repeating Thermal Bridges
- Individual Workshops 1+2
- Lunch
- Air Layers
- Corrections
- Group Workshop 2
- Additional Roof scenarios
- Individual Workshop 3
- Floor and Basement U-Values
- Individual Workshops 4+5
- Key Considerations
- Next Steps & Final Questions

4

WHY ARE U-VALUES IMPORTANT?

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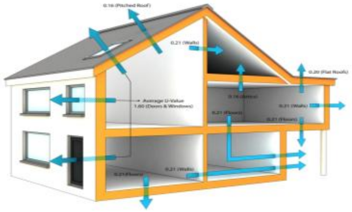
5

Why are U-values important?

- U-values are the key indicator of heat loss from a building.
- U-values are a well known, industry standard method of assessing heat loss.
- For new buildings, conversions, and extensions there are mandatory limiting U-values constructions must adhere to in the building regulations.



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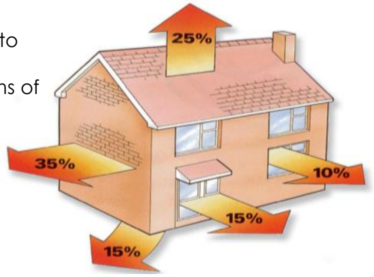
A Fabric First Approach

- The introduction of the Target Fabric Energy Efficiency (TFEE) has seen a change in the way designers have to approach building design.
- It is very much in builder's interests to seek out **fabric first** solutions since typically they offer simplicity in terms of build-ability.
- Buildings can no longer be 'green-washed' with renewables to achieve compliance.



7

The As Built Performance Gap

- Zero Carbon Hub have investigated the 'As Built Performance Gap'.
- *On a survey of 26 plots, <u>all</u> of them were found to have differences between the u-value calculations and construction on site*.

8

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The As Built Performance Gap

- *"There is a suspected low level of thermal detailing knowledge across the industry, and thermal bridging and U-value calculations are of varying quality"*
- *"Improved training for those undertaking U-value calculations is required to drive up standards"*

9

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Future Considerations?

- In both the Future Homes Standard for England and the next Part L in Wales consultations, u-values standards will be tightened.
- Future consultations/new regulations in Scotland and Northern Ireland are expected to do the same.
- PAS 2035 and Retrofit may require U-value calculations rather than RdSAP default u-values.

10

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Fabric Standards

Minimum Standards for Fabric Performance		
	Part L 2013	**Part L 2021 > 15.06.22**
External walls	0.3 w/m^2k	**0.26 w/m^2k**
Party walls	0.2 w/m^2k	**0.2 w/m^2k**
Floors	0.25 w/m^2k	**0.18 w/m^2k**
Roofs	0.2 w/m^2k	**0.16 w/m^2k**
Windows (inc. Roof windows)	2.0 w/m^2k	**1.6 w/m^2k**
Rooflights	2.0 w/m^2k	**2.2 w/m^2k**
Doors	2.0 w/m^2k	**1.6 w/m^2k**
Air Permeability	10 $m^3/m^2/hr$ @ 50Pa	**8.0 $m^3/m^2/hr$ @ 50Pa** **1.57 $m^3/m^2/hr$ @ 4Pa**

11

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RdSAP and SAP Conventions

- RdSAP conventions have guidance for overwriting u-values;

Evidence of suitable expertise and experience can be demonstrated by, but is not limited to, membership of a recognised U-value calculation competency scheme or OCDEA[1] or Level 4 non-domestic energy assessor membership, or any other process recognised by Accreditation Schemes/Approved Organisations and Government.

- SAP conventions;

SAP assessors should establish the specification of the construction for each element and should satisfy themselves that the U-values used in the calculation are correct.

Acceptable routes are:

- calculation provided by a person that is a member of a recognised U-value calculation competency scheme, or,

- calculation provided by an OCDEA, level 4 NDEA or any other process recognised by Accreditation Schemes/Approved Organisation and Government, or,

- calculation provided by another party and checked by the assessor

12

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TB 167

- Technical Bulletin TB 167

13

THE COMPETENCY SCHEME

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14

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An Introduction to the scheme

- U-values are an important part of the industry.
- An increasing number of support queries regarding innovative constructions, new products, calculation methods etc. has been recorded.
- Elmhurst recognised there was a need for additional training for assessors to produce U-value calculations that could be used with confidence.

15

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An Introduction to the scheme

- Aimed at industry professionals with an interest in u-values e.g. Energy Assessors, Architects, Manufacturers, Retrofit Assessors/co-ordinators.
- **Elmhurst Design SAP or U-Value Calculator licence required, to be part of the scheme.**
- Must have your own PI insurance covering U-values.
  - (If a standalone calculation)
- Voluntary scheme.
- **On completion of todays course, You can apply to be registered on the scheme.**
- **We will then issue you with 10 test cases to be assessed, that once completed and passed will allow you to become a scheme member.**

16

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Benefits of the U-Value Competency Scheme

- U-Value Competency Scheme certificate.
- Scheme members listed on Elmhurst website (optional).
- Use of Elmhurst U-Value Competency Scheme Logo.
- In depth knowledge of U-value calculation procedures and conventions.
- The initial course qualifies for 5 hours CPD.
- Provides additional credibility of U-values.

17

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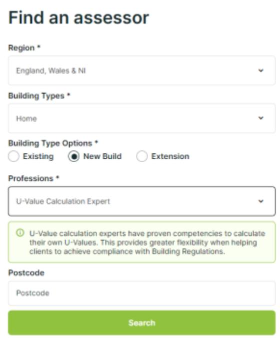

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18

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Competency Assessment

- A series of specifications will be provided via email following your application to join the scheme.
- These need to be completed by the assessor and once complete we can then look at your account and check for accuracy.
- We recommend submissions are completed within four weeks of attending the course.
- All U-values must achieve the required standard to join the scheme.

19

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Membership Renewal

- As part of the scheme we are required to ensure assessors are producing accurate U-Values.
- In order to do this we will provide a set of assessments once a year.
- The assessor must complete these to a satisfactory standard to remain a part of the scheme.
- **This will be charged at £195 + VAT per assessor per year**.

20

Elmhurst U-value Calculator

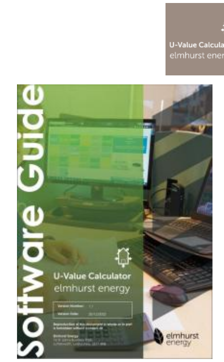
21

Elmhurst's U-value Calculator

- For todays course and the following 4 weeks you will have a training licence to use.
- This will give access to complete the exercises today and then also the ten test cases should you wish to complete.
- Please be aware the licence is for the purposes of training only.
- Please note that after 4 weeks a full licence will need to be purchased.

If you have an Elmhurst ID we will associate the training u value licence to that ID.

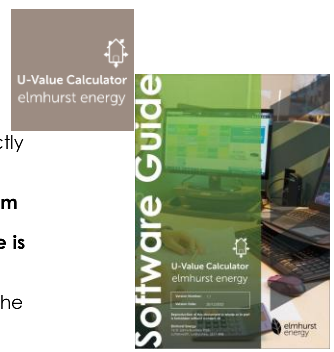
If you do not have an Elmhurst ID prior to the course then we will create an ID for you to use for 4 weeks.



22

Elmhurst's U-value Calculator

- Elmhurst have produce a U-value Calculator application found on Access Elmhurst.
- Allows creation of U-value calculations in accordance with BR 443 and BS EN ISO 6946.
- Once created these figures can then be directly entered into Design SAP 10.
- **The u-value calculator is included in a premium Design SAP licence at £245 + VAT per year. Alternatively a U-value calculator only licence is £175 + VAT per user, per year.**
- There is a comprehensive user manual within the On Construction Section of Access Elmhurst.

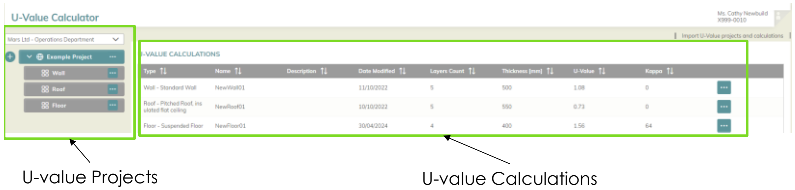


23

U-value Calculator Structure

- The U-value Calculator is structured as follows;
- **U-value Projects** – this holds groups of u-value calculations i.e for a building, project or customer.
- **U-value Calculations** – this area displays the u-value calculations contained within each Project i.e wall, floor and roof.

24



25

Common Symbols

Symbol	Function
+	Add a new item
	Edit the currently selected item
	Delete the currently selected item
	Import U-value calculations from Design SAP 2012
	Copy/Save as function. Duplicate the selected item

26

Using the U-value Calculator

- We will now go through a basic guide of how to use the U-value Calculator including;
  - How to find the U-value Calculator
  - How to add Projects and U-value calculations
  - How to add/edit/delete layers
  - How to edit layer data
  - How to produce reports
- If you have not used this before please ask any questions.

27

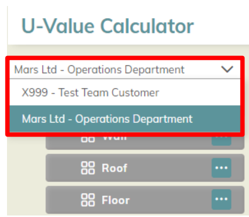
Workspaces

- The data displayed in the U-value Calculator is controlled by the workspace. There are two types of workspace available;
  - **'Personal'** workspace. All U-value Calculator licence holders have access to a personal workspace to add, edit and view work created by themselves.
  - **'Shared'** workspace. Members of a companies' Operations Department will also have access to the companies shared workspace. This allows all associated members to add, edit and view work created by themselves and other members of the same Operations Department.
- The workspace should always be checked upon login to the U-value Calculator to ensure it is the correct one before you start to add work.

28

Changing Workspaces

- The list of available workspaces is displayed above the navigation area of U-value Calculator;
- A shared workspace will have the term 'Operations Department' in the description.



29

The Navigation Area

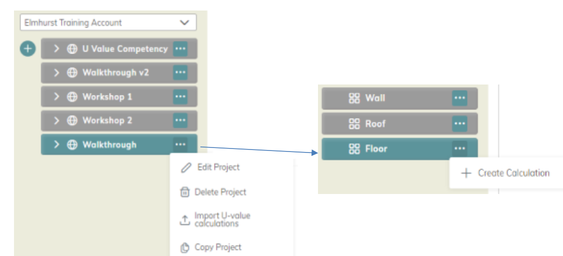
- The left hand side of the Workspace is the Navigation area.
- Here you can navigate through your U-value Calculator workspace, drilling down into the different levels.
- Each level contains an action button allowing different functions to be performed e.g. adding, deleting, editing and copying.

30

The Contents Area

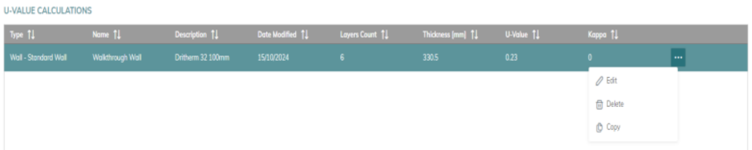
- The right hand side of the Workspace is the Contents area.
- Here you can navigate through the Contents of the level selected in the Navigation area.
- Again each item allows different actions to be performed e.g. adding, deleting, editing and copying.

31



- Within the '+' function you can create a project.
- Once you have a project you will then have a wall. Roof and Floor section.
- Within each section you can then create a calculation.

32



- Within the 3 dots tile you can then edit, delete or copy that u value.

33

PROJECTS

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34

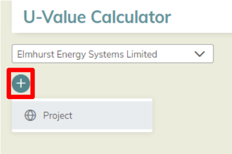
Projects

- The highest level of data segregation in the U-value Calculator.
- Projects contain groups of u-value calculations which can be selected in the navigation area.
- Many users create a Project for each client e.g. house builder A, house builder B.

35

Adding new Projects

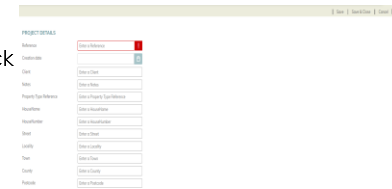
- On your first login you will have no Projects.
- To add a new Project, click the button and select 'Project';



36

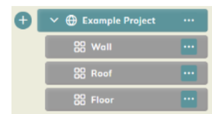
Adding new Projects

- Enter Project details and then click 'Save and Close' to add your Project.



37

U-VALUE CALCULATIONS



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38

U-value Calculations

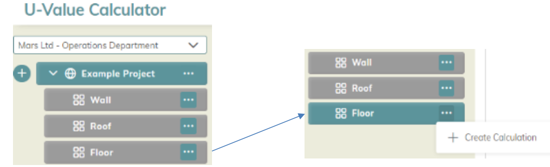
- Within a Project you can create U-value calculations.
- These are divided between Walls, Roofs and Floors;

39

1. Creating U-value Calculations

- First create a U-value Project.
- You can then start to create U-value Calculations for this Project in the Walls, Roofs or Floors sections by selecting Create Calculation in each one;

U-Value Calculator



40

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2. Navingating U-value Calculations

- The U-value calculator will now launch.
- There are five areas within a u-value calculation;
  - Details – basic details of the u-value calculation
  - Environment – used for condensation risk calculations only – function to follow.
  - Unheated space – to add a shelter factor for elements adjacent to unheated spaces
  - Layers – entry of construction layers of the element
  - Results – view of results and generation of reports

41

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3. Layers

- The ‘Layers’ section is where we add the components of the construction into the U-value calculation i.e. insulation, blockwork etc.
- Layer data is displayed in the ‘Layer Details’ section i.e. thickness, thermal conductivity, resistance etc.
- Layers can be repositioned by drag and drop using the

42

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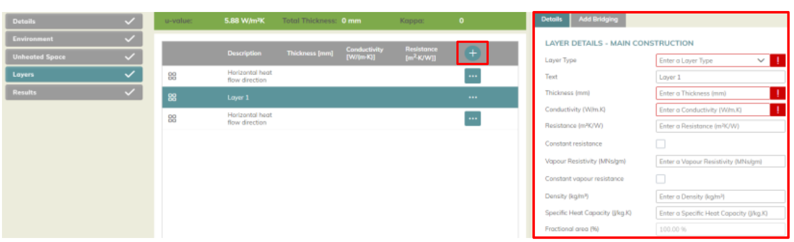
4. Adding Layers

- Layers can be entered in two ways;
  1. Click the symbol. This will add a layer which you can then edit the details in the Details section;



43

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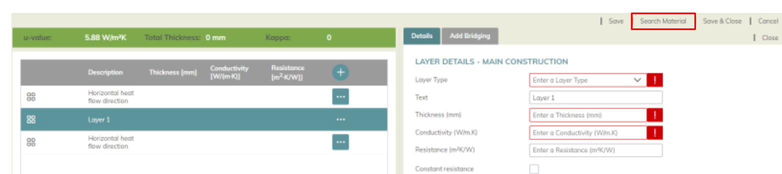
4. Adding Layers

2. Click the symbol. Then click ‘Search Material’ to use the Materials Database to populate the layer details. This is a pre-populated list of manufacturer products with data already stored.

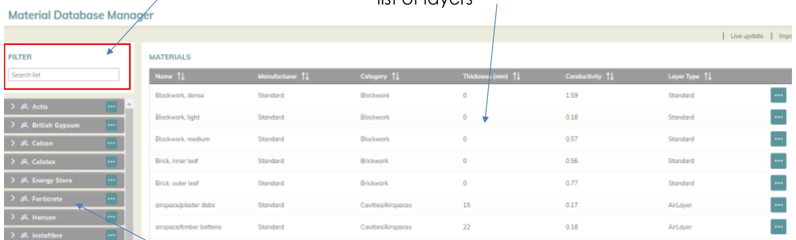


44

Navigating the Materials Database

Use ‘Filter’ to find materials quickly;

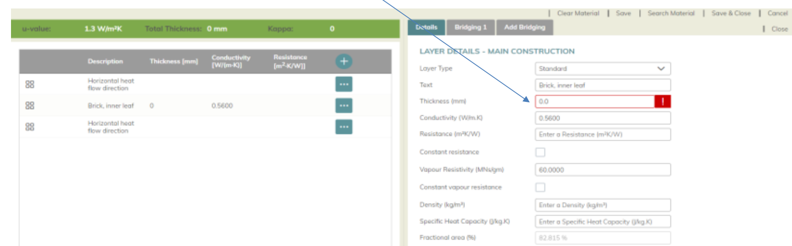
Double click a material to add to your list of layers



Or browse through the folders to find a material

45

Enter thickness and any other details;

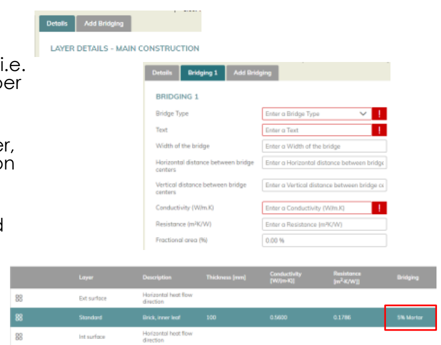


- Continue to add layers using the button.

46

5. Adding Thermal Bridging

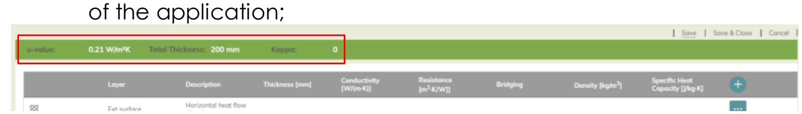
- Add any repeating thermal bridging. This is where a layer is interrupted by another material i.e. a insulation layer broken by timber studs.
- This is done by selecting the layer, clicking the ‘Add Bridging’ button in ‘Layer Details’.
- The bridging type (material) and either dimensions or bridging fraction need to be entered.
- Layers with bridging present are displayed in the list of layers;



47

6. Viewing Results

- The calculated U-value is displayed in the results bar at the top of the application;



- Clicking on the ‘Results’ section allows a more detailed view of the calculation of results and generation of a U-value Calculation report;

48

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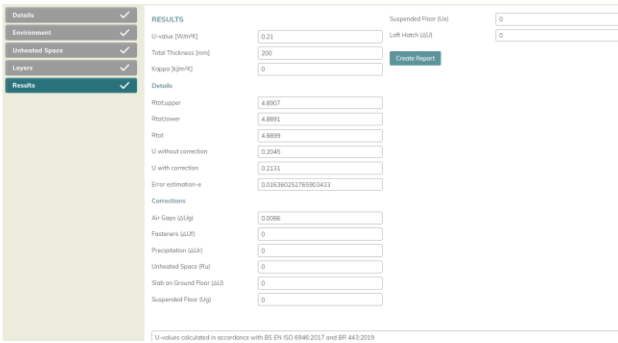
6. Viewing Results



49

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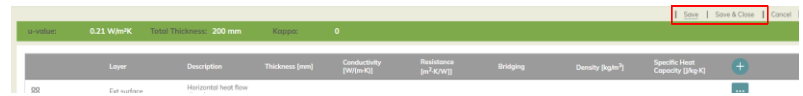
7. Saving work

- To Save your work click 'Save' or to save and return to the Project click 'Save and close'.



50

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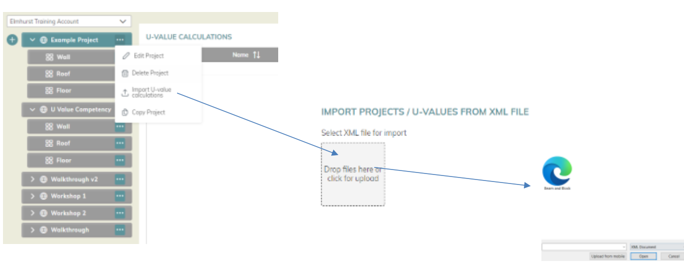
8. Importing from SAP 2012

- You can import u values that have previously been calculate in SAP 2012



51

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Common U-value Calculation Errors

- These are the areas where we see assessors making errors;
  - Missing timber thermal bridging in insulation
  - Missing metal wall ties in cavity wall insulation
  - Not accounting for low emissivity airspaces
  - Incorrectly assigning airspaces as ventilated or unventilated
  - Not including ventilated loft space layer in cold roofs
  - Ground Floor P/A ratio missing from Floor Details section

52

Group Workshop U Value

53

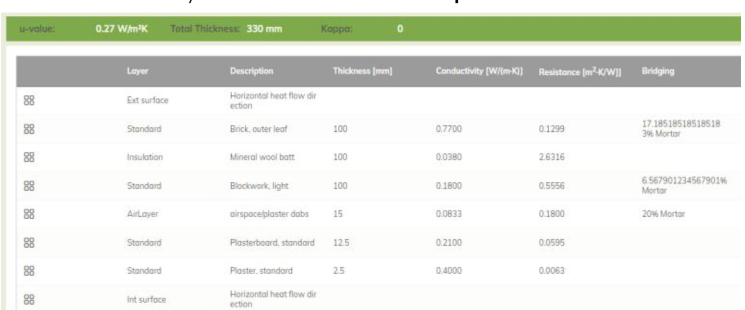
Create the following U Value

- Generate the layers below as save as **'Example Wall 1'**
  - Layer 1 > Brick Outer Leaf @ 100mm
  - Layer 2 > Mineral Wool Batt @ 100mm
  - Layer 3 > Blockwork Light @ 100mm
  - Layer 4 > Airspace Plaster Dabs @ 15mm (Default BR443)
  - Layer 5 > Plasterboard @ 12.5mm
  - Layer 6 > Plaster standard @ 2.5mm

54

Create the following U Value

- Generate the layers below as save as **'Example Wall 1'**



u-value: 0.27 W/m²K Total Thickness: 330 mm Kappa: 0

Layer	Description	Thickness [mm]	Conductivity [W/(m·K)]	Resistance [m²·K/W)]	Bridging
Ext surface	Horizontal heat flow dir ection				
Standard	Brick, outer leaf	100	0.7700	0.1299	17.185185185185183% Mortar
Insulation	Mineral wool batt	100	0.0380	2.6316	
Standard	Blockwork, light	100	0.1800	0.5556	6.567901234567901% Mortar
AirLayer	airspace/plaster dabs	15	0.0833	0.1800	20% Mortar
Standard	Plasterboard, standard	12.5	0.2100	0.0595	
Standard	Plaster, standard	2.5	0.4000	0.0063	
Int surface	Horizontal heat flow dir ection				

55

Break Time

After the Break:
Heat Transfer Methods
U-Value Calculation Methods
- Simplified
- Combined
- Dynamic

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56

HEAT TRANSFER METHODS

57

Heat Transfer

- Heat is a form of energy.
- Heat always tries to move in one direction - from hot to cold.
- Heat loss through building envelopes is calculated in u-values, psi values and air tightness.
- Heat is transferred through construction elements in different ways which are reflected in u-values.

58

Methods of Heat Transfer

- There are three methods of heat transfer accounted for in U-value;
  - Conduction
  - Convection
  - Radiation

- All three will influence heat loss in a building element in some form.

59

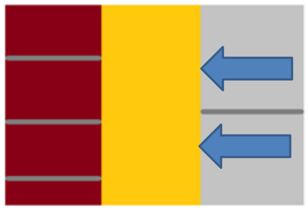
CONDUCTION

60

Conduction

Conduction

- Heat travelling through a material, we deal with this in buildings using insulation / generally measured as u values & psi values



61

Thermal Conductivity (λ)

- The thermal performance of a material can be compared by looking at the lambda value (λ) aka it's Thermal Conductivity.
- This is the measure of heat conduction through a 1m x 1m x 1m cube of the material (W/mK).

Material	Thermal Conductivity (W/mK)
Aluminium	160.00
Stainless Steel	17.00
Concrete	2.3
Brick	0.77
Timber	0.13
Mineral Wool	0.04

62

Thermal Conductivity (λ)

Product	Type	Thermal Conductivity (W/mK)
Celotex CW4000	Polyurethane Insulation	0.022
Kingspan GG300	Extruded Polystyrene Insulation	0.034
Thermalite Hi-Strength 7	Aircrete (AAC) Block	0.18
Rockwool Thermal Insulation Roll	Mineral Wool Roll Insulation	0.044
Celcon Solar	Aircrete (AAC) Block	0.11
Knauf Earthwool Dritherm 32	Mineral Wool Slab Insulation	0.032
Plasmor Fibolite (3.6N)	Aggregate Block	0.215
Gyproc Thermaline Super (40 mm)	Insulated Plasterboard	0.027

63

Workshop

- Match the conductivities to the materials;

64

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Thermal Resistance (R)

- Resistance is the measure of heat flow through a given thickness of material.
- Resistance is calculated as:

  R (m^2K/W) = thickness (m) / thermal conductivity (W/mK)

- A high thermal resistance means that a low amount of heat can be transferred through the element.
- However there are materials e.g. ventilated airspaces that have the same resistance regardless of thickness – ‘Constant resistance’.

65

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Thermal Resistance (R)

- For an element with a conductivity of 0.0220 W/mK;

CELOTEX GA4000						
Conductivity / W/mk	0.022	0.022	0.022	0.022	0.022	0.022
Thickness / mm	50	60	70	80	90	100
Resistance / m2K/w	2.2727	2.7273	3.1818	3.6364	4.0909	4.5455

66

Group Workshop 1

67

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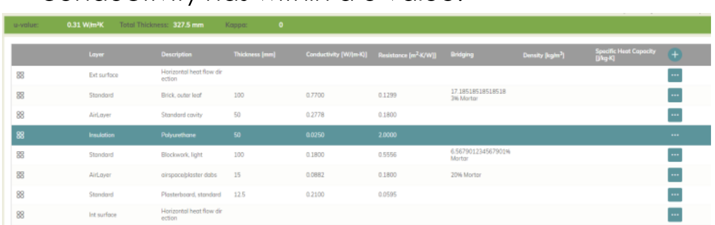
Group Workshop 1

- We will now look at the influence a change in conductivity has within a u value.



u-value: 0.31 W/m²K Total Thickness: 327.5 mm Kappa: 0

Layer	Description	Thickness [mm]	Conductivity [W/(m·K)]	Resistance [m^2·K/W]	Bridging	Density [kg/m^3]	Specific Heat Capacity [J/kg·K]
Ext surface	Horizontal heat flow direction						
Standard	Brick, outer leaf	100	0.7700	0.1299	17.185185185185183% Mortar		
AirLayer	Standard cavity	50	0.2778	0.1800			
Insulation	Polyurethane	50	0.0250	2.0000			
Standard	Blockwork, light	100	0.1800	0.5556	6.5679012345679016% Mortar		
AirLayer	airspace/plaster dabs	15	0.0882	0.1800	20% Mortar		
Standard	Plasterboard, standard	12.5	0.2100	0.0595			
Int surface	Horizontal heat flow direction						

68

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Group Workshop 1

u-value:	0.31 W/m²K	Total Thickness:	327.5 mm	Kappa:	0

Layer	Description	Thickness [mm]	Conductivity [W/(m-K)]	Resistance [m²-K/W)]	Bridging	Density [kg/m³]	Specific Heat Capacity [J/kg-K]
Ext surface	Horizontal heat flow direction						
Standard	Brick, outer leaf	100	0.7700	0.1299	17.18518518518518 3% Mortar		
AirLayer	Standard cavity	50	0.2778	0.1800			
Insulation	Polyurethane	50	0.0250	2.0000			
Standard	Blockwork, light	100	0.1800	0.5556	6.5679012345679 01% Mortar		
AirLayer	airspace/plaster dabs	15	0.0882	0.1800	20% Mortar		
Standard	Plasterboard, standard	12.5	0.2100	0.0595			
Int surface	Horizontal heat flow direction						

- Altering this figure here from 0.0250 to 0.0200.
- Look at the resulting change in u value.
- Results alter from 0.31 > 0.27

69

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Data Sources

- Most manufacturers will provide conductivities and resistances.
- Another source of data can be BBA Certificates. They are produced for products tested by the BBA and can be found at www.bbacerts.co.uk.
- Publications such as Environmental Design: CIBSE Guide A also provide data.

70

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Environmental Design: CIBSE Guide A

- A guide by CIBSE with a table of conductivities and resistances for common materials;

Table 3.36 Thermal conductivity, density and specific heat capacity: impermeable materials

Material	Condition/test (where known)	Source	Thermal conductivity / $W \cdot m^{-1} \cdot K^{-1}$	Density / $kg \cdot m^{-3}$	Specific heat / $J \cdot kg^{-1} \cdot K^{-1}$
Asphalt		C	0.50	1700	1000
		E	1.20	2300	1700
— poured		T	1.20	2100	920
— reflective coat		E	1.20	2300	1700
— roofing, mastic		E	1.15	2330	840
Bitumen					
— composite, flooring		E	0.85	2400	1000
— insulation, all types		T	0.20	1000	1700
Ceramic, glazed		T	1.40	2500	840
Glass					
— cellular sheet		T	0.048	140	840
— foam	At 50°C	I	0.056	130	750
		S	0.052	140	840
— solid (soda-lime)	At 10°C	C	1.05	2500	840

71

CONVECTION

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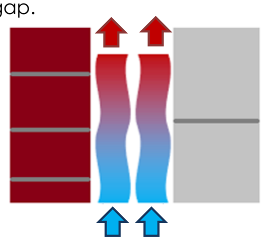
72

Convection

Convection

- Heated particles moving around a space, warm air being actively displaced by cooler denser air e.g. Hot air displaced by cold air via an open window/ air gap.



73

Convection

- This occurs in airspaces within constructions.
- Dependent on the ventilation rate in the airspace.
- This is the reason heat loss is also assigned to party walls in SAP.

74

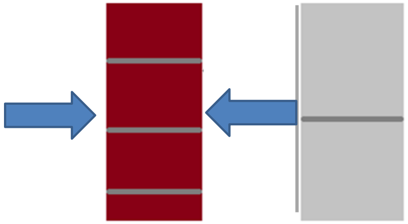
RADIATION

75

Radiation

Radiation

- Light waves leaving an object, e.g. bounced back into an airspace from a foil faced insulation.



76

Radiation

- Again only occurs in airspaces.
- Dependent on the emissivity (e) of adjacent surfaces either side of airspace.
- Many products can reduce heat loss through radiation with special finishes.

77

U-VALUE CALCULATION METHODS

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78

U-value Calculations Methods

- U-values in their simplest form are an expression of heat transfer from inside to out in a straight line.
- However almost all construction methods have irregularities such as mortar joints, timber rafters, wall ties etc.
- As a result of these irregularities heat does not travel in a straight line through the construction.

79

U-value Calculations Methods

- As a result of this there are three possible methods of calculating U-values;
  - The Simplified Method
  - The Combined Method
  - Dynamic/Numerical Analysis

80

THE SIMPLIFIED METHOD

81

U-value Calculations – The Simplified Method

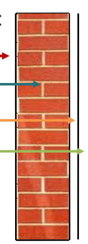
- This method can be used to calculate U-values where there is no repeating thermal bridging or non parallel layers so heat can only flow in one path.
- The u-value is simply the sum of the resistances of each layer;
  - Material Resistances (R)
  - Airspace Resistances (Ra)
  - Internal Surface Resistance (Rsi)
  - External Surface Resistance (Rse)
- Calculate the various thermal resistances
- Add together to find the Total Resistance (RT)
- Calculate the composite U-value (U = 1/RT)

82

220mm Solid Brick Wall with 13mm Plaster

To calculate the U-value, starting with layers from outside to inside:

Rse = **0.04 m²K/W** (standard default value)
Standard Brickwork (RB): 0.220m / λ = 0.77 W/mK = **0.286 m²K/W**
Standard Plaster (RP): 0.013m / λ = 0.40 W/mK = **0.032 m²K/W**
Rsi = **0.13 m²K/W** (standard default value)



Total Resistance (RT) = Rse+RB+RP+Rsi

RT = **0.04 + 0.286 + 0.032 + 0.13** = 0.488m²K/W

U = 1/RT 1/0.488 = U-value 2.05 W/m²K

83

THE COMBINED METHOD

84

The Combined Method

- The Combined method is the method used in U-value calculations for SAP/SBEM.
- Defined in BS EN ISO 6946 (2017).
- This method takes account of irregularities such as repeating thermal bridging, air gaps around insulation, metal wall ties etc.

85

The Combined Method cont.

- Calculation of the 'upper and lower limit' of thermal resistance of the construction.
- The U-value is the mean of these two limits.
- 'Corrections' are applied for air gaps and metal wall ties.
- Any layer which is 'bridged' creates two heat flow paths.

86

Calculation Procedure

- We will now look at the procedure to calculate a U-value using the combined method in accordance with BS EN ISO 6946.
- There are five steps to calculate a U-value using the combined method.

87

Step 1: Upper Resistance

- Firstly we calculate the upper resistance limit (R_{upper}) by combining the total resistances of all possible heat-flow paths through the element.
- This is dependent on how many layers are bridged. Where an element is bridged it is considered to consist of two thermal paths.

89

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Step 1: Upper Resistance

- The Upper limit of thermal resistance is calculated by combining the alternative resistances of the bridged layer in proportion to their respective areas;

$$R_{upper} = \frac{1}{\frac{F_1}{R_1} + \frac{F_2}{R_2}}$$

- Where F1 and F2 are the fractional areas of the two sections, and R1 and R2 are the total resistance of the two sections.

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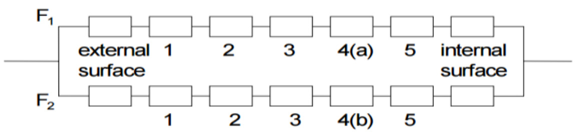
Step 1: Upper Resistance

- So if an element has 5 layers, and layer 4 is bridged it would be modelled as below.



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Step 2: Lower Resistance

- Calculate the lower resistance limit (R_{lower}) by combining the resistances of the heat flow paths of each layer separately.
- Therefore a bridged layers' resistance is determined by calculating the resistance of the bridged part and the resistance of the unbridged part of the layer in proportion of bridging.
- Resistances of all layers then added together to give the lower limit.

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Step 2: Lower Resistance

- For example a insulation layer bridged by timber would be calculated as follows;

$$R = \frac{1}{\frac{F_{insul}}{R_{insul}} + \frac{F_{timber}}{R_{timber}}}$$

- Where F_{insul} is fraction of insulation and F_{timber} is fraction of timber bridging.
- Where R_{insul} is resistance of insulation and R_{timber} is resistance of timber bridging.

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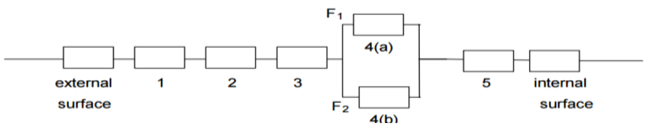
Step 2: Lower Resistance

- So if an element has 5 layers, and layer 4 is bridged it would be modelled;



94

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Step 3: Total Thermal Resistance

- Calculate the total thermal resistance (R_T);

$$R_T = \frac{R_{upper} + R_{lower}}{2}$$

- This is the average of the upper and lower resistances.

95

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Step 4: Corrections

- Corrections for **air gaps** (ΔU_g) and **mechanical fasteners** (ΔU_f) are now calculated.
- Corrections due to air gaps are calculated as follows;

$$\Delta U_g = \Delta U'' \times (R_I/R_T)^2$$

- Where;
  - R_I is thermal resistance of layer containing gaps
  - R_T is total resistance of element from step 3
  - $\Delta U''$ is correction factor based on how insulation is installed
- There is a third that we will cover later / Inverted flat roof.

96

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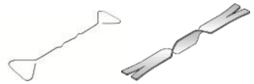
Step 4: Corrections

- Level 0 – no gaps exceeding 5 mm width penetrating the insulation. **ΔU = 0.00**
- Level 1 (default) – sum of the length or width tolerance of insulation board is more than 5 mm, or the squareness tolerance is more than 5 mm. **ΔU = 0.01**
- Level 2 – air gaps as per level 1 and also air circulation possible on the warm side of the insulation. **ΔU = 0.04**

97

Step 4: Corrections

- Corrections for mechanical fasteners (ΔU_f) must also be incorporated.
- For metal wall ties in an insulated cavity wall BR 443 provides the following typical data;



Thermal conductivity	
Mild steel	50 w/m.k
Stainless steel	17 w/m.k
Cross section	
Double triangle types	12.5 mm²
Vertical twist types	80 mm²
Density	
For walls < 15 m in height and leaf thickness > 90 mm	2.5 per m²

98

Step 4: Corrections

- Calculated as follows;

$$\Delta U_f = \alpha \frac{\lambda_f A_f n_f}{d_0} \left(\frac{R_1}{R_{T,h}} \right)^2$$

- Where;
  - λf is the thermal conductivity of the fastener
  - nf is the number of fasteners per square metre
  - Af is the cross sectional area of one fastener in m^2
  - d_0 is the thickness of the insulation layer containing the fastener, in m
  - d_1 is the length of the fastener that penetrates the insulation later, in m
  - R_1 is the total thermal resistance of the insulation layer penetrated by the fasteners in $m^2 K/W$
  - $R_{T,h}$ is the total thermal resistance of the component ignoring any thermal bridging in $m^2 K/W$

99

Step 5: Calculation of U-value

- Calculate the U-value from;

$$U = (1/R_T) + \Delta U_g + \Delta U_f$$

- **If ΔU_g and ΔU_f combined are less than 3% of the U-value they can be omitted from the calculation.**

100

Combined Method Example

- We will now walkthrough a combined method U-value calculation from start to finish.
- Based on the steps described previously we will assess each part of the element and also consider bridging, air gaps and mechanical fasteners.

101

Combined Method Example

- We have the following cavity wall;
  - 100 mm brick (conductivity 0.77 W/m.k)
  - 100 mm insulation in cavity (conductivity 0.04 W/m.k), with stainless steel, vertical twist wall ties
  - 100 mm AAC blocks (conductivity 0.11 W/m.k) bridged by mortar (conductivity 0.88 W/m.k) @ 6.7%.
  - 3 mm plaster skim (conductivity 0.57 W/m.k)

102

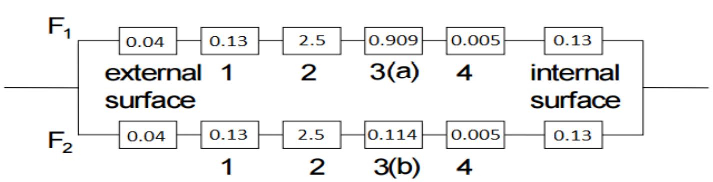
Combined Method Example

Layer	Material	Thickness (mm)	Conductivity (W/m.k)	Resistance (m^2k/w)
	External surface	-	-	0.04
1	Brick	100	0.77	0.130
2	Insulated cavity	100	0.04	2.50
3a	AAC block	100	0.11	0.909
3b	Mortar joints	100	0.88	0.114
4	Plaster skim	3	0.57	0.005
	Internal surface	-	-	0.13

103

Upper Resistance

- Based on the data previously shown there are two heat paths through the construction;



104

Upper Resistance

Layer	Material	Resistance (m^2k/w)
	External surface	0.04
1	Brick	0.130
2	Insulated cavity	2.50
3a	AAC block	0.909
4	Plaster skim	0.005
	Internal surface	0.13
		3.714

Layer	Material	Resistance (m^2k/w)
	External surface	0.04
1	Brick	0.130
2	Insulated cavity	2.50
3b	Mortar joints	0.114
4	Plaster skim	0.005
	Internal surface	0.13
		2.919

105

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Upper Resistance

$$R_{upper} = \frac{1}{\frac{F_1}{R_1} + \frac{F_2}{R_2}} \qquad R_{upper} = \frac{1}{\frac{0.933}{3.714} + \frac{0.067}{2.919}}$$

$$R_{upper} = 3.647 \text{ m}^2\text{K/W}$$

106

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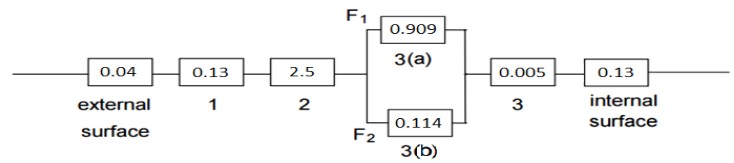
Lower Resistance



107

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Lower Resistance

Layer	Material	Resistance (m²k/w)
	External surface	0.04
1	Brick	0.130
2	Insulated cavity	2.50
3	AAC block	0.62
4	Plaster skim	0.005
	Internal surface	0.13

$$= \frac{1}{\frac{0.933}{0.909} + \frac{0.067}{0.114}} = 0.62$$

$R_{lower} = 3.425 \text{ m}^2\text{K/W}$

108

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Total Thermal Resistance

$$R_T = \frac{R_{upper} + R_{lower}}{2}$$

$$R_T = \frac{3.647 + 3.425}{2} = 3.536 \text{ m}^2\text{K/W}$$

109

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Corrections – Air Gaps

- Corrections for air gaps (ΔU_g)
- Corrections due to air gaps are calculated as follows;

$$\Delta U_g = \Delta U'' \times (R_I/R_T)^2$$

$$\Delta U_g = 0.01 \times (2.5/3.537)^2$$

$$\Delta U_g = 0.005$$

- Where;
  - R_I is thermal resistance of layer containing gaps (insulation layer)
  - R_T is total resistance of element from step 3
  - $\Delta U''$ is correction factor based on how insulation is installed (level 1 assumed here)

110

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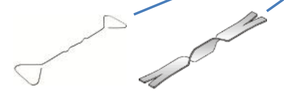
Corrections – Wall Ties

- Corrections for mechanical fasteners (ΔU_f) must now be incorporated.
- In this example these occur in the insulated cavity.



Thermal conductivity	
Mild steel	50 W/m.k
Stainless steel	17 W/m.k
Cross section	
Double triangle types	12.5 mm²
Vertical twist types	80 mm²
Density	
For walls < 15 m in height and leaf thickness > 90 mm	2.5 per m²

111

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Corrections – Wall Ties

- Stainless steel, vertical twist specified; $\Delta U_f = \alpha \dfrac{\lambda_f A_f n_f}{d_0}\left(\dfrac{R_1}{R_{T,h}}\right)^2$
- Where;
  - *a = 0.8 if the fastener fully penetrates the layer e.g cavity wall ties*
  - *a = 0.8 x d_1/d_0 if a recessed fastener e.g. Recessed roof fastener*
  - λ_f is the thermal conductivity of the fastener
  - A_f is the cross sectional area of one fastener in m2
  - n_f is the number of fasteners per square metre
  - d_0 is the thickness of the insulation layer containing the fastener, in m
  - d_1 is the length of the fastener that penetrates the insulation later, in m
  - R_1 is the total thermal resistance of the insulation layer penetrated by the fasteners in m².K/W
  - $R_{T,h}$ is the total thermal resistance of the component ignoring any thermal bridging in m².K/W

112

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Corrections

$$\Delta U_f = 0.8 \times \frac{17 \times 0.00008 \times 2.5}{0.1} \times \left(\frac{2.5}{3.537}\right)^2$$

$$\Delta U_f = 0.8 \times \frac{0.0034}{0.1} \times \left(0.7068136\right)^2$$

$$\Delta U_f = 0.8 \times 0.034 \times 0.4995854$$

$$\Delta U_f = \underline{\mathbf{0.0135887}}$$

113

Calculation of U-Value

- Calculate the U-Value from;

$$U = (1/R_T) + \Delta U_g + \Delta U_f$$

$$U = (1/3.536) + 0.005 + 0.0135887$$

$$\underline{U = 0.30\ w/m^2k}$$

- ΔU_g and ΔU_f are **6.2%** of the U-Value so cannot be omitted from the calculation.

114

DYNAMIC / NUMERICAL ANALYSIS

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115

Numerical methods

- However certain scenarios are too complex for the combined method. Numerical Analysis is then used.
- This is a detailed computer calculation allowing for heat flows through multiple dimensions.
- Specialist software packages are used and BS EN ISO 10211 and 10077-2 must be followed.

116

Numerical Analysis

- Examples where this is required can include;
  - Curtain Walling
  - Unusually shaped floor constructions
  - Insulation penetrated by metal component (except wall ties)
- There are two possibilities for numerical analysis;
  1. Use numerical analysis to calculate the U-value of the whole element
  2. Use numerical analysis to calculate the thermal resistance of the layer or layers, then use the result in a combined method U-value calculation.

117

U-VALUE CONVENTIONS

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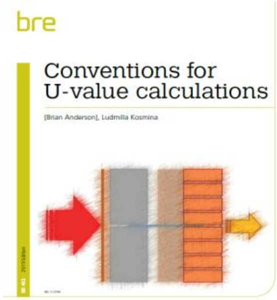
118

BR 443 – 2002 > 2006 > 2019

- Published by the BRE in 2002 and revised in 2006. A new version was published in 2019.
- Contains all standards for calculations of U-values for Walls, Floors and Roofs.
- Within BR 443 different calculation methods and their associated supporting documents are described.



119

BR 443 – 2002 > 2006 > 2019

- Also within this latest version was the acceptance of in-situ thermal measurement – section 1.5.1+2
  - Heat flow meter method.
  - Infrared method for frame structure dwelling.

1.5 U-values obtained by in-situ measurement

While calculated U-values are used for Building Regulations and most other energy calculations, direct in-situ measurement of U-values is also possible for other (non-regulatory) purposes.

1.5.1 Heat flow meter method

BS ISO 9869-1 provides the description of a heat-flow method that allows the U-values of walls in existing dwellings to be established by in-situ measurements.

The approach given in BS ISO 9869-1 is based on assuming that mean values of heat flow rate and temperatures over a reasonably long period of time (minimum 72 hours) give an estimate of the steady-state condition, but this may give erroneous results if not carried out correctly. The procedures apply only where a defined number of measurements are undertaken for an element at different times to calculate an average U-value figure. To ensure that a representative value is achieved, the standard suggests that an infrared survey is carried out (in accordance with ISO 6781:1983) to ensure that the element in question is part of the sample represented by the measurement.

1.5.2 Infrared method for frame structure dwelling

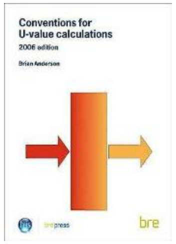
BS ISO 9869-2 describes the infrared method for measuring the thermal resistance and thermal transmittance of opaque building elements on existing buildings. The method uses an infrared camera to measure the thermal transmittance (U-value) of a frame structure dwelling with light thermal mass, typically with a daily thermal capacity (calculated according to BS EN ISO 13786) below 30 kJ/(m²K). This method is useful for screening tests to identify defective areas of building elements, but the accuracy of any U-value established by this method may be limited.

The heat transfer of the outer surface of building elements depends strongly on the outdoor wind velocity and varies with time, making it difficult to measure or estimate the density of the heat flow through building elements. Therefore, according to BS ISO 9869-2, the internal surface temperature is observed with an infrared camera only at night. This condition is applied because the outdoor air temperature and room temperature are relatively stable at night, temperature is unaffected by sunlight, and heat transmission through building elements is in a relatively steady state condition because of the relatively low thermal mass of the dwellings under consideration. Although the method in this standard is only applied to low thermal capacity building elements (eg timber-framed construction) the U-value of building elements for the steady state condition should be estimated statistically.

120

U-values in SAP/SBEM

- SAP 2012 software applies the conventions for calculating U-values set out in BR 443: 2006.
- This document covers resistance of layers and the repeating thermal bridges (timber studs, wall ties across cavity walls, mortar in masonry) that cross those layers.
- It applies standard resistances for certain layers, e.g. surfaces and unventilated airspaces.
- It also factors in the greater heat losses at edges of materials, e.g. floor slabs and corners of walls.



121

BR 443 – Conventions for U-value Calculations

- Further documents are referred to within different sections;
  - BS EN ISO 6946 : 2017 – *Building components and building element – Thermal resistance and thermal transmittance – Calculation method*
  - BS EN ISO 13370 : 2007 – *Thermal performance of buildings – Heat transfer via the ground – Calculation methods*
  - BRE Digest 465 : 2002 – *U-values for light steel frame construction*
  - CIBSE Guide A : 2006 – *Environmental design*

122

THERMAL PROPERTIES OF MATERIALS / AIR LAYERS

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123

Thermal Properties of materials and products

- In regards to performance data used within u-value calculations, BR 443 states;
  - *"Where products are covered by a harmonised European standard (EN) or a European Technical Approval (ETA), product declarations should conform to the requirements of the EN or ETA."*
- The standards for the measurement of thermal conductivity and thermal resistance are BS EN 12664, BS EN 12667 and BS EN 12939.

124

Thermal Properties of materials and products

- BR 443 provides a range of conductivity and resistances for various construction elements.
- These can be used in absence of specific performance data within u-value calculations.

125

Masonry

- Mortar conductivity can be used as;
  - Outer leaves – 0.94 W/m^2k
  - Inner leaves – 0.88 W/m^2k
- Brick conductivity can be used as;
  - Outer leaves – 0.77 W/m^2k
  - Inner leaves – 0.56 W/m^2k
- Concrete beams/screed;
  - Reinforced concrete beam – 2.3 W/m^2k
  - Concrete screed – 1.15 W/m^2k

126

Plaster dabs & Timber battens

- In BR 443 Section 4.5 the following default data is provided;
- Airspace and plaster dabs uses the following;
  - Fraction of plaster dabs – 20%
  - Thickness of plaster dabs – 15 mm
- Airspace and timber battens;
  - Fraction of timber – 11.8%
  - Thickness of battens – 22 mm
- This is defaulted in our Materials Database.

127

Plasterboard

- In absence of specific product data the following can be used;
  - Standard wallboard – 0.21 W/m^2k
  - Higher density wallboard – 0.25 W/m^2k
- This does not apply to insulation backed plasterboard which will have a much higher performance.

128

Structural Timber

- The following data can be used;
  - Prefabricated timber frame wall panels – 0.12 W/m^2k
  - All other softwood (joists, rafters etc.) – 0.13 W/m^2k
  - Hardwood – 0.18 W/m^2k
- Hardwoods are mainly from deciduous trees including oak, beech, teak etc.
- Softwoods are mainly from coniferous trees including cedar, juniper, pine, spruce etc.

129

Metals and Alloys

- The following data can be used in u-value calculations;
  - Mild steel - 50 W/m²k
  - Stainless steel - 17 W/m²k
  - Aluminium - 160 W/m²k
- Remember any metal is generally not going to improve a u-value!

130

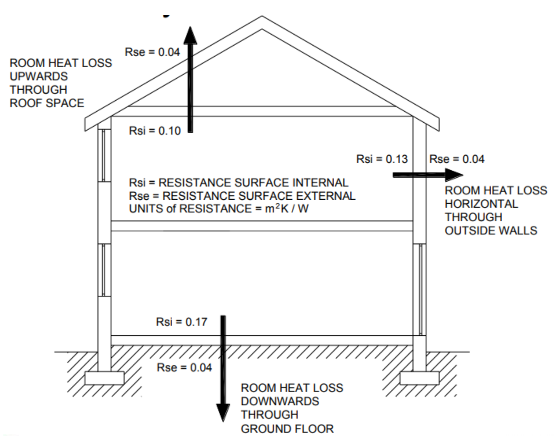
Surface Resistances

- This is additional resistance caused by the very thin layer of still air that is attached by friction to the surface of the element.
- BR 443 provides the following resistances for use in U-values;

Heat flow direction	Element type	Rsi	Rse
Horizontal	Wall	0.13	0.04
Upwards	Roof	0.10	0.04
Downwards	Floor	0.17	0.04

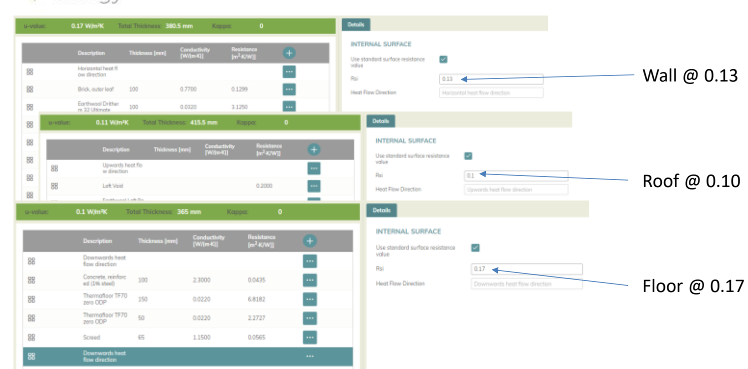
- R_{si} - internal surface resistance
- R_{se} - external surface resistance
- These are programmed into our U-Value Calculator;

131



132

Internal Surface Resistances



133

REPEATING THERMAL BRIDGES

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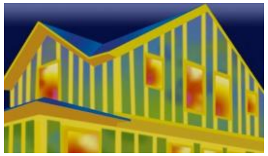
134

Repeating Thermal Bridging

- In constructions there are various different elements that can 'interrupt' layers.
- These are known as thermal bridges and can result in an increase in heat loss through a construction.
- Therefore these need to be reflected in U-value calculations.
- Common examples are timber joists, mortar, wall ties etc.
- BR 443 provides default values to use in U-value calculations for the amounts of bridging.



135

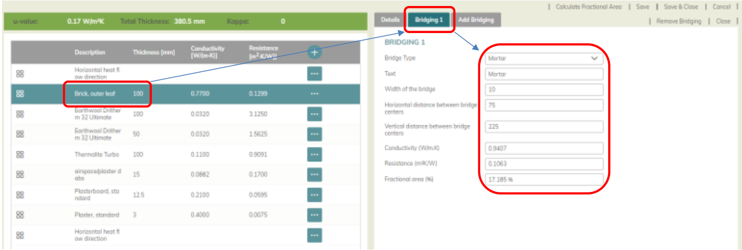
Mortar joints

- Mortar joints for both inner and outer leaves of walls are classed as bridging.
- <u>However joints may be disregarded if the difference in thermal resistance between mortar and brick/block is less than 0.1 m^{2}K/W.</u>
- Dense blockwork does not need mortar bridging as the difference between resistance is less than 0.1 m^{2}K/W.

136

Mortar joints

- To add these into a U-value Calculation (Bricks)



137

Mortar joints

- Otherwise mortar fraction is calculated in BR 443, section 4.2 as;
  - For **blocks** of face area 440 x 215 mm with 10 mm joints the fraction is 6.7%
  - For other cases the fraction is calculated as follows;

$$1 - \frac{\text{block length} \times \text{block height}}{(\text{block length} + \text{joint thickness}) \times (\text{block height} + \text{joint thickness})} + 0.001$$

138

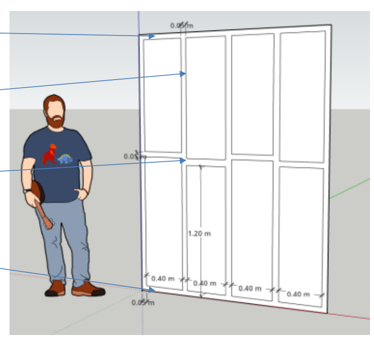
Timber Bridging

- Where insulation or an airspace is broken by timber, it needs to be reflected due to the additional path for heat loss.
- The default fraction for timber frame is **15%**, based on 38 mm timbers @ 600 centres for one and two storey buildings.
- A fraction of 12.5% can be used if all of the following are met;
  - There is a single top plate as part of the external wall panels
  - The sole (base) plate is below finished floor level
  - There are no mid-height, full depth noggins in external walls
  - The studs at junctions where internal walls meet external walls are not more than 38 mm deep and have continuous insulation behind them

139

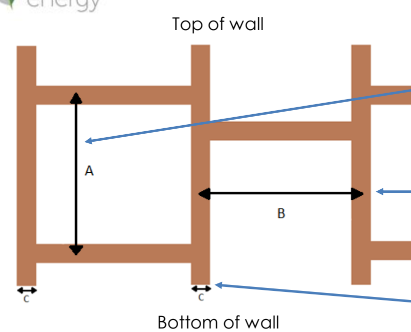
Timber Bridging cont.

- Head
- Studs
- Noggins
- Sole Plate



140

Timber Bridging cont.



- A – Vertical distance between bridge centres
- B – Horizontal distance between bridge centres
- C – Width of the bridge

141

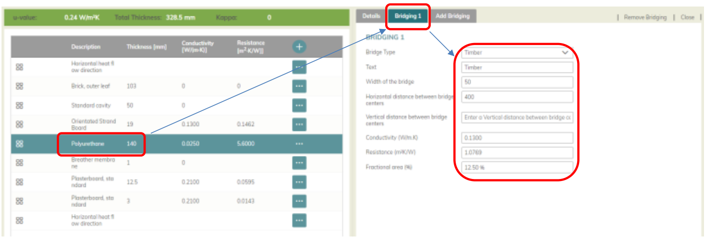
Timber Bridging cont.

- In other cases the timber fraction can be calculated using the following guidelines;
  - Exclude timbers that are outside the wall area used for heat loss calculations
  - Exclude a zone around windows and doors of 50 mm at the sill and each jamb and 175 mm at the top (lintel zone)
  - Include all timbers that are not insulated behind
- Fraction = timber width/horizontal distance + additional timber (e.g. noggins = 1%).

142

Timber Bridging cont.

- To add these into a U-value Calculation;



143

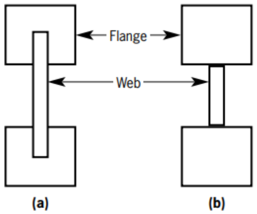
Timber fraction in other elements

- In BR 443 Section 4.5 the following fractions are provided;
- For ceiling joists;
  - Trussed rafters; 35 mm @ 600 centres: 5.8%
  - 50 mm joists @ 400 centres: 12.5%
  - Add for additional timbers (noggins, loft hatch): 1%
- Suspended timber floors
  - Default fraction; 38 mm timbers @ 400 mm centres plus a noggin every 3 metres: 11%

144

Timber I beam studs

- If the thermal conductivity of the material used for the flanges does not differ by more than 20% from that of the web, the penetration of the web into the flanges can be disregarded for the purposes of U-value calculations; that is, the calculations can be based on geometry (b) (see left) rather than (a).
- Shape (b) is then treated as three separate layers within the u-value calculation.
- Insulation within the stud should be bridged as follows;
  - Flanges 38 mm wide 15% or 12.5%
  - Flanges 48 mm wide 17% or 14.5%
  - Webs 8-10 mm wide 4%



145

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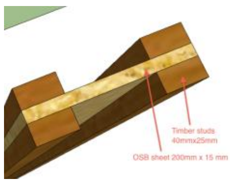
Timber I beam studs

- Insulation within the stud should be bridged as follows;
  - Flanges 38 mm wide 15% or 12.5%
  - Flanges 48 mm wide 17% or 14.5%
  - Webs 8-10 mm wide 4%



	Layer	Description	Thickness [mm]	Conductivity [W/(m·K)]	Resistance [m²·K/W]]	Bridging
	Ext surface	Downwards heat flow direction				
	Insulation	Mineral wool	40	0.0400	1.0000	17% Timber
	Insulation	Mineral wool	60	0.0400	1.5000	4% Timber
	Insulation	Mineral wool	40	0.0400	1.0000	17% Timber
	Standard	OSB Floorboard	15	0.1300	0.1154	
	Int surface	Downwards heat flow direction				

146

SHELTER FACTORS

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147

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Shelter Factors

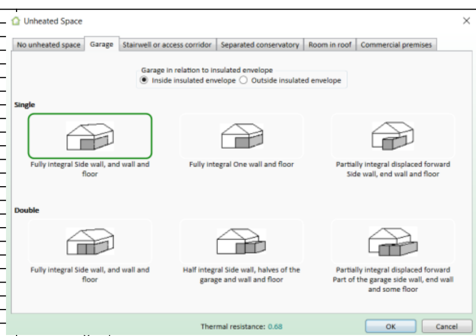
Design SAP 10 label
Garage single 1 inside
Garage single 2 inside
Garage single 3 inside
Garage single 1 outside
Garage single 2 outside
Garage single 3 outside

Garage double 1 inside
Garage double 2 inside
Garage double 3 inside
Garage double 1 outside
Garage double 2 outside
Garage double 3 outside

Stairwell Stairwell 1
Stairwell Stairwell 2

Stairwell Access Corridor 1
Stairwell Access Corridor 2
Stairwell Access Corridor 3
Stairwell Access Corridor 4

Room in roof



148

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Shelter Factors

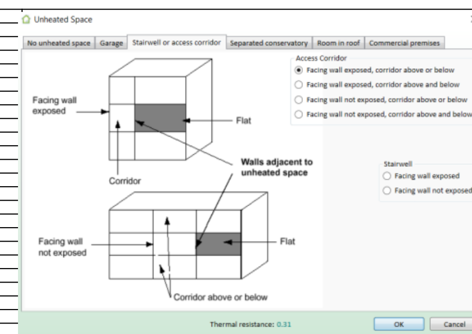
Design SAP 10 label
Garage single 1 inside
Garage single 2 inside
Garage single 3 inside
Garage single 1 outside
Garage single 2 outside
Garage single 3 outside

Garage double 1 inside
Garage double 2 inside
Garage double 3 inside
Garage double 1 outside
Garage double 2 outside
Garage double 3 outside

Stairwell Stairwell 1
Stairwell Stairwell 2

Stairwell Access Corridor 1
Stairwell Access Corridor 2
Stairwell Access Corridor 3
Stairwell Access Corridor 4

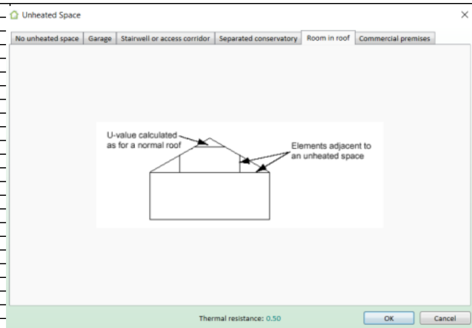
Room in roof



149

Shelter Factors

Design SAP 10 label
Garage single 1 inside
Garage single 2 inside
Garage single 3 inside
Garage single 1 outside
Garage single 2 outside
Garage single 3 outside
Garage double 1 inside
Garage double 2 inside
Garage double 3 inside
Garage double 1 outside
Garage double 2 outside
Garage double 3 outside
Stairwell Stairwell 1
Stairwell Stairwell 2
Stairwell Access Corridor 1
Stairwell Access Corridor 2
Stairwell Access Corridor 3
Stairwell Access Corridor 4
Room in roof



150

Please complete Individual Workshops 1+2

151

Lunchtime

After Lunch:
Air Layers
Corrections

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152

AIR LAYERS

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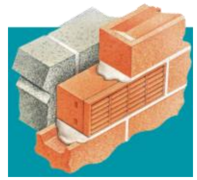
153

Air Layers

- Air layers in building elements have an associated thermal resistance that needs to be included.
- This resistance will depend upon:
  - Temperature across the air space
  - Mean temperature of the air space
  - Direction of heat travel
  - Emissivity of adjacent surfaces
  - Width of the airspace



- Air layer resistances are calculated in accordance with BS EN ISO 6946 (2007).

154

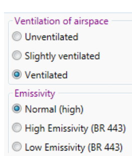
Air Layers

- Air layers are often misunderstood and misrepresented in u-value calculations.
- Determining whether the air layer is ventilated or not is crucial to deriving a resistance.
- Air layers with adjacent foil faced products are classed as ‘low emissivity’ and will have an improved resistance.
- Almost all methods of construction contain air layers within the elements.

155

Ventilated Air Layers

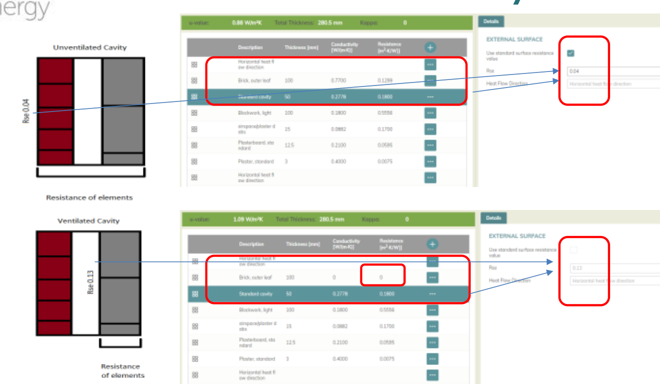
- Defined as a having ventilation openings;
  - (greater than or equal to) ≥ 1500 mm² per m of length for vertical air layers – cavities in walls
  - ≥ 1500 mm² per m of surface area for horizontal air layers – voids in flat roofs
- For all elements between the ventilated air layer and the exterior, resistance is disregarded – set as 0 m²K/W.
- However as layers outside of the airspace offer some ‘shelter’, the following external surface resistances (R_{se}) are used;



	R_{se}
High-emissivity surface, walls	0.13 m²K/W
High-emissivity surface, roofs	0.1 m²K/W
Low-emissivity surface, walls	0.29 m²K/W
Low-emissivity surface, roof	0.17 m²K/W

156

Ventilated Air Layers cont.



157

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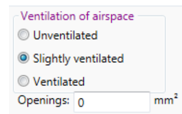
Slightly Ventilated Air Layers

- Defined as a having ventilation openings (A_v) within;
  - 500-1500 mm² per m of length for vertical air layers – cavities in walls
  - 500-1500 mm² per m of surface area for horizontal air layers – voids in flat roofs



- The thermal resistance is calculated as follows;

$$R_T = \frac{1500 - A_v}{1000} R_{T,u} + \frac{A_v - 500}{1000} R_{T,v}$$

- Where
  - $RT_{,u}$ is the total thermal resistance with an unventilated air layer
  - $RT_{,v}$ is the total thermal resistance with a well-ventilated air layer

158

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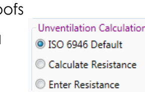
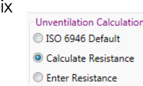
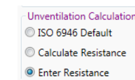
Unventilated Air layers

- Defined as a having ventilation openings;
  - (less than)<500 mm² per m of length for vertical air layers – cavities in walls
  - <500 mm² per m of surface area for horizontal air layers – voids in flat roofs
- For unventilated air layers with high emissivity surfaces adjacent, a resistance of 0.18 w/m²k is specified in BS EN ISO 6946/BR 443.
- For unventilated air layers with low emissivity surfaces adjacent, resistance can either be 'calculated' in accordance with Appendix B of BS EN ISO 6946 or taken as the following from BR 443;







	Resistance
Low-emissivity surface, walls	0.44 m²K/W
Low-emissivity surface, roof	0.34 m²K/W
Low-emissivity surface, floor	0.5 m²K/W

159

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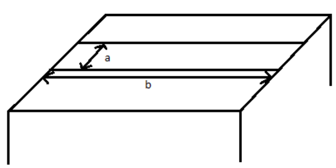
Unventilated Air layers

- To calculate an unventilated air layer resistance, the following information is required;
  - Airspace thickness (mm) - a
  - Airspace width (mm) - b
  - Mean temperature (°C)
  - Emissivity of inner surface (e1)
  - Emissivity of outer surface (e2)
  - Delta T (K)



- BR 443 states; "*Calculations of airspace resistance for normal building applications should be based on a mean temperature of 10°C and a temperature difference across the airspace of 5 K*"

160

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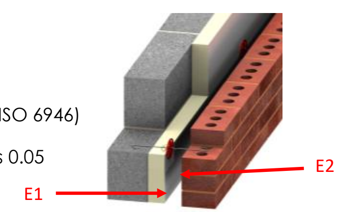
Low Emissivity Surfaces

- Materials with reflective foil finishes **can** reduce heat loss from radiation.
- But low emissivity airspace resistance changes where;
- Airspace is **unventilated**
- Has a width **≥ 25 mm**
- E2 has the default figure of 0.9 (ISO 6946)
- E1 Can be adjusted to as low as 0.05



161

Emissivity Data

- To calculate resistance of the air later the hemispherical emissivity (ε) of adjacent surfaces is required.
- Default emissivity of building surfaces is 0.9.
- Products such as foil faced insulation offer emissivity values as low as 0.03
- BBA Certificates or manufacturer's literature often have the emissivity data available for use.

162

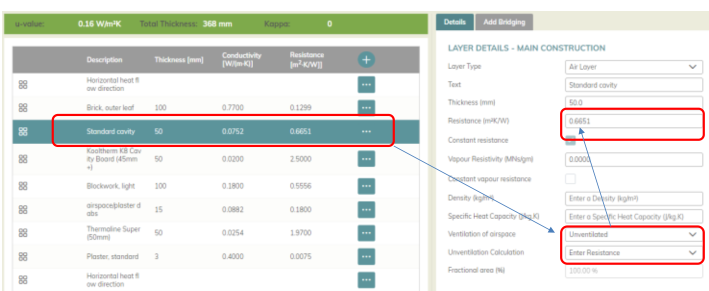
Emissivity Data

- Examples;
  - Default for materials - ε = 0.9 / Airspace Resistance = 0.1844
  - Generic foil – ε = 0.10 / Airspace Resistance = 0.5700
  - Celotex CW4000 – ε = 0.05 / Airspace Resistance = 0.6651

  - Kooltherm K8 – ε = 0.05/ Airspace Resistance = 0.6651
  - Tyvek Dupont – ε = 0.05/ Airspace Resistance = 0.6651
  - TLX Silver – ε = 0.05/ Airspace Resistance = 0.6651

163

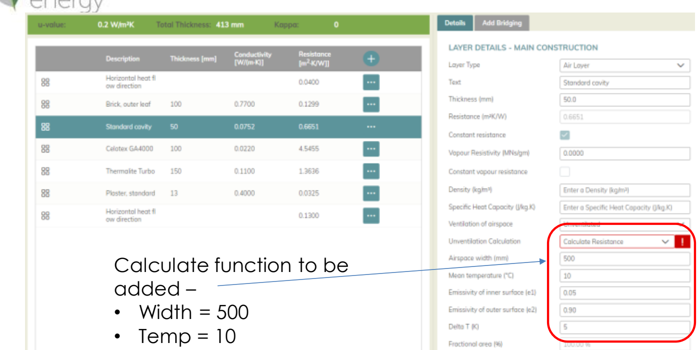
Emissivity Data



U Value with no adjustment = 0.18 W/m2K !!

164

Emissivity Data - Development



Calculate function to be added –
- Width = 500
- Temp = 10
- Delta = 5

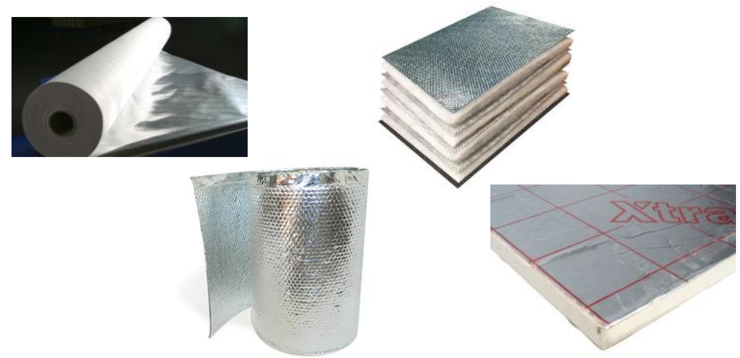
165

Reflective Foil Products

- Bubble sheet with foil facing, layers of foil separated by other material or insulation with foil facings
- TLX Silver, Tri Iso Super 10 (now H Control Hybrid & Boost'R Hybrid) , Alreflex 2L2, Xtratherm, Celotex, Tyvek Airguard etc.
- Important manufacturers installation instructions followed to gain full benefit.

166

Reflective Foil Products



167

Modelling Reflective Foil Products

- Emissivity is the key here.
- Product manufacturers often have u-value calculations available on their websites.
- To check validity these can be recreated on Elmhurst's U-value calculator.
- TLX Silver BBA Certificate data;
  - Thickness – 30 mm
  - Emissivity - ε = 0.05

168

Modelling Reflective Foil Products

- BR443 / 2019 now asks that there is a level of expansion of the multifoil into the cavity either side.
- In a slope this is assumed to be 30% into the topside and 70% below
- For a wall installation this will be 50/50.
- Additionally, the layers should be broken down into their constituent parts (foil+insulation+foil)

169

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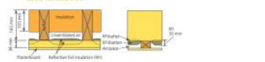
Modelling Reflective Foil Products

- The opposite is from BR443
- Below is in our calculator

	Layer	Description	Thickness [mm]	Conductivity [W/(m-K)]	Resistance [m²-K/W)]	Bridging
	Ext surface	Upwards heat flow direction			0.1000	
	Standard	Tiles, clay	15	0	0	
	AirLayer	Batten layer	25	0	0	11.11% Timber
	Membrane	Breather membrane	1	0	0	
	Insulation	Rafter & Polyurethane	100	0.0220	4.5455	8.00% Timber
	AirLayer	Rafter & Cavity	31	0.0689	0.4500	8.00% Timber
	Insulation	Rafter & Multifoil ins	9	0.0300	0.3000	8.00% Timber
	Insulation	Batten & Multifoil ins	21	0.0350	0.6000	6.00% Timber
	AirLayer	Batten & Cavity	17	0.0378	0.4500	6.00% Timber
	Standard	Plasterboard, standard	12.5	0.2100	0.0595	
	Int surface	Upwards heat flow direction			0.1000	

18 Appendix C: Example of calculating U-value for elements with multi-foil insulation



Element type: Roof – pitched roof – insulated slope, sloping ceiling
Calculation methods: BS EN ISO 6946 and BS EN 16012

Reflective foil insulation: uncompressed thickness 30 mm; core resistance R=0.91m²K/W

Layer	d (mm)	λ Layer	λ Bridge	Fraction	R layer	R bridge	Description
					0.100		R_{si}
1	12.5	0.210			0.060		Plasterboard
2	17	R-value¹	0.130	0.0600	0.450	0.131	Air unventilated low-E (0.05)
3	21	R-value	0.130	0.0600	0.610	0.162	Battens (38 mm)/multi-foil
4	9	R-value	0.130	0.0800	0.300	0.069	Rafters (140 mm)/multi-foil
5	31	R-value¹	0.130	0.0800	0.450	0.238	Air unventilated low-E (0.05)
6	100	0.022	0.130	0.0800	4.545	0.769	Insulation (100 mm)/rafters
7	–	–					Breather membrane
8	25	R-value	-	-	-	-	Air layer ventilated
9	15	1.000				0.015	Tiles (clay)
						0.100*	R_{se}
	231 mm (total roof thickness)				6.615		

- This is a multifoil of 30mm thickness

170

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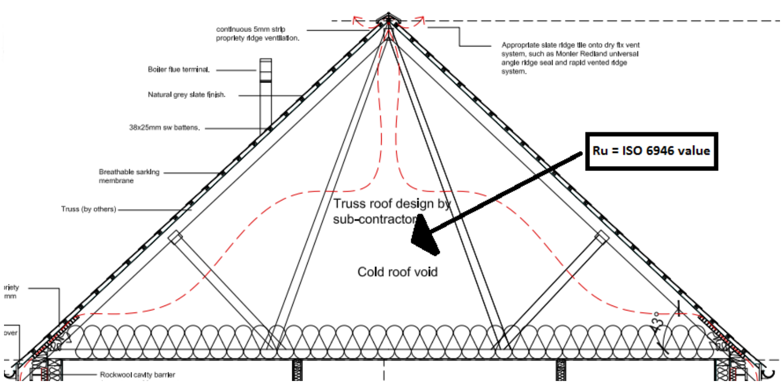
Ventilated Roof Spaces

- For a pitched roof with an insulated flat ceiling a ventilated roof space can be deemed to have a resistance of;

	Characteristics of roof	R_u
1	Tiled roof with no felt, boards or similar	0.06
2	Sheeted roof, or tiled roof, with felt or boards or similar under tiles	0.2
3	As 2 but with aluminium cladding or other low emissivity surface at underside of roof	0.3
4	Roof lined with boards and felt	0.3

- This can be applied as a layer in the U-value calculation.

171



172

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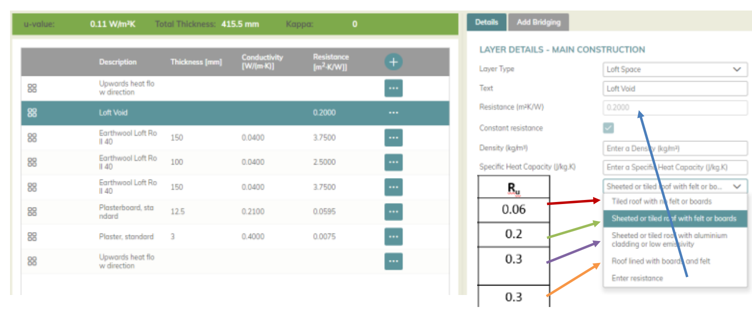
Ventilated Roof Spaces

- To add this into a U-value calculation;



173

CORRECTIONS

174

Corrections

- Corrections to the u-value are made as a result of
  - Air Gaps in insulation,
  - Mechanical Fasteners (wall ties) within insulation,
  - Rainfall on Inverted flat roofs.
- These are then incorporated into the u-value calculation to model the additional heat loss created.
- Remember if these total <3% (less than) of u-value then they are disregarded.

175

Corrections due to air gaps

- Air circulation around insulation in building elements can have a significant impact on the performance of the insulation.
- Air gaps are caused by small variations in the dimensions of the insulation product (dimensional tolerances), during cutting and installation.
- This is accounted for in a u-value calculation by the "Air Gap Correction".
- Expressed as ΔU_g

176

Corrections due to air gaps

- There are three levels of correction for air gaps in an **Insulation layer**.
  - **Level 0** – No air voids within the insulation, or where only minor air voids are present that have no significant effect on the thermal transmittance. = ΔU_g **= 0.00**
  - **Level 1** – Air gaps bridging between the hot and cold side of the insulation, but not causing air circulation between the warm and cold side of the insulation. = ΔU_g **= 0.01**
  - **Level 2** – Air gaps bridging between the hot and cold side of the insulation, combined with cavities resulting in free air circulation between the warm and cold sides of the insulation. = ΔU_g **= 0.04**
- BR 443 states "*Level 1 is the default and should be assumed unless the conditions applying to Level 0 are fulfilled.*"

177

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Corrections due to air gaps

- Level 0 =
- *"Single layer of continuous insulation with butt joints, where dimensional tolerances on length, width and squareness combined with dimensional stability results in gaps at joints that are less than 5 mm wide. The insulation is in firm contact with the construction, without cavities on both sides between the construction and the insulation."*

- *"Single layer of insulation in a construction, where the thermal resistance of the insulation is less than or equal to half the total thermal resistance of the construction. The insulation is in firm contact with construction, without cavities on both sides between the construction and the insulation."*

178

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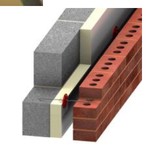
Corrections due to air gaps

- Level 1 = Default option
- *"One layer of insulation, interrupted by construction elements, e.g. studs, rafters or joists. The insulation is in firm contact with the construction, without cavities between the construction and the insulation."*

- *"Single layer of continuous insulation with butt joints, where dimensional tolerances on length, width and squareness combined with dimensional stability result in gaps in joints more than 5 mm wide. The insulation is in firm contact with the construction, without cavities on both sides between the construction and the insulation."*



179

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Corrections due to air gaps

- Level 2 =
- *"One or more layers of insulation with no firm contact with the warm side of the construction, with cavities between the construction and the insulation resulting in air movement between the warm and cold side of the insulation."*

180

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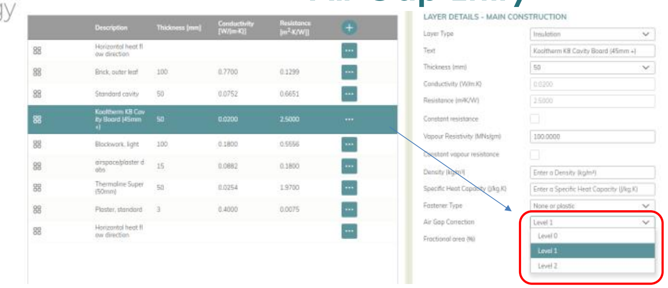
Air Gap Entry

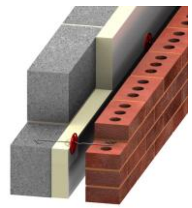


- Any insulation layer will have the option to add this correction
- Remember the 3% rule, and if the u value changes?

181

Wall Ties

- BR 443 suggests that metal wall ties can be ignored if in open airspaces (cavities) and plastic wall ties can be ignored totally. This is because their additional heat loss is insignificant.
- However metal ties penetrating insulation layers provide a path for heat loss from the inside to the outside of wall construction.



182

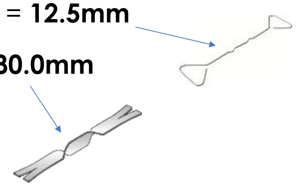
Wall Ties

- Heat loss is calculated in accordance with ISO 6946 and data required includes;
  - Thermal conductivity of the ties,
  - Number of ties per m^2 of wall (BR443 Default of 2.5 per m2),
  - Cross sectional area of the ties,
  - Penetration depth of the ties.

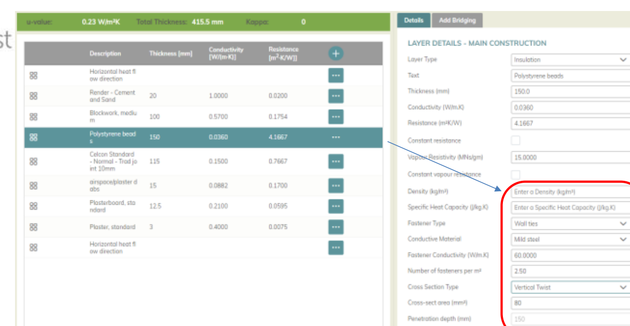
183

Wall Ties

- Stainless Steel > Conductivity = **17.0 w/mk**
- Mild Steel > Conductivity = **60.0 w/mk**
- Double Triangle > Cross Section = **12.5mm**
- Vertical Twist > Cross Section = **80.0mm**



184



- U Value without wall ties = 0.19 W/m2k
- If a different type of tie is used the data can be entered manually.

185

Group Workshop 2

186

Group Workshop 2 – Air Gap

- From the example u value we created this morning adjust the following within the insulation layer.
- Initial value 0.27 W/m2k
  - Air gap correction level 0 = ??
  - Air gap correction level 1 = ??
  - Air gap correction level 2 = ??

187

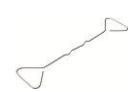
Group Workshop 2 – Air Gap

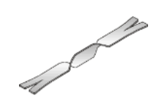
- From the example u value we created this morning adjust the following within the insulation layer.
- Initial value 0.27 W/m2k
  - Air gap correction level 0 = 0.27
  - Air gap correction level 1 = 0.27
  - Air gap correction level 2 = 0.29
  - Why no change in the first 2?

188

Group Workshop 2 – Wall Ties

- Add Stainless steel, double triangle wall ties running through the insulation. Note the change in u-value.
- Add Mild steel, vertical twist wall ties running through the insulation. Note the change in u-value.





189

The effect of wall ties

- Using the same cavity wall as before;
  - None or plastic ties – u value ?? w/m²k
  - Stainless steel, double triangle ties – u value ?? w/m²k
  - Mild steel, vertical twist ties – u value ?? w/m²k

190

The effect of wall ties

- Using the same cavity wall as before;
  - None or plastic ties – u value 0.27 w/m²k
  - Stainless steel, double triangle ties – u value 0.27 w/m²k
  - Mild steel, vertical twist ties – u value 0.33 w/m²k

191

ADDITIONAL ROOF SCENARIOS

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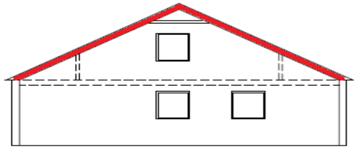
192

Pitched roof, flat ceiling, insulated at rafter level

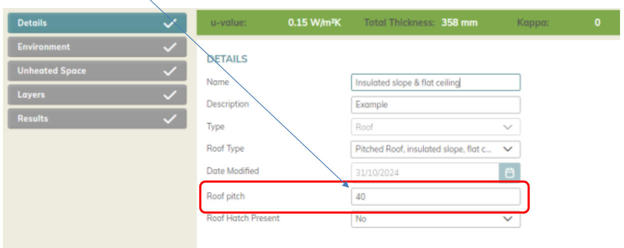
- This is where insulation runs up the rafters to roof ridge, but there is a flat ceiling below.
- The construction is broken into two parts – the pitched roof and horizontal ceiling.



193

Pitched roof, flat ceiling, insulated at rafter level

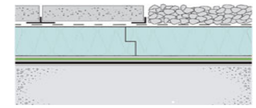
- The roof pitch is set within the u value details tab.



194

Inverted Flat Roofs

- In this type of flat roof the insulation is above the roof structure and the waterproofing.



- This results in the waterproofing, deck and support structure being a similar temperature to the dwelling.
- However this can also result in additional heat loss as rainwater can flow beneath the insulation boards and remove heat directly from the building fabric – rainwater cooling.
- Generally only used in roofs with concrete structures due to the weight loading that becomes necessary to restrain the insulation against wind uplift and flotation.

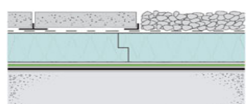
195

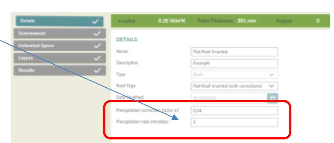
Inverted Flat Roofs

- A correction is applied to take into account the rainwater cooling effect.
- Data required includes;
  - **Average rate of precipitation during heating season in mm/day (*p*)**
  - Drainage factor (*f*) - fraction of rain reaching the waterproofing membrane.
  - Factor for increase heat loss – (x)

– For a single layer of insulation above the membrane, with butt joints and open covering such as gravel, *f x = 0,04*

– *Seasonal precipitation rates can be found on the UK Met Office Website*





196

Please complete Individual Workshop 3

199

FLOOR U VALUES

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200

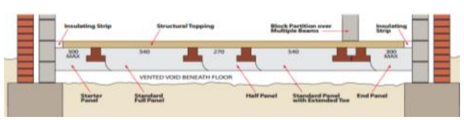
Floor U-values

- Heat loss through a floor has an extra consideration – the effect of the ground.
- Floor U-values are calculated in accordance with BS EN ISO 13370.

201

Floor U-values

- Heat transfer through a floor varies, being greatest at the edge of the floor.
- BS EN ISO 13370 calculates a U-value that is representative of the floor as a whole.
- It is possible for very large floors to have low U-values without insulation.



202

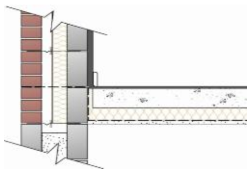
Floor U-values

- U-values for floors are based on the exposed perimeter and the floor area – P/A ratio.
- The exposed perimeter should include all walls to unheated spaces, including walls to unheated garages, corridors etc.
- Floor types include; slab on ground floor, suspended floors and exposed floors.

203

Slab on ground floor

- This is where the floor construction is in contact with the ground over its whole area.
- The calculation is based on insulation covering the entire area, where only edge insulation is provided or a combination of both.
- Dense floor slabs (>1800 kg/m^3) and floor coverings can be disregarded from the calculations.



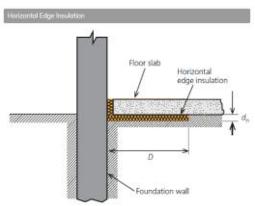
204

Edge Insulation

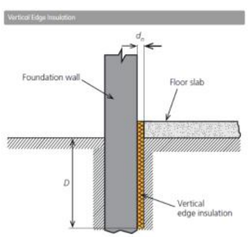
- The effect of edge insulation is applied as a correction factor to the U-value.
- The thickness and thermal conductivity is required in order to calculate this.
- Low density, AAC foundation blocks can be classed as vertical edge insulation.
- BR443 recommends a conductivity of 0.25 w/m.k for AAC foundation blocks.

205

Edge Insulation Types



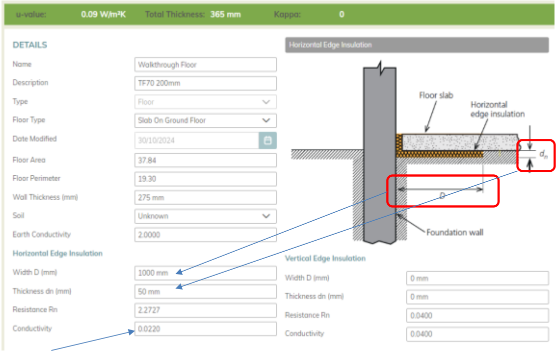
Horizontal Edge Insulation



Vertical Edge Insulation

206

Edge Insulation Types



Conductivity of the edge insulation @ 0.0220

207

Thermal Properties of the ground

- The resistance of the ground is based on soil type, with ISO 13370 providing the following;

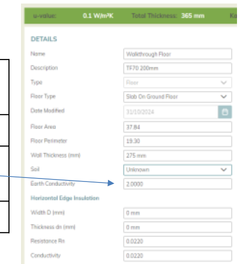
Description	Thermal Conductivity (w/m·k)
Clay or silt	1.5
Sand or gravel	2.0
Homogeneous rock	3.5

208

Thermal Properties of the ground

- The resistance of the ground is based on soil type.

Description	Thermal Conductivity (w/m·k)
Clay or silt	1.5
Sand or gravel & Unknown	2.0
Homogeneous rock	3.5



209

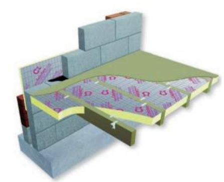
Suspended floors

- Suspended floors have ventilated floor voids below the construction.
- The U-value calculation includes the heat loss through the construction, the heat transfer from the void to the exterior via the walls, and the ventilation of the void space.
- The ventilation rate of the void is calculated from;
  - the mean wind speed, taken as 5 m/s in the absence of specific information
  - the wind shielding factor, values taken from BS EN ISO 13370 for sheltered, average and exposed locations.
  - the area of ventilation openings around the exposed perimeter. 0.0015 m^2/m for one air brick per 2 metres is the minimum allowable for building regulations.

210

Suspended Floors

- The following data is required by ISO 13370;
  - Exposed perimeter (m)
  - Floor area (m^2)
  - Wall thickness (mm)
  - Soil type
  - Floor height above ground level (m)
  - U-value of walls above ground level
  - U-value of walls below ground level
  - Depth of underfloor space (void) below ground level (m)



211

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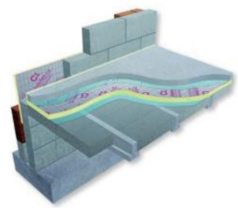
Suspended Beam and Block

- Block-work is entered, with bridging provided by the concrete beams.
- For floors with polystyrene between the beams, use instead of blockwork.
- For floors with precast concrete planks, the material between the planks is treated as a bridged layer.



212

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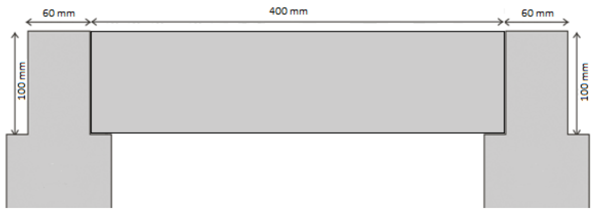
Suspended Beam and Block

- Concrete Bridging (Conductivity = 2.30 w/m.k)
  - Width of bridge – 60 mm
  - Horizontal distance between centres – 460 mm
  - Vertical distance between centres – 0 mm



213

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Suspended Beam and Block

Reinforced Concrete Bridging (Conductivity = 2.30 w/m.k – BR443 Default)

214

Please complete Individual Workshops 4+5

215

BASEMENTS

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216

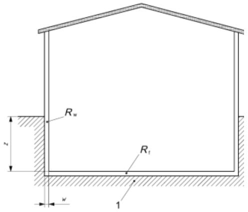
Basements

- The procedure for calculating basement wall and floor u-values is described in BS EN IS0 13370.
- Compared to a ‘normal’ u-value, extra data is required to calculate the sheltering effect of the ground.

217

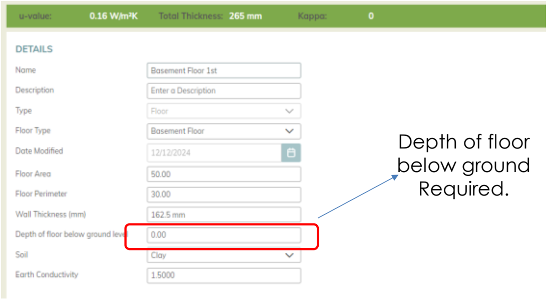
Basement Floors

- Create Floor u value.
- Data required includes;
  - Area and Perimeter
  - Wall thickness (w)
  - Depth of floor below ground level (z)
  - Type of soil



218

Basement Floors

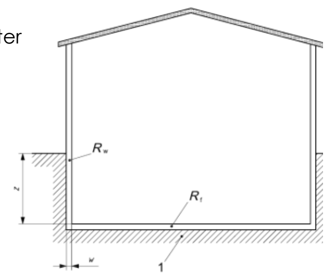


Depth of floor below ground Required.

219

Basement Walls

- Data required includes;
  - Basement floor area and perimeter
  - Depth of basement floor below ground (z)
  - Thickness of walls (w)
  - Type of soil



220

Basement Example

Calculate u-values for the following;

Basement floor;

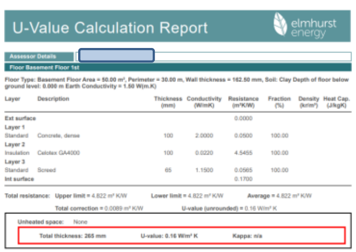
- Area 50 m², perimeter 30 m
- Depth below ground 2.5 m
- Wall thickness – 162.5 mm
- Type of soil – Clay
  - Construction
- 100 mm dense slab
- 100 mm Celotex GA 4000
- 65 mm screed.

Basement wall;

- Construction
- 100 mm dense concrete
- 50 mm polyurethane
- 12.5 mm standard plasterboard.

221

Basement Example



U-Value Calculation Report

Assessor Details

Floor Basement Floor 1st

Floor Type: Basement Floor Area = 50.00 m², Perimeter = 30.00 m, Wall thickness = 162.50 mm, Soil: Clay Depth of floor below ground level: 0.000 m Earth Conductivity = 1.50 W(m.K)

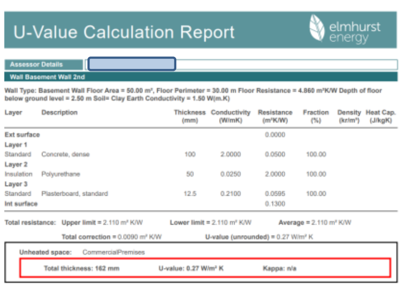
Layer	Description	Thickness (mm)	Conductivity (W/mK)	Resistance (m²K/W)	Fraction (%)	Density (kr/m³)	Heat Cap. (J/kgK)
Ext surface				0.0000			
Layer 1							
Standard	Concrete, dense	100	2.0000	0.0500	100.00		
Layer 2							
Insulation	Celotex GA4000	100	0.0220	4.5455	100.00		
Layer 3							
Standard	Screed	65	1.1500	0.0565	100.00		
Int surface				0.1700			

Total resistance: Upper limit = 4.822 m² K/W Lower limit = 4.822 m² K/W Average = 4.822 m² K/W

Total correction = 0.0089 m² K/W U-value (unrounded) = 0.16 W/m² K

Unheated space: None

Total thickness: 265 mm U-value: 0.16 W/m² K Kappa: n/a



U-Value Calculation Report

Assessor Details

Wall Basement Wall 2nd

Wall Type: Basement Wall Floor Area = 50.00 m², Floor Perimeter = 30.00 m Floor Resistance = 4.860 m²K/W Depth of floor below ground level = 2.50 m Soil= Clay Earth Conductivity = 1.50 W(m.K)

Layer	Description	Thickness (mm)	Conductivity (W/mK)	Resistance (m²K/W)	Fraction (%)	Density (kr/m³)	Heat Cap. (J/kgK)
Ext surface				0.0000			
Layer 1							
Standard	Concrete, dense	100	2.0000	0.0500	100.00		
Layer 2							
Insulation	Polyurethane	50	0.0250	2.0000	100.00		
Layer 3							
Standard	Plasterboard, standard	12.5	0.2100	0.0595	100.00		
Int surface				0.1300			

Total resistance: Upper limit = 2.110 m² K/W Lower limit = 2.110 m² K/W Average = 2.110 m² K/W

Total correction = 0.0090 m² K/W U-value (unrounded) = 0.27 W/m² K

Unheated space: CommercialPremises

Total thickness: 162 mm U-value: 0.27 W/m² K Kappa: n/a

222

KEY CONSIDERATIONS

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223

Key Considerations

- There is a lot to remember in BR 443 !!!!
- This section is to look at the key points to remember for different wall, roof and floor types…

224

Cavity walls

- Key items include;
  - Wall ties – metal or plastic?
  - Air gap correction – insulation bridged or not?
  - Mortar bridging around block work required?
  - Air layer in partial fill walls – ventilated, low emissivity?

225

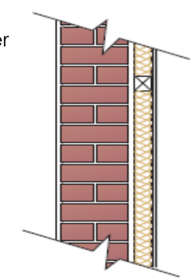
Timber Frame Walls

- Key items include;
  - Timber bridging fraction is crucial.
  - Air gap correction – should be 1 as insulation is bridged.
  - Air layer within or outside of the timber frame – ventilated, low emissivity?

226

Solid Masonry walls

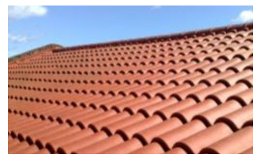
- Key items include;
  - Is insulation bonded to wall or within a timber frame? If within a frame bridging fraction crucial.
  - Air gap correction – could be 0 or 1 if insulation is either bonded or within a stud frame.
  - Air layer behind insulation – ventilated, low emissivity?



227

External Roofs

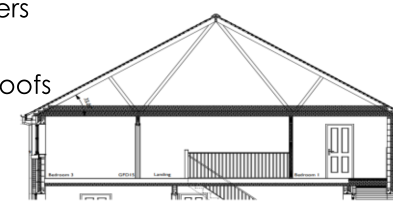
- Pitched roofs come in three forms;
  - Insulated at ceiling joist level
  - Insulated at rafter level
  - A flat ceiling, but insulation runs up rafters above.
- Flat roofs also come in three varieties;
  - Warm flat roof
  - Cold flat roof
  - Inverted flat roof



228

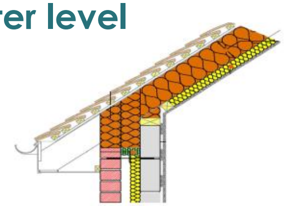
Pitched roof, insulated at joist level

- Key items include;
- One layer of insulation will be bridged by timber joists.
- Air gap correction – layers should be 1.
- Remember to add the roofs pace layer.



229

Pitched roof, insulated at rafter level

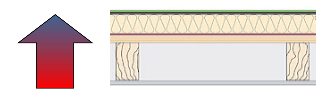


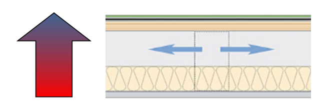
- Key items include;
  - Timber bridging fraction is crucial.
  - Air gap correction – insulation between rafters should be 1, above/below rafters could be 0.
  - Air layer within or outside of the rafters – ventilated, low emissivity?

230

Flat roofs

- Key items include;
  - Is the roof a warm, cold or inverted flat roof?
  - Air gap correction – insulation between joists should be 1, above/below joists could be 0.
  - Inverted flat roofs – is precipitation data representative of the location?

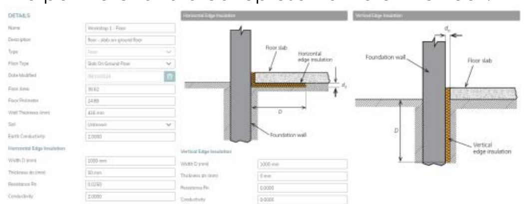




231

Ground Floors - Slab on ground

- Key items include;
  - Is there edge insulation?
  - Is the perimeter and area representative of the floor?



232

Suspended floors

- Key items include;
  - Has the void dimensions been entered correctly?
  - Beam and block, timber joists – bridging fraction crucial.
  - Is the perimeter and area representative of the floor?

233

NEXT STEPS & FINAL QUESTIONS?

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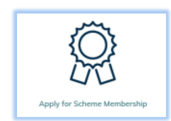
234

What's next ?

- Joining the Scheme ?
  - As part of todays course the cost of application to join the scheme is included, this covers the first year and also the submission and marking of your test cases.



  - Those of you with training 'x' account numbers will have a 4-week access to the software, after which you will need to apply for a seperate licence.

235

What's next ?

- Joining the Scheme ?
  - Once applied - We will issue you with the 10 u value specifications and these will need returning to us for evaluation.
  - Once complete and passed we will place your details on the scheme register.
  - Yearly renewals will be offered at **£195.00 plus vat** and will require the completion of additional test cases.

236

Clocks ticking though!!

- Test cases **MUST** be submitted within a 6 month time scale.
- After 6 months an extension may be allowed but we will charge an additional £250.00+vat for a further 3 month time period
- After 9 months we may allow one extra extension at the same rate of £250.00+vat.
- Maximum total will be 12 months from the course, after which we will ask that you re-sit the course before submitting.

237

238

239

240

Feedback Forms

Please complete our feedback form by using the QR link below.

241

242