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Case Study: Energy Survey

ENERGY EFFICIENCY IN BUILDINGS (ACBA5011)

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Abbreviations

I.	University of Wales Trinity Saint David: UWTSD
II.	Sick Building Syndrome: SBS
III.	Carbon Dioxide: CO₂
IV.	Health & Safety Executive: HSE
V.	United Kingdom: UK
VI.	Limited Company: LTD
VII.	North East: NE
VIII.	South East: SE
IX.	South West: SW
X.	North West: NW
XI.	Accredited Construction Detail: ACD
XII.	Standard Assessment Procedure: SAP
XIII.	Computer-aided Design: CAD
XIV.	British Standard: BS
XV.	Construction (Design & Management): CDM
XVI.	Personal Protective Equipment: PPE
XVII.	Damp Proof Membrane: DPM
XVIII.	Damp Proof Course: DPC
XIX.	Target Emission Rate: TER
XX.	Heating, Ventilation & Air Conditioning: HVAC
XXI.	Building Research Establishment: BRE
XXII.	Construction Industry Training Board: CITB
XXIII.	Building Research Establishment Environmental Assessment Method: BREEAM



1.0 Introduction

This report provides a record of the internal and external condition of the building at UWTSD's Business Campus, High Street, Swansea, City & County of Swansea, SA11NE. The survey was undertaken by Adam Meyrick and assistant surveyor Lewis Williams of University of Wales Trinity Saint David on Tuesday 30th October 2018.

1.0.1 Aims & Objectives

The purpose of this report is to provide information of any cold bridges, and the state of any aspects of the property that are likely to be affected by the proposed refurbishment work. This research is important because of the economic, environmental, health, and structural impacts associated with cold bridging.

"Increasing energy efficiency not only allows individuals and organizations to reduce their capital and operational costs, it can also help lower fuel consumption and so reduce the emission of greenhouse gases and help prevent climate change." (Energy Efficiency of Buildings, 2018)

1.0.2 Rationale

Cold bridging is a massive problem facing the construction industry today. *"Thermal bridges occur where the insulation layer within the building envelope is penetrated by a material with a relatively high thermal conductivity, and at interfaces between building elements where there is a discontinuity in the insulation (Way, 2016).*

Thermal bridges are generally referred to as either 'repeating' or 'non-repeating'. Repeating thermal bridges, such as wall ties do not need to be considered as thermal bridges if they are properly accounted for in heat loss calculations. Non-repeating cold bridges are the most important defect however, they typically occur at junctions between building elements.

Thermal bridges result in:

- Heat losses, meaning more energy is required to preserve the internal temperature of the building.
- Lower internal surface temperatures around the thermal bridge which can cause condensation that may lead to mould growth and consequently SBS.

SBS is commonly used to describe *"A situation in which the occupants of a building experience acute health - or comfort-related effects that seem to be linked directly to the time spent in the building." (HSE, 2017)*

The thermal performance of an element is articulated as a U-value. The assistant surveyor's role is to calculate the U-values from the existing elements and to compare them to the proposed cold bridging solutions offered by the main surveyor. The lower the U-value corresponds to higher levels of thermal insulation.

To satisfy Building Control in the UK, it is necessary to demonstrate compliance with the Building Regulations. The resultant value should then suffice **Part L of the Building Regulations (Conservation of fuel and power)** which addresses energy efficiency



requirements in buildings in England and Wales. Approved Document L2A provides guidance on buildings other than dwellings.

It is a certainty that the structure being assessed for refurbished will have cold bridging non-conformities due to its construction method and material composition appropriate to the time of construction. The surveyors should therefore offer solutions to be implemented during refurbishment.

1.1 Methodology

1.1.1 Case Study

There is to be significant refurbishment undertaken by Kier Construction LTD in the summer of 2021. Therefore, the following steps must be undertaken to ensure that all the building aspects are investigated appropriately to determine where thermal bridging is currently and whether it is within acceptable limits. This information will be pivotal to understanding what corrections should be implemented.

1.1.2 Characteristics of Construction

It can be assumed that this structure is steel framed. This assumption can be supported by the case study found on **Appendix A.1** which is a similar building that has age, materials, location and previous building function in collectiveness.

The structure is currently an educational facility and therefore sees peak usage during week days and term times. The normal opening hours for the school are 8am – 8pm and the term times for the 2018 – 2019 academic year are as follows:

- **Semester 1:** 24th September 2018 – 14th December 2018 (12 weeks)
- **Semester 2:** 7th January 2019 - 5th April 2019 (13 Weeks)
- **Semester 3:** 29th April 2019 - 12th July 2019 (11 Weeks)

It is during these time constraints that maximum energy is consumed. This is also the peak time where heat energy is lost through cold bridges and the most prevalent time that condensation and dampness occur. Where as the warm, moist internal air encounters the potentially cold surface.

1.1.3 Identification of Construction Method

This survey process was limited to a non-intrusive, visual appraisal of the elements under review that were readily accessible at the time. Scientific tests were not carried out to assess performance of components. Off-limits areas were not surveyed as well as areas which would have necessitated the use of special tools which would cause damage to fixtures and fittings and therefore are unable to report that such areas remain free from defects.

It is important to comprehend the construction method of the structure as this will dictate the constructor's approach to the refurbishment works. To learn the construction method three activities will be undertaken; a visual inspection, thermal imaging assessment and interviews.



Visual Inspection

Firstly, to identify the construction method a visual examination was undertaken by the surveyor. During this inspection the following characteristics were highlighted;

- Steel beam method identified,
- Block internal leaf,
- Suspended concrete block and beam floors,
- Beam condition excellent,
- New energy efficient windows,
- Fire safety conformity (sprinklers, extinguishers, doors and signage)
- 1.3m wall thickness,
- Aluminium sandwich facade panels.

Ventilation and heating systems were the identified to comprehend the air flow and convection currents within the environment. Evidence of moisture build up was sought after which would indicate cold bridging, but none were surveyed visually present.

Thermal Imaging Study

To further dimension the identification of the construction method, thermal images were taken by the surveyor to identify existing cold bridges. A thermal imaging survey of building fabric identifies where air leaks in or out of buildings and shows thermal insulation defects. Benefits of this thermographic survey include:

- Quick and non-disruptive testing,
- Results are clearly shown in pictures,
- Visually show compliance with specifications,
- Help to obtain sustainability assessment credits such as BREEAM,
- Help resolve disagreements with sub-contractors as to where faults lie,
- Can be used to show the effectiveness of HVAC installations.

The images were taken at 13:24pm on the 30th of October 2018 where at this time the sun would be low altitude of 22° with a SE sun rise and SW sun set of 07:05 and 16:52 respectively (**see Figure 1.1**).

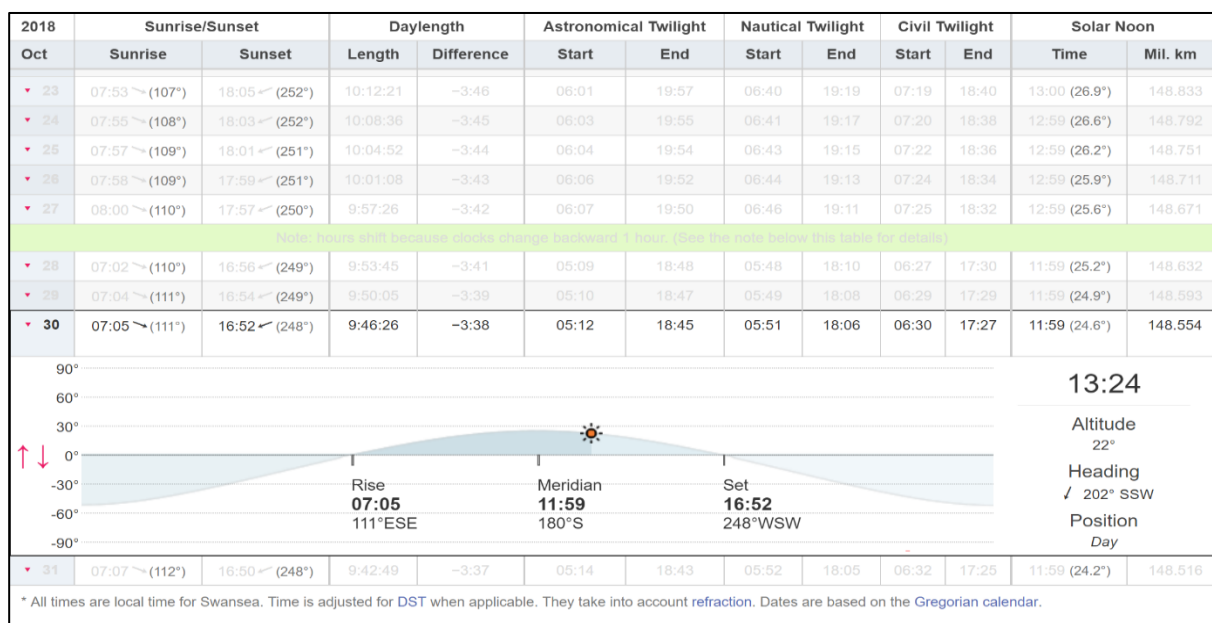


Figure 1.1: 30th October 2018 sun graph of Swansea (**Sun Graph for Swansea, 2018**).



The thermal images found on **Appendix A.2** were abstracted from room AS2K1 and clearly show an area just above the window where a cold surface has been made apparent. This dilapidation is recorded and amended with the relevant construction details on **Detail 6**. The orientation of room AS2K1 is NE, where at the time of surveyance the room remains shaded with minimum thermal gains. This facade has little potential to therefore harness solar gains.

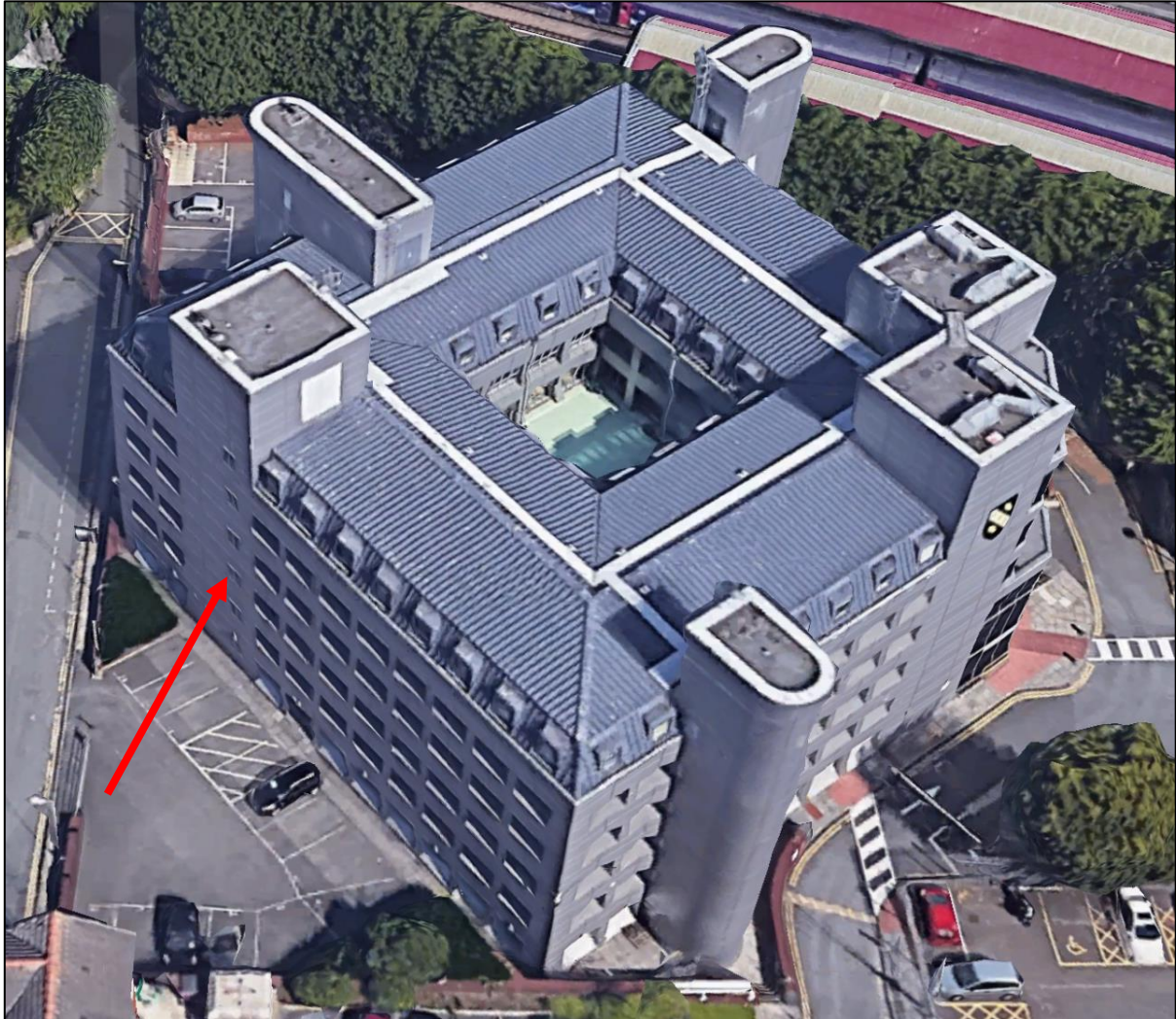


Figure 1.2: Location of room AS2K1 which is NE in orientation (*Google Maps, 2019*)

It is important that solar orientation is considered early during the refurbishments design stage. The designing software package “SketchUp” has built-in shading software that calculates building shade automatically given the structures orientation in the model. Alternatively, **Gaisma** can be consulted to generate a sun path diagram (solar chart) for the anticipated building plot.

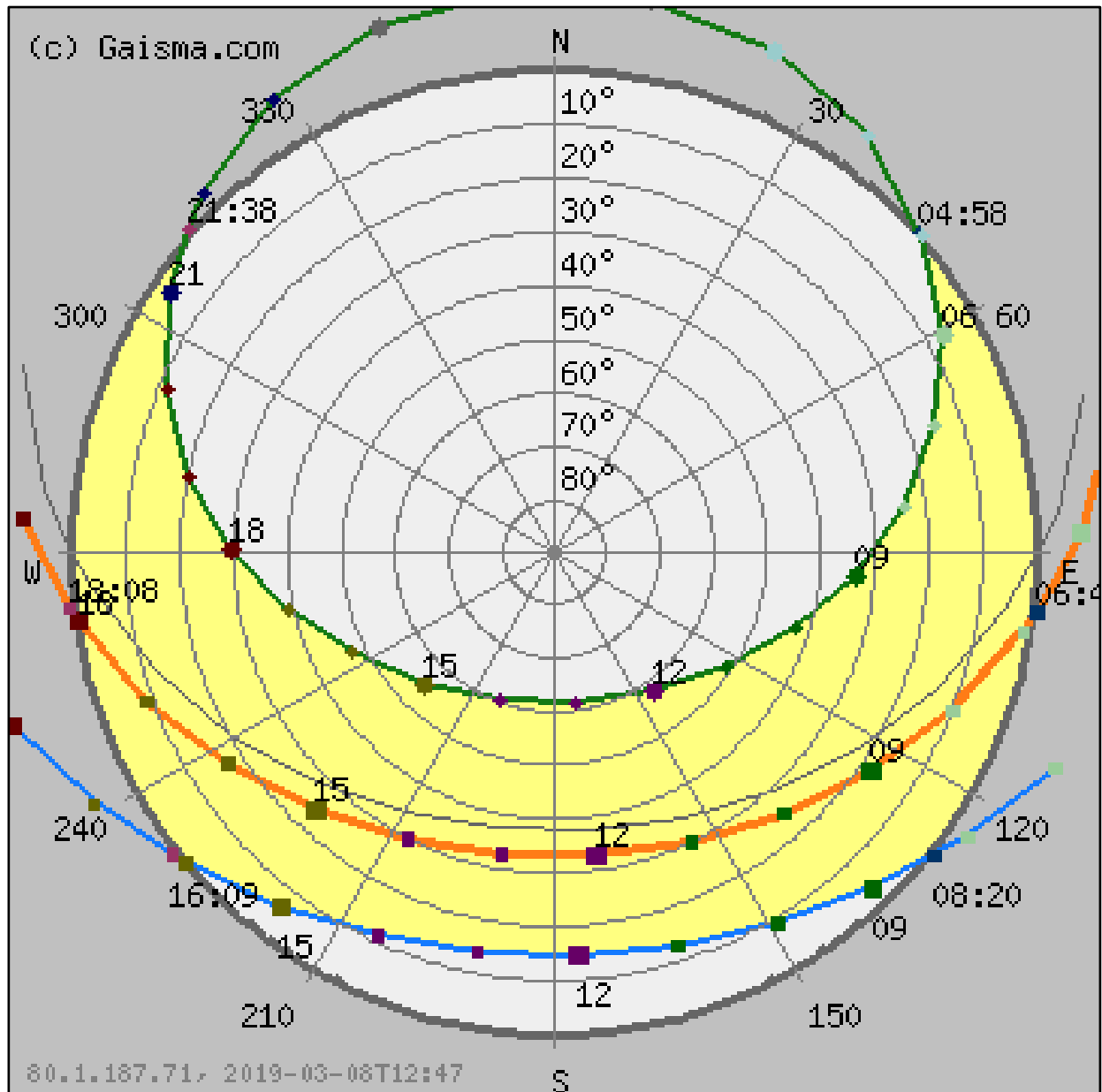


Figure 1.3: Sun path diagram for Swansea, UK. It shows the sun's path, where it rises and its angle of elevation all year around. (Gaisma, 2019)

It can be concluded from the sun path diagram that the SE and SW facing facades have great potential to exploit solar gains through the external wall and window sections. These sections can therefore be redesigned in such a way that the structure benefits with lower energy costs. This innovative element is known as adaptive façade technology.

Interview Techniques

The best qualified person to discuss cold bridging and the external wall configuration of the structure is Cenwyn Jones, the schools head of maintenance. Cenwyn oversees the building maintenance and general upkeep as well as having over 30 years' experience in his profession. The head of maintenance also has unrestricted access to construction details and other relevant documentation. This interview can be found on **Appendix A.3**. The purpose employing the interview technique is to gain primary data to find the following;

- Type of construction,
- Further understanding of the external wall and cladding layers,
- Age of the structure,
- Psi and U-values by gaining information on materials present.



The evidence gained from Cenwyn Jones is extremely useful for the following reasons:

- 1) The time of the cladding implementation is defined meaning construction methods from the time can be used to make detail assumptions. The structure predates the Building Regulations 2010.
- 2) The previous usage of the structure is defined which can assist in assumed the structure to be of a steel frame where the buildings function can be altered.
- 3) It is also known that the external cladding conforms to national standards, this has been confirmed by a recent health & safety report ordered by the Welsh Government in 2017 on the structure.

1.2 Identification of Cold Bridges

Non-repeating cold bridges are often caused by discontinuities in the thermal envelope, for example:

- Geometry, e.g. corners which provide additional heat flow paths.
- Building borders (window sills, jambs and headers),
- Structural borders (floor to wall & wall to roof junctions),
- Penetration of the building envelope (fixings and structural elements),
- Structural support (lintels and cladding supports),
- Poor construction practice (gaps in insulation and debris in wall cavity).



Figure 2.1: **RED** indicates areas susceptible to cold bridging at the UWTSO Business Campus (Meyrick, 2019)

1.2.1 Accredited Construction Details (ACD)

The Accredited Construction Details (ACD's) are a set of standardised junction details developed in 2002 that can be followed to 'design out' thermal bridges in compliance with the energy efficiency requirements (Part L) of the Building Regulations. They are available specifically for steel frame medium-rise buildings.

The surveyor has utilised the ACD's and cross referenced them to what is and what is to be assumed present in the structure. From this, an adapted construction detail has been produced by the surveyor, this is the proposed solution to correcting the cold bringing within the structure.

Psi' (Ψ) values:

The ACD also gives approved 'Psi' (Ψ) values for each cross section from Table K1 of SAP 2012 (**see Appendix A4**). "Psi (Ψ) values are a measure of the linear thermal transmittance of a thermal bridge and have units of W/mK where 'm' is the linear metres of the thermal bridge. To calculate the heat loss through a thermal bridge, then the length of the thermal bridge (m) must be multiplied by its respective Psi value." (**Psi values, Y values and Thermal Bridging, 2018**)

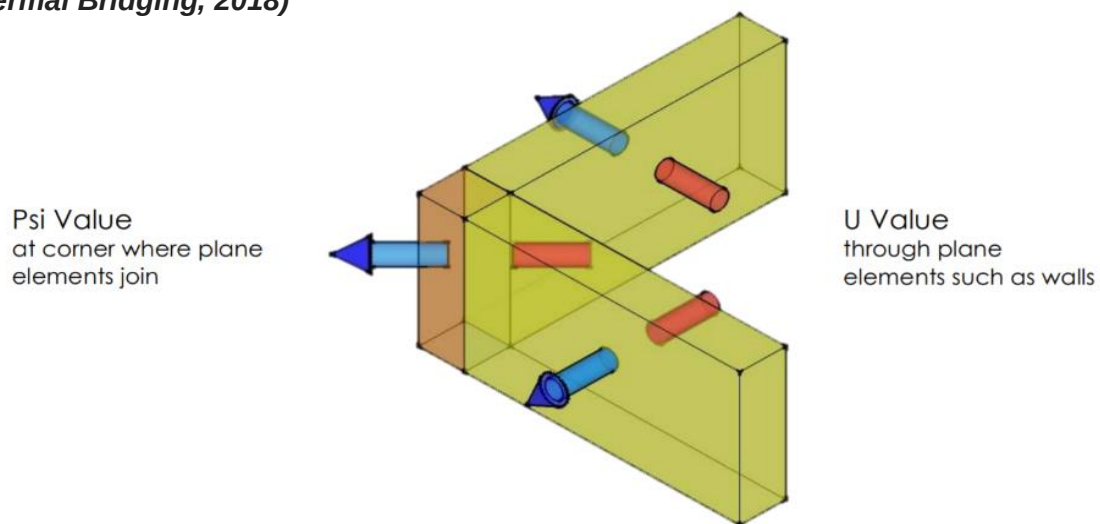


Figure 2.2: Diagram of a corner junction showing the difference between the Psi Value and U-Value (**Thermal Bridge Assessment, 2015**).

The ACD's provide a specific checklist by which can be used by designers, constructors and building control bodies to ensure provision has been made to limit thermal bridges.

1.2.2 Thermal Conductivity & U-Values

Steel has a high thermal conductivity (λ) compared with other construction materials (**see Table 2.3**). This means that both the existing structural steel frame and steel cladding system of the structure, must be sensibly designed to decrease unwanted heat transfer.

Material	Thermal conductivity, λ (W/mK)
Steel	45 to 50
Stainless steel (20% Ni)	15 to 17
In-situ normal weight concrete	1.7 to 2.2
Brickwork	0.6 to 0.8
Gypsum based board	0.16 to 0.22
Plywood	0.12 to 0.15
Mineral wool insulation	0.03 to 0.04
Closed cell insulation	0.02 to 0.03

Figure 2.3: Thermal conductivity of common construction materials (**CIBSE, 2015**).

For instance, composite “sandwich” cladding panels have been developed to guarantee that the steel elements are not cold bridging continuously throughout the cladding system (**see Figure 2.4**).

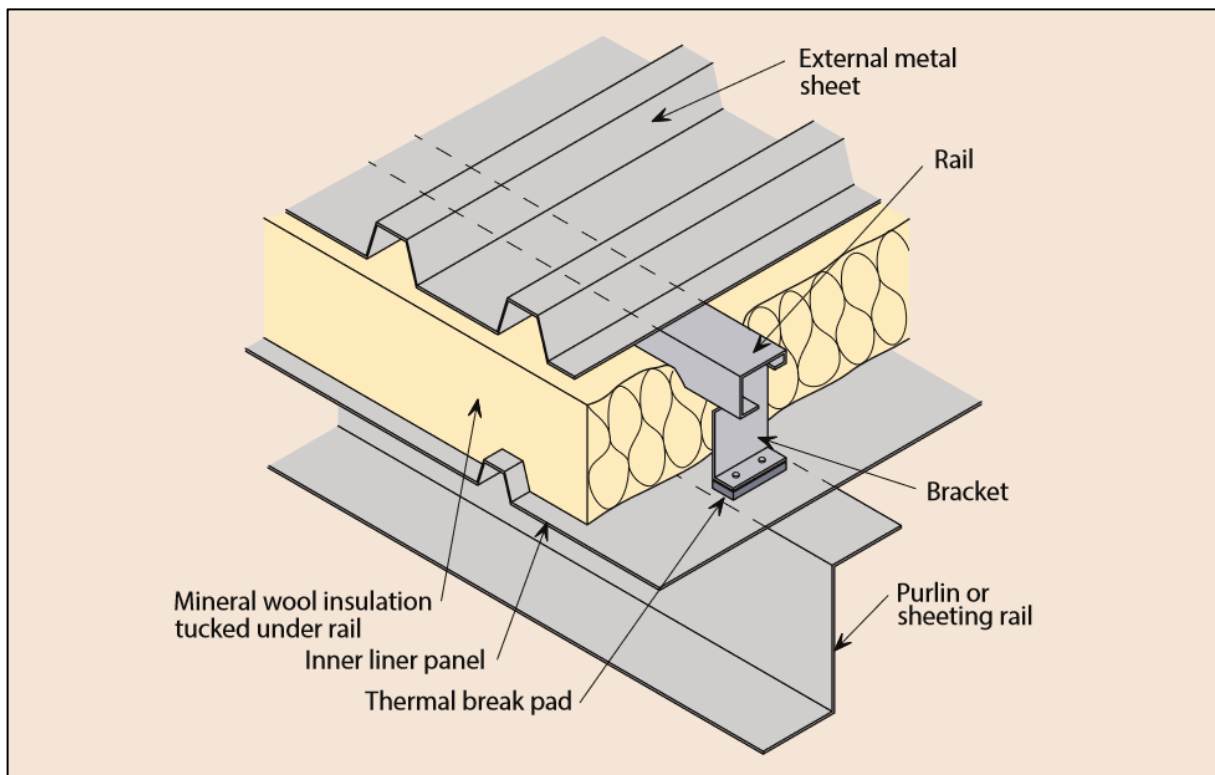


Figure 2.4: Example of a cladding detail to avoid thermal bridges (Way, 2016).

1.2.3 Standard Assessment Procedure (SAP) 2012

The Standard Assessment Procedure (SAP) is adopted by the UK government as the methodology for calculating the energy performance of structures. It is essential to be commenced as part of the refurbishment. The calculation is based on a range of factors that contribute to energy efficiency:

- Materials used,
- Thermal insulation,
- Air leakage & ventilation,
- Efficiency and control of the heating system,
- Solar gains,
- The fuel used to provide space and water heating, ventilation and lighting,
- Renewable energy technologies.

The procedure used for the calculation is based on the BRE framework and is consistent with **BS EN ISO 13790**.

The SAP calculation assesses thermal bridging at junctions between elements and around openings. The heat loss through a thermal bridge is defined by its linear thermal transmittance “ Ψ -value or Psi-value”. Due to a lack information available to the surveyor concerning materials present, structural forms and material thickness **Table K1 found on Appendix A.4** can be consulted for a guideline value.

1.2.4 Condensation

Condensation is an additional undesirable impact of thermal bridging and as well as cold bridges, unavoidable. Low internal surface temperatures at cold bridges can lead to surface condensation if they are below the dew point of the air. *“The dew point is the temperature to which air must be cooled to become saturated with water vapor” (Lallanilla, 2014).*

For non-absorbent surfaces such as steel, condensation can origin a collection of water and can eventually reason rust. For absorbent materials such as insulation or plasterboard, a loss of thermal performance and/or structural integrity and mould growth can be the resultant factors. **BS 5250: 2002 Code of Practice for control of condensation in buildings**, describes the reasons and effects of condensation in buildings and lists recommendations for their control which can be useful to the surveyors for applying remedies for the cold bridging.

An indicator of condensation risk is provided by the temperature factor ' f_{CRsi} '. Minimum recommended values of f_{CRsi} are presented in **Table 2.5**. ****RED highlights what f_{CRsi} value the UWTSD refurbishment must conform toward****

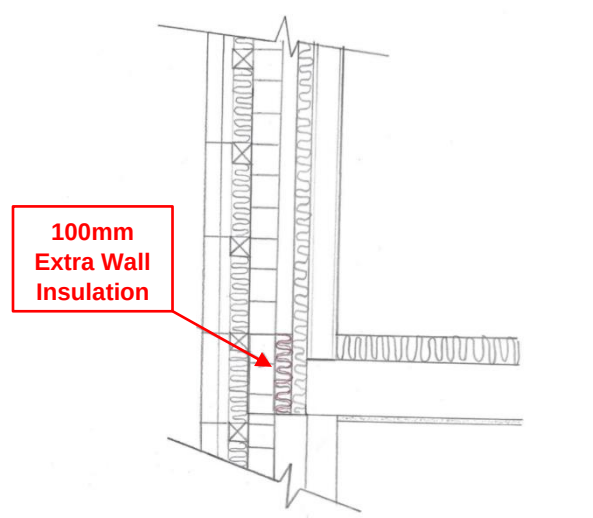
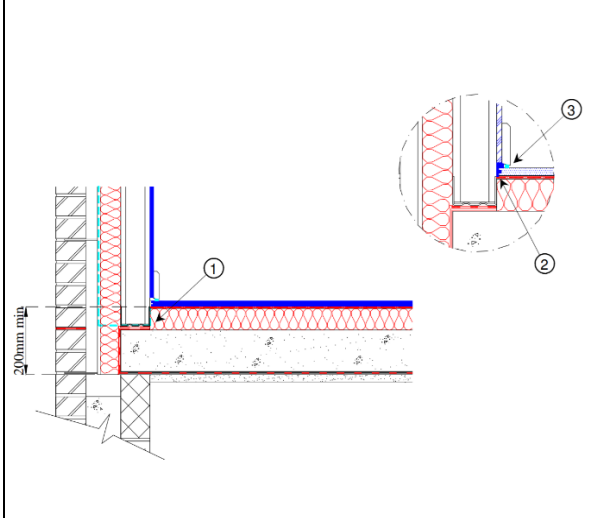
Type of building	f_{CRsi}
Storage buildings	0.30
Offices, retail premises	0.50
Dwellings, residential buildings, schools	0.75
Sports halls, kitchens, canteens	0.80
Swimming pools, laundries, breweries	0.90

Figure 2.5: Recommended f_{CRsi} values (Ward, 2006)

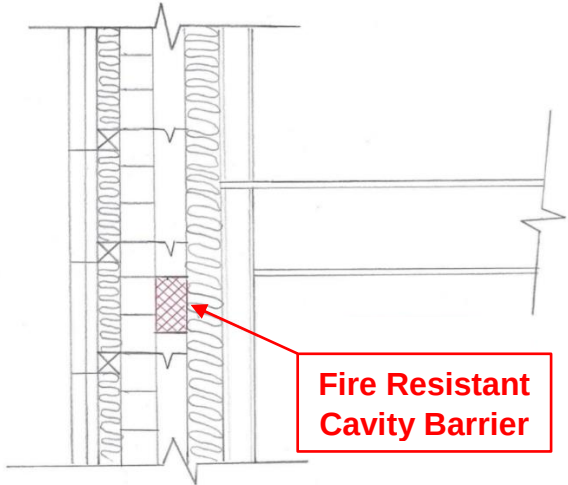
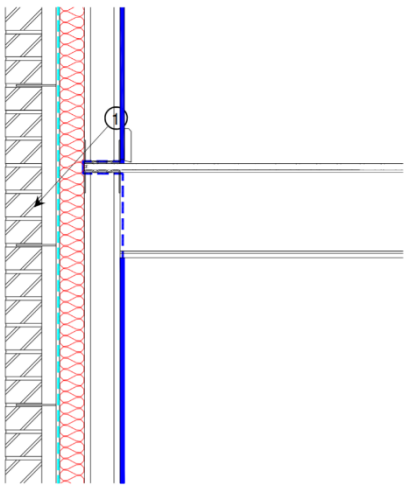
1.3 Results

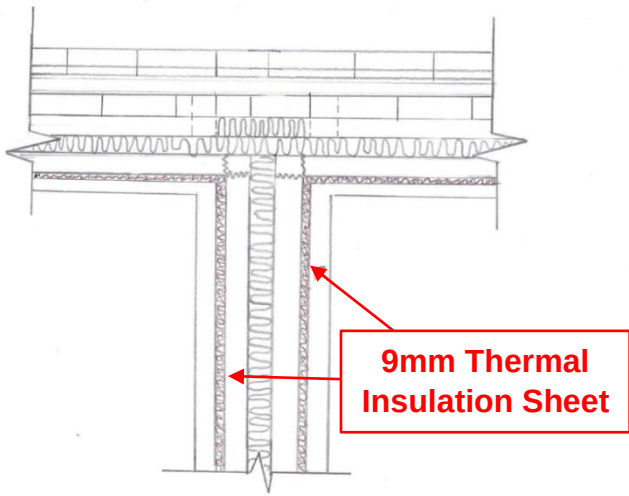
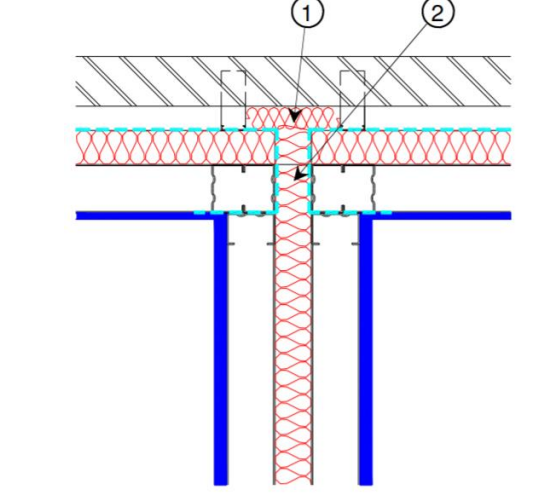
Resultantly from the surveyor's investigations, evidence has been obtained that will result in corrections having to be made to the external wall and window sections during upcoming refurbishment works. Using the template found on **Appendix A.5**, each cold bridging section has been assessed and corrected.



Detail 1: SFW – GF – 01 Ground Bearing Floor	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (See appendix A.4) lists that the Ψ -value for this junction should be 0.32. $\Psi = 0.32$.
Thermal Performance Checklist	Assumptions
▪ Ensure wall insulation is installed at least 200mm below the top of floor insulation. ▪ Floor insulation must tightly abut the inner face of steel frame. (1) ▪ If screed is used, then the floor insulation must have a minimum R-value of $0.75\text{m}^2\text{K/W}$. ▪ Must comply with Table K1 of SAP 2012 (See appendix A.4)	▪ Inevitable cold bridges where cavity ties are installed. ▪ Inevitable cold bridging formed between frame and concrete slab. ▪ Cold bridging between frame and slab is not within acceptable limits in accordance to SAP 2012.
Recommendations	
This linear thermal bridge can be reduced by increasing the distance the heat has to travel, by overlapping the partial-fill cavity-wall insulation and the floor insulation. DPM should be removed and replaced and an increase in wall insulation thickness is required for conformity. 200mm of 100mm thick insulation should be installed across the perimeter of the structure to lessen cold bridging between the frame and floor slabs. DPM: Visqueen EcoMembrane®. Compliance: BS EN 13967. Wall insulation: 1200mm x 2400mm x 100mm Celotex GA4000 Insulation Board. Compliance: BS EN 13165. From the assistant surveyors U-value calculations the existing resistance does not meet the minimum requirement of $0.18\text{ W/m}^2\text{K}$ (see Appendix A.6 for the full equation).	
U-Value Before: $0.399\text{W/m}^2\text{K}$	U-Value After: $0.108\text{W/m}^2\text{K}$



Detail 2: SFW – IF – 01 Lightweight Intermediate Floor	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (<i>See appendix A.4</i>) lists that the Ψ-value for this junction should be 0.14. $\Psi = 0.14$.
Thermal Performance Checklist	Assumptions
▪ Continue wall insulation across the floor abutment zone. ▪ Must comply with Table K1 of SAP 2012 (<i>See appendix A.4</i>)	▪ There is no fire resisting cavity barrier. ▪ Complies with Table K1 of SAP 2012 (<i>See appendix A.4</i>)
Recommendations	
Fire resisting cavity barriers must be implemented within the cavity where possible. Cavity barriers are used to close concealed spaces and prevent penetration of smoke or flame to restrict the movement of fire within a building. According to both BS EN 9991 and Approved Document B2, cavity barriers are required to have 30 minimum integrity and 15 minimum insulation. In addition, BS EN 9999 requires that non-domestic cavities should have cavity barriers installed. Cavity Barrier: Rockwool PWCB Cavity Barrier 1.2m x 100mm x 200mm. Compliance: BS 476. Further investigation is required when refurbishing suspended floor space. Some non-regulatory factors than might be advisory for improvement may include: ▪ Thermal mass properties of the external layers and concrete floor slab, ▪ Acoustic non conformity, ▪ Suspended floor implementation required for changed building use. See Appendix A.7 for an example thermal model for this section.	

Detail 3: SFW – IW – 01 Separating Wall/External Wall Abutment	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (<i>See appendix A.4</i>) lists that the Ψ -value for this junction should be 0.15. $\Psi = 0.15$.
Thermal Performance Checklist	Assumptions
- Continue external wall insulation across the abutment zone. (1) - Ensure continuity of insulation between the separating wall and external wall construction. (2) - Must comply with Table K1 of SAP 2012 (<i>See appendix A.4</i>)	Insulation where separating wall and external wall meet does not conform to Table K1 of SAP 2012.
Recommendations	

To increase the thermal properties of the section, an additional layer of thermal insulation sheet on each side of the wall can be applied to deliver conformity.

Insulation Sheet: Superwool 607 Paper Thermal Insulation Sheet, 1.2m x 610mm x 9mm
Compliance: [BS EN 61340](#).

Insulated plasterboard: Knauf XPS Thermal Insulated Laminate Plus Tapered Edge Plasterboard 2400mm x 1200mm x 35mm.

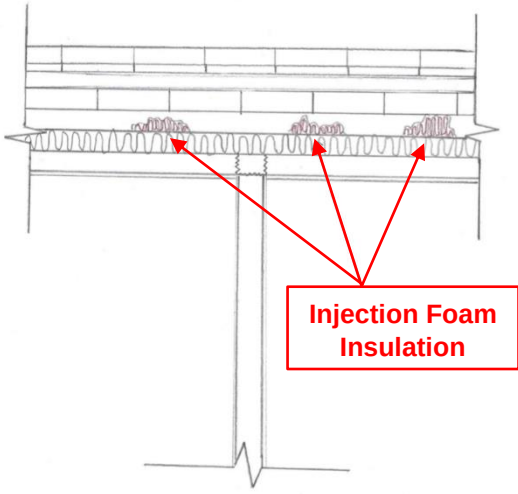
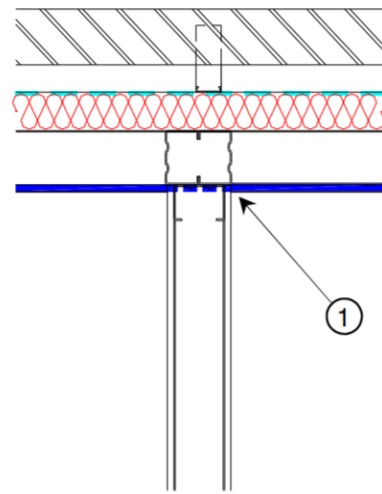
Construction Method:

- 1) Ensure all risk assessments have been undertaken and other documentation under [CDM 2015](#) and that qualified personnel are to carry out work using appropriate PPE.
- 2) Existing plasterboard must be removed.
- 3) Apply Superwool Thermal Insulation sheeting around the perimeter of the internal wall using staples and alumaflex tape.
- 4) New insulated plasterboards can then be re-applied using dot n' dab techniques. Considerable assessment must be undertaken to negotiate electrical and plumbing services present.
- 5) Finishes such as skirting boards and plaster can then be applied.

From the assistant surveyors U-value calculations the existing resistance is does not meet the minimum thermal transmittance (see **Appendix A.6** for the full equation on how this change has corrected the problem).

U-Value Before: $0.389\text{W/m}^2\text{K}$

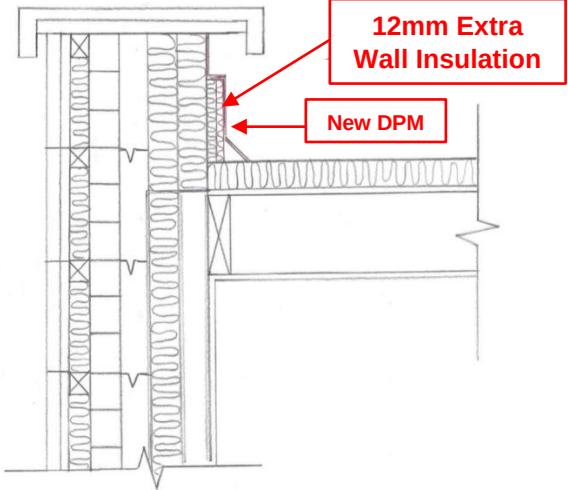
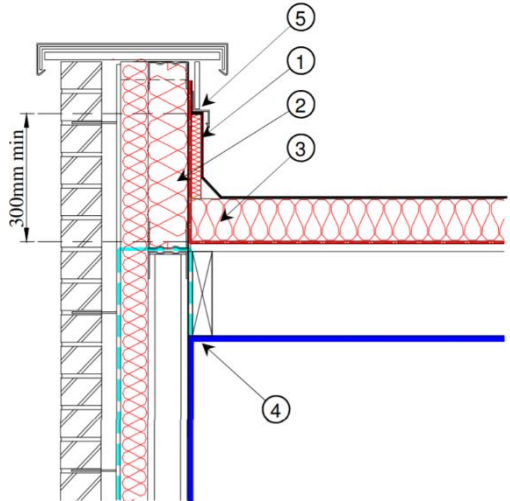
U-Value After: $0.224\text{W/m}^2\text{K}$

Detail 4: SFW – IW – 03 Metal Stud Partition Wall / External Wall Abutment	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (See appendix A.4) lists that the Ψ-value for this junction should be 0.7. Ψ = 0.7.
Thermal Performance Checklist	Assumptions



▪ Continue wall insulation across the abutment zone. (1) ▪ Must comply with Table K1 of SAP 2012 (See appendix A.4)	▪ Wall insulation does not continue across the abutment zone and therefore does not comply with Table K1 of SAP 2012 (see Appendix A.8).
Recommendations	
All other locations where this detail exists should undergo further investigation to search for the same dilapidation. In areas of non-conformity injection foam technology can be employed to fill the cavity where gaps exist in the insulation.	
Injection Foam: Icynene®, is an environmentally friendly spray foam insulation that insulates and prevents air leakages when implemented within structures. Compliance: BS EN 5250.	
Benefits of using expanding foam insulation include:	
1) Provides U-value insulation and air sealing, 2) Reduces air pollution and protects against mould growth, 3) Reduces drafts and noise, 4) Enhances structural integrity.	
Construction Method:	
1) Ensure all risk assessments have been undertaken and that qualified personnel are to carry out work using appropriate PPE. 2) Existing insulation and plasterboard must be removed, taking care so they can be reapplied. 3) The qualified person(s) is to drill holes Ø20mm at bottom of the delapidated block walls using hammer drills with carbide-tipped masonry bits. 4) Expanding foam is to be injected from the bottom of the wall to ensure that no air gaps are produced, and no areas left uninsulated. 5) Once foam has cured thermal imaging assessments can be undertaken to assess the effectiveness of the works. 6) If found effective, the holes can be suitably plugged using concrete plugs and more expanding foam. 7) The existing plasterboard can then be introduced back onto the wall where suitable, alternatively new sheets must be applied using dot n' dab techniques. 8) Perform further tests to ensure the dilapidation has been remediated. 9) Finishes such as skirting boards and plaster can then be applied if the treatment is successful.	



Detail 5: SFW – RF – 02 Flat Roof with Parapet	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (See appendix A.4) lists that the Ψ-value for this junction should be 0.30. Ψ = 0.30.
Thermal Performance Checklist	Assumptions
- Insulation upstand must have a minimum R-value of $0.75\text{m}^2\text{K/W}$. (1) - Maintain minimum distance of 300mm between top of the insulation upstand and bottom of horizontal insulation. - Install compressible insulant between the wall studs above the level of roof deck. (2) - Ensure that the roof insulation tightly abuts the inner face of the parapet wall. (3) - Must comply with Table K1 of SAP 2012 (See appendix A.4)	- Insulation upstand does not meet the minimum R-value of $0.75\text{m}^2\text{K/W}$ criteria. - Insulation between the wall studs and the level of roof deck does not meet minimum R-value of $0.75\text{m}^2\text{K/W}$ criteria.
Recommendations	
The insulation within the upstand can either replaced for insulation with a higher R-value that meets the criteria, or the existing insulation can be upgraded in thickness to meet the conformities. The wall insulation between the wall studs and the level of the roof must also undergo the same upgrades. New DPM over upstand and roof flashings will be required as a result of either of these works. From the assistant surveyors U-value calculations, an increase of 12mm in insulation thickness would surpass the Building Controls minimum criteria. Although it is placed upon the principle designer and the principle contractor to decide which upgrade option to undertake. Wall insulation: 1200mm x 2400mm x 12mm Celotex GA4000 Insulation Board. Compliance: BS EN 13165. DPM: Visqueen EcoMembrane®. Compliance: BS EN 13967.	

Insulation Plugs: IMco MID35 Metal Insulation Disc 35mm.

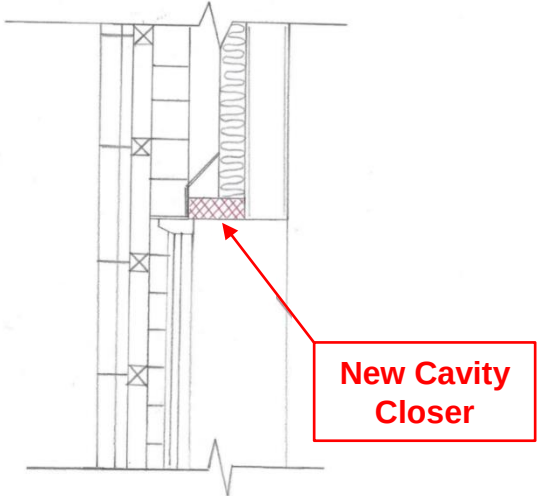
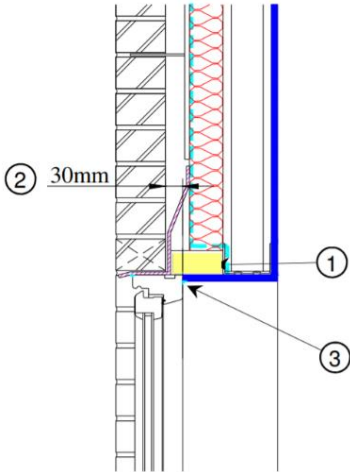
Construction Method:

- 1) Ensure all risk assessments have been undertaken and that qualified personnel are to carry out work using appropriate PPE. If possible, works should be performed on a dry today to ensure the envelope is kept dry.
- 2) DPM and flashings surrounding the upstand must be carefully removed to gain access to the upstand.
- 3) An additional layer of 12mm insulation board must be implemented, being fixed using insulation disc fixings.
- 4) DPM can then be reapplied ensuring overlapping of existing material.
- 5) If applicable flashing can also be re-installed ensuring a 45° angle fillet has been preserved.
- 6) Perform further tests to ensure the dilapidation has been remediated.

From the assistant surveyors U-value calculations the existing resistance is does not meet the minimum thermal transmittance (see **Appendix A.6** for the full equation on how this change has corrected the problem).

U-Value Before: 0.274W/m²K

U-Value After: 0.188W/m²K

Detail 6: SWF – WD- 01 Windows and Doors. Lintels.	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (See appendix A.4) lists that the Ψ-value for this junction should be 1.00. Ψ = 1.00.
Thermal Performance Checklist	Assumptions
▪ The cavity closer should be fitted correctly and have a minimum thermal resistance of 0.45 m²K/W. (1) ▪ The minimum frame overlap must be 30mm. (2) ▪ Ensure a suitable membrane is installed to ensure air continuity. (3)	▪ Cavity closer not fitted correctly and does not meet the minimum thermal resistance of 0.45 m²K/W criteria (see Appendix A.2)



▪ Must comply with Table K1 of SAP 2012 (See appendix A.4)	
---	--

Recommendations

The principle designer has insisted that windows on SW and SE façade elevations should be increased in area to harness maximum solar gains. These adaptive facades also do not require as much insulation due to their orientation.

As a result of these upgrades, larger lintels will be required for the SE and SE elevations. Window sizes remain will remain in NW and NE facades but will need to be temporarily removed as new cavity closers are installed. Cavity closers around the surveyed windows not fitted correctly which has been picked up during the thermal imaging study (**see Appendix A.2**) and therefore does not meet the minimum thermal resistance of 0.45 m²K/W criteria

As a result, cavity closers, DPM and DPM will need to be re-installed correctly. Weep holes can also be implemented as a further barrier against moisture build-up. Further investigation will be pivotal during refurbishment works around the window details, the following can be checked:

- Lintel damage,
- Asbestos,
- Rising damp,
- Wall tie damage.

Heat-loss from junctions around window or door openings can be further reduced by insulating the reveal. Considering the age and construction method of the structure, it would be appropriate to expect the risk of encountering asbestos. Therefore, the **Control of Asbestos Regulations (2012)** protocol must be adhered to. Where qualified personnel will notify the PM on how the works can proceed.

Cavity Closer: Manthorpe G240 uPVC Cavity Closer Double Flange 100mm x 2440mm. Compliance: **BS EN 18001**.

Galvanised Steel Lintel: Catnic CG90/100 3000mm. Compliance: **BS EN 5977**.

DPM: Visqueen EcoMembrane®. Compliance: **BS EN 13967**.

Cavity Tray: Manthorpe Horizontal Cavity Tray 900mm Compliance: **BS 8215**.

Construction Method:

- 1) Under the recommendation of a structural engineer and calculations within the in-house team recommendations will be made on how to perform the works.
- 2) The process will likely involve the careful removal of all existing windows 2/3 at a time. The vacant spaces will then be levitated by Acropop supports.
- 3) **In the SE and SW facades brickwork will need to be removed to remove existing lintels by cutting through mortar to be replaced by larger ones to accommodate larger window frames. DPC should also be reimplemented to overlap the lintel. Weep holes should be preserved.**
- 4) In all window sections, existing defective cavity closers should be removed and replaced with modern ones. Insulation boards within the cavity should also be replaced if found defective during further investigation.
- 5) **In the SE and SW facades, larger window and be implemented. Care should be taken to ensure air tightness of the cavity is preserves after installation.**



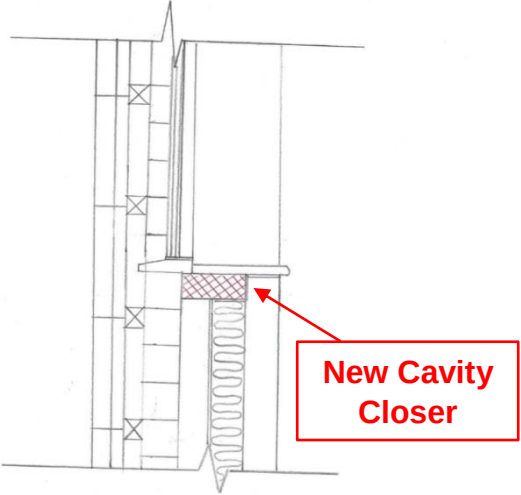
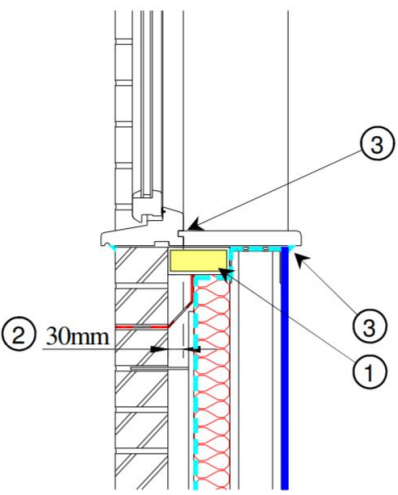
- 6) In the NE and NW faces, the same windows removed can be re-implemented, also ensuring air tightness continuity.
- 7) Further tests should be performed to ensure that the cavity closers and cold bridging sections now conform to SAP 2012.

It is important that these works are performed in stages to allow building movements to adapt as a result of structural changes. This will also help negate the risk of new lintels cracking under extreme pressures.

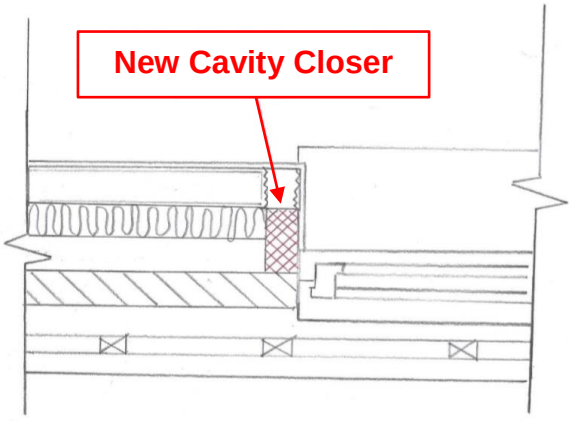
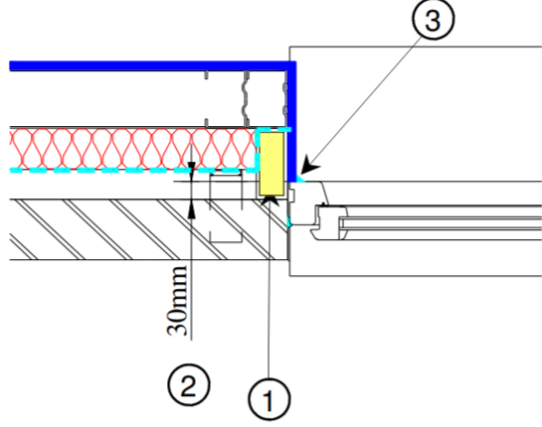
From the assistant surveyors U-value calculations the existing resistance is does not meet the minimum thermal transmittance (see **Appendix A.6** for the full equation on how this change has corrected the problem). This procedure of refurbishment works is demonstrated for all window sections in **Details 7-9**.

U-Value Before: 0.110W/m²K

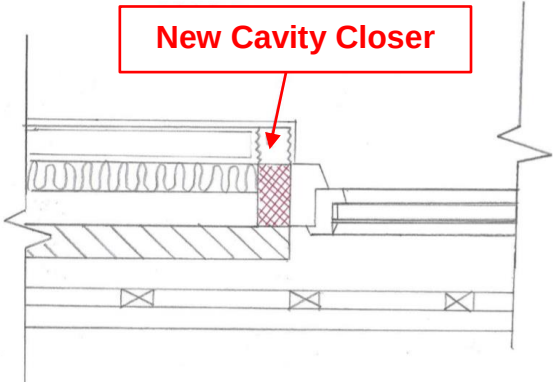
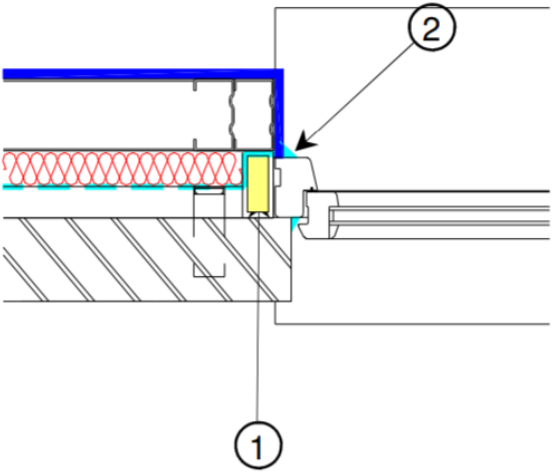
U-Value After: 0.073 W/m²K

Detail 7: SWF – WD- 02 Windows and Doors. Cills.	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (See appendix A.4) lists that the Ψ-value for this junction should be 0.10. Ψ = 0.10.
Thermal Performance Checklist	Assumptions
- Install a proprietary cavity closer having a path of minimum thermal resistance path through the closer no less than 0.45m²K/W. (1) - Minimum frame overlaps to be 30mm (2) - Flexible sealant should also be applied to the junction linings (3) - Must comply with Table K1 of SAP 2012 (See appendix A.4)	Cavity closer does not achieve minimum thermal resistance path through the closer of no less than 0.45m²K/W.



Detail 8: SWF – WD- 03 Windows and Doors. Jambs.	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (See appendix A.4) lists that the Ψ-value for this junction should be 0.10. Ψ = 0.10.
Thermal Performance Checklist	Assumptions
▪ Install a proprietary cavity closer having a path of minimum thermal resistance path through the closer no less than $0.45m^2K/W$. (1) ▪ Minimum frame overlaps to be 30mm (2) ▪ Flexible sealant should also be applied to the junction linings (3) ▪ Must comply with Table K1 of SAP 2012 (See appendix A.4)	▪ Cavity closer does not achieve minimum thermal resistance path through the closer of no less than $0.45m^2K/W$.



Detail 9: SWF – WD- 04 Windows and Doors. Checked Reveals.	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
	
Default 'Psi' Ψ-Value	Table K1 of SAP 2012 (<i>See appendix A.4</i>) lists that the Ψ-value for this junction should be 0.10. Ψ = 0.10.
Thermal Performance Checklist	Assumptions
▪ Install a proprietary cavity closer having a path of minimum thermal resistance path through the closer no less than $0.45\text{m}^2\text{K/W}$. (1) ▪ Flexible sealant should also be applied to the junction linings (2) ▪ Must comply with Table K1 of SAP 2012 (<i>See appendix A.4</i>)	▪ Cavity closer does not achieve minimum thermal resistance path through the closer of no less than $0.45\text{m}^2\text{K/W}$.

1.4 Discussion

Since the external cladding of the structure was erected in 2008/2009, the Psi (Ψ) values used for conformity were that from Table K1 of SAP 2005 whereas now, refurbished buildings are required to conform to Table K1 of SAP 2012 where the standards are a lot tougher to meet due to greater energy efficiency considerations. This means that a lot of material present in the structure needs amendment and construction methods altered.

1.4.1 Problems & Limitations

The surveyor was unable to calculate the factual Psi-values for the cold bride section due to several reasons:

- 1) 'PsiTherm' is a software package that provides the user an interface to construct detailed building sections to determine heat flows & surface temperatures. The software automatically calculates Psi-values & f_{CRsi} values and generates comprehensive reports in accordance with the relevant standards. This software was not accessible due to financial constraints and a lack of training.

- 2) A lot of the report is founded upon assumptions as invasive investigation was not performed, therefore inaccuracies may transpire.
- 3) Due to time constraints, the whole building envelope was unable to be surveyed and in addition to this, there were spaces off limits to the surveyor.

Only access to archived construction details of the structure, invasive investigation and the cladding report produced by the Health & Safety Officer in 2017 will give a definitive indication of what materials are existent within the external wall and it's cladding. Meaning suggestions for improvement are based upon the surveyor's investigation and knowledge of construction methods at the time of construction.

The hardest sections to remediate are **Detail 2** where the cavity wall needs to be invasively accessed to implement cavity fire barriers and **Details 6-9** where in SW and SE facades the window areas have been increased and therefore require larger and stronger lintels and sills. These works have the potential to be extremely expensive and pose risk to the structural integrity of the structure. Specialist contractors should be sourced to plan and perform these works.

During the thermal imaging study, the external heat losses would have been more accurate if performed at night time. This is because there would be no sunlight to confuse readings and it will also show how the envelope performs in ordinary conditions. It would have also been advantageous to be performed on a dry and not too windy night.

For non-domestic buildings, the use of building monitoring with control systems to achieve the TER has been highlighted by the UK government to improve energy efficiency. For instance, HVAC control and temperature data collection if implemented within the structure have the potential to identify rooms that are losing the most heat. These rooms can then be highlighted for further investigated and regular cold bridging assessments.

1.4.2 BREEAM Certification

The control of cold bridges from the refurbishment can help the building achieve the BREEAM 'Refurbishment and fit-out' for non-domestic buildings certificate. *"The primary aim of BREEAM UK Refurbishment and Fit-out is to promote the delivery of sustainable refurbishment and fit-out, in order to mitigate the life cycle impacts of existing buildings on the environment in a robust and cost-effective manner. This is achieved through integration and use of the scheme by clients and their project teams at key stages in the design and refurbishment/fit-out works process."* (BREEAM, 2014)

Of the 11 credit sections, cold bridging directly associates to 5 of them, credits that the eradication of cold bridging can achieve is shown on **Figure 4.1**.

Figure 4.1: What BREEAM credits the control of cold bridging can accomplish.	
Energy	Materials
▪ Reduction of energy use and carbon emissions, ▪ Energy monitoring, ▪ Low carbon design, ▪ Drying space.	▪ Environmental impact of materials, ▪ Responsible sourcing of materials - Insulation, ▪ Designing for durability and resilience, ▪ Material efficiency.



Waste	Health and wellbeing
▪ Project waste management, ▪ Recycled aggregates, ▪ Operational waste, ▪ Adaptation to climate change, ▪ Functional adaptability.	▪ Indoor air quality, ▪ Thermal comfort, ▪ Acoustic performance, ▪ Safety and security.
Management	
▪ Project brief and design, ▪ Life cycle cost and service life planning, ▪ Responsible construction practices, ▪ Commissioning and handover, ▪ Aftercare.	

The benefits of the client pursuing the BREEAM Refurbishment and fit-out certificate include:

- Reduction in building functioning costs.
- Decreases the expenses of demolition and re-building.
- Minimalizes the use of natural resources.
- Improves occupant comfort and productivity.
- Internationally applicable.
- Property value increase,
- Raises consciousness in sustainable design.

1.5 Report Summary

The ACD's give constructors vital information when considering energy efficient steel frame construction. SAP 2012 and the Building Regulations also ensure that the energy efficiency at junctions is at its maximum. The refurbishment of UWTSD's Business Campus requires a lot of money spent on it to allow it to reach modern efficiency and safety standards.

Refurbishment is far more financially viable than demolition although as energy costs in the long run will be decreased, user wellbeing and comfort will improve, and the envelope will be a lot safer place should accidents occur. The implementation of adaptive facades within the retrofit have the potential to improve all these factors and make the project a leading flagship development.

According to the publication ***"Handbook of energy efficiency in buildings - A life cycle approach"* by Francesco Asdrubali (2019)** retrofitting of the existing building stock has been identified as a major work area for reaching the sustainability targets in the built environment. Adaptive facades can potentially play a large role in this context, because the desired effect can often be achieved by just replacing the building skin without influencing the building's structural integrity or the need for major reconstruction activities.

The journal ***"Current guidance on cladding post-Grenfell"* by Geoff Wilkinson (2019)** gives caution to all mid/high rise structures undergoing retrofitting and identifies the need for improved standards of facades and cold bridge sections. Refining the understanding of façade and cold-bridging sections will ensure that the architect and labourers do not construct defective building components.



References

A.G.J. Way, (2016) **Thermal Bridging in Steel Construction**. (1 vols). SCI Steel Knowledge.

Accredited Construction Details (ACD) (2007): National Archives. Available at: <https://webarchive.nationalarchives.gov.uk/20141202131824/http://www.planningportal.gov.uk/uploads/br/accredconbk.pdf> (Accessed: 12 March 2019)

BRE (2005) **The Government's Standard Assessment Procedure for Energy Rating of Dwellings**: BRE. Available at: http://projects.bre.co.uk/sap2005/pdf/SAP2005_9-83.pdf (Accessed: 1st April 2019)

BRE (2016) **Treatment Of Thermal Bridges**: BRE. Available at: https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-06---Treatment-of-thermal-bridges---V1_0.pdf (Accessed: 16th March 2019)

BREEAM (2014) **BREEAM UK Refurbishment and Fit-out (non-domestic)**. BREEAM, p. 401.

CIBSE (2015) **Guide A: Environmental Design**. CIBSE, p. 402.

CPD: Cavity Closer And Thermal Bridging (2018). Available at: <http://www.constructionmanagemagazine.com/cpd-articles/cpd-cavity-closers-and-thermal-bridging/> (Accessed: 23rd March 2019).

Everett, C. (2019) **Cavity Barriers in External Walls**. Available at: <https://www.labcwarranty.co.uk/blog/faq-cavity-barriers-in-external-walls/> (Accessed: 21st March 2019)

Francesco Asdrubali (2019) **Handbook Of Energy Efficiency In Buildings - A Life Cycle Approach**. Matthew Deans, p. 836.

Gaisma (2019) **Swansea, United Kingdom - Sun path diagram**. Available at: <https://www.gaisma.com/en/> (Accessed: 24th March 2019)

HSE (2017) **How To Deal With Sick Building Syndrome (SBS)**. HSE, p. 23.

Lallanilla, M. (2014) **What Is Dew Point?** Available at: <https://www.livescience.com/43269-what-is-dew-point.html> (Accessed: 16th March 2019)

Psi Values, Y Values and Thermal Bridging (2018). Available at: <https://www.pinewood-structures.co.uk/content/1/95/psi-values--y-values-and-thermal-bridging.html> (Accessed: 14th March 2019)

Chudley R, Greeno R, Hurst M, Topliss, S (2011) **Construction Technology**. 5th edition.: Pearson Education LTD.

Sun Graph for Swansea (2018). Available at: <https://www.timeanddate.com/sun/uk/swansea?month=10&year=2018> (Accessed: 31st March 2019)



Thermal Bridge Assessment (2015). Available at: <https://lowenergydesign.ie/wp-content/uploads/sites/246/Thermal-Bridge-Assessment-FAQ.pdf> (Accessed: 27th March 2019)

Ward, T. (2006) **Assessing The Effects Of Thermal Bridging At Junctions And Around Openings**. BRE, p.75.

Wilkinson, G. (2019) **Current Guidance On Cladding Post-Grenfell**, pp. 13.



Appendices

Appendix A.1: Case Study.

Source: Adam Meyrick.

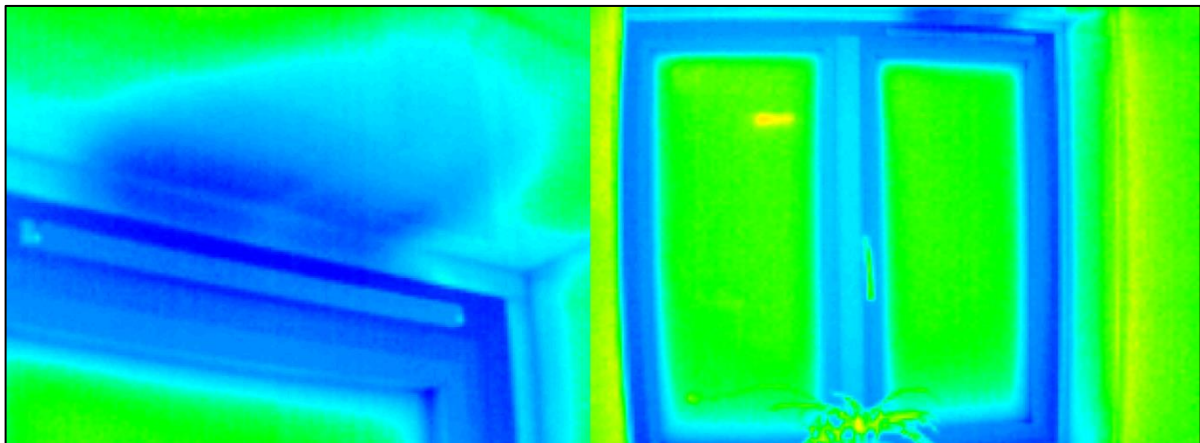
Accessed: 2nd April 2019.

The Civic Centre (County Hall) is true to the period of construction of UWTSD's Business School being erected in 1982 and additionally, is a steel frame structure. Like the Business School, it has seen building occupancy changes during its life cycle with a library being implemented during its 2008/2009 renovation. This is also the same year that UWTSD refurbished the business school, meaning materials compositions in both structures will be very similar since the materials and standards are true to the time of refurbishment.

Appendix A.2: Thermal Image Window.

Photo Credit: Adam Meyrick.

Date: 30th October 2018.



Description: Cold bridging in room AS2K1 at window section.

Appendix A.3: Cenwyn Jones Interview.

Date: 28th February 2019.

Interviewee: Cenwyn Jones (Head of Estates at UWTSD Business Campus)

Question 1 (Adam): When was the structures current cladding implemented?

Answer (Cenwyn): The buildings cladding has been changed more than once in the building life cycle, but the current installation was installed about 10 years ago in 2008/2009.

Question 2 (Adam): What are the buildings current and previous usages?

Answer (Cenwyn): The current structure serves as a place of education for UWTSD students, but previously was land registry offices, it was then left disused for 4 years before being bought by UWTSD.



Question 3 (Adam): Are there any construction details for the cladding available?

Answer (Cenwyn): There are details relating specifically to the buildings cladding but are difficult to obtain. A cladding report was ordered after the Grenfell disaster and completed last year (2018) by a relevant Health & Safety Officer.

Appendix A.4: Table K1 SAP Ψ -values 2012.

Source: The Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings. BRE (2005).

Accessed: 23rd March 2019.

Ref no	Junction	Approved Ψ Value ^c (W/mK)	Default Ψ Value ^c (W/mK)	Reference Ψ Value ^d (W/mK)
E1	Steel lintel with perforated steel base plate	0.50	1.00	0.05
E3	Sill	0.04	0.08	0.05
E4	Jamb	0.05	0.10	0.05
E5	Ground floor (normal)	0.16	0.32	0.16
E7	Party floor between dwellings (a)	0.07	0.14	0.07
E8	Balcony within a dwelling (b)	0.00	0.00	0.00
E9	Balcony between dwellings (a, b)	0.02	0.04	0.02
E23	Balcony within or between dwellings, balcony support penetrates wall insulation	No value	1.00	0.02
E12	Gable (insulation at ceiling level)	0.24	0.48	0.06
E10	Eaves (insulation at ceiling level)	0.06	0.12	0.06
E16	Corner (normal)	0.09	0.18	0.09



Appendix A.5: Surveyors Cold Bridge Assessment Template.

Detail:	
Adapted Construction Detail	Steel Frame Accredited Construction Detail
Default 'Psi' Ψ-Value	
Thermal Performance Checklist	Assumptions
Recommendations	



Appendix A.6: U-Value Calculations.

Detail 1: SFW – GF – 01 Ground Bearing Floor

Before:

Material	Length (m)	Thermal Transmittance (W/mK)
Old DPM	0.0002m	0.045
Insulation	0.1m	0.044
Cavity	0.1m	-
Brick	0.1m	0.8
Steel	0.305m	50
Calculation:		
$R = \left(\frac{0.0002}{0.045}\right) + \left(\frac{0.1}{0.44}\right) + 0.1 + \left(\frac{0.1}{0.8}\right) + \left(\frac{0.35}{50}\right) = 2.508\text{m}^2\text{K/W}$		
$U \text{ Value} = \left(\frac{1}{2.508}\right) = \mathbf{0.399\text{W/m}^2\text{K}}$		

After:

Material	Length (m)	Thermal Transmittance (W/mK)
New DPM	0.0002	0.039
Insulation	0.2	0.022
Cavity	-	-
Brick	0.1	0.8
Steel	0.305	50
Calculation:		
$R = \left(\frac{0.0002}{0.039}\right) + \left(\frac{0.2}{0.022}\right) + \left(\frac{0.1}{0.8}\right) + \left(\frac{0.305}{50}\right) = 9.227\text{m}^2\text{K/W}$		
$U \text{ Value} = \left(\frac{1}{9.227}\right) = \mathbf{0.108\text{W/m}^2\text{K}}$		

Sources:

DPM: Visqueen EcoMembrane

Wall Insulation: 1200mm x 2400mm x 100mm Celotex GA4000 Insulation Board.

Brick: Figure 2.3.

Steel: Figure 2.3.



Detail 3: SFW – IW – 01 Separating Wall/External Wall Abutment

Before:

Material	Length (m)	Thermal Transmittance (W/mK)
Insulation	0.1	0.044
Cavity	0.1	-
Brick	0.1	0.8
Steel	0.305	50
Plasterboard	0.0125	0.019
Calculation:		
$R = \left(\frac{0.1}{0.044} \right) + 0.1 + \left(\frac{0.1}{0.8} \right) + \left(\frac{0.305}{50} \right) + \left(\frac{0.0125}{0.019} \right) = 2.570 \text{m}^2\text{K/W}$		
$U \text{ Value} = \left(\frac{1}{2.570} \right) = \mathbf{0.389 \text{W/m}^2\text{K}}$		

After:

Material	Length (m)	Thermal Transmittance (W/mK)
Insulation	0.1	0.044
Cavity	0.1	-
Brick	0.1	0.8
Steel	0.305	50
Insulated Plasterboard	0.035	0.033
Insulation Sheet	0.09	0.1
Calculation:		
$R = \left(\frac{0.1}{0.044} \right) + 0.1 + \left(\frac{0.1}{0.8} \right) + \left(\frac{0.305}{50} \right) + \left(\frac{0.035}{0.033} \right) + \left(\frac{0.09}{0.1} \right) = 4.464 \text{m}^2\text{K/W}$		
$U \text{ Value} = \left(\frac{1}{4.464} \right) = \mathbf{0.224 \text{W/m}^2\text{K}}$		

Sources:

Insulation Sheet: Superwool 607 Paper Thermal Insulation Sheet, 1.2m x 610mm x 9m.

Insulated plasterboard: Knauf XPS Thermal Insulated Laminate Plus Tapered Edge Plasterboard 2400mm x 1200mm x 35mm.

Brick: Figure 2.3.

Steel: Figure 2.3.



Detail 5: SFW – RF – 02 Flat Roof with Parapet.

Before:

Material	Length (m)	Thermal Transmittance (W/mK)
Old DPM	0.0002	0.045
Cavity Insulation	0.1	0.044
Steel	0.305	50
Upstand Insulation	0.05	0.044
Cavity	0.1	-
Brick	0.1	0.8
Calculation:		
$R = \left(\frac{0.0002}{0.045} \right) + \left(\frac{0.1}{0.044} \right) + \left(\frac{0.305}{50} \right) + \left(\frac{0.05}{0.44} \right) + 0.1 + \left(\frac{0.1}{0.8} \right) = 3.645 \text{m}^2\text{K/W}$		
$U = \left(\frac{1}{3.645} \right) = 0.274 \text{W/m}^2\text{K}$		

After:

Material	Length (m)	Thermal Transmittance (W/mK)
New DPM	0.0002	0.039
Cavity Insulation	0.1	0.044
Steel	0.305	50
Upstand Insulation	0.062	0.022
Cavity	0.1	-
Brick	0.1	0.8
Calculation:		
$R = \left(\frac{0.0002}{0.039} \right) + \left(\frac{0.1}{0.044} \right) + \left(\frac{0.305}{50} \right) + \left(\frac{0.062}{0.22} \right) + 0.1 + \left(\frac{0.1}{0.8} \right) = 5.327 \text{m}^2\text{K/W}$		
$U = \left(\frac{1}{5.327} \right) = 0.188 \text{W/m}^2\text{K}$		

Sources:

DPM: Visqueen EcoMembrane.

Wall Insulation: 1200mm x 2400mm x 100mm Celotex GA4000 Insulation Board.

Brick: Figure 2.3.

Steel: Figure 2.3.



Detail 6, 7, 8, 9: Window Sections.

Before:

Material	Length (m)	Thermal Transmittance (W/mK)
Old DPM	0.0002	0.045
Old Cavity Tray	0.01	0.4
Steel	0.305	50
Old Plasterboard	0.0125	0.019
Cavity	0.1	-
Brick	0.1	0.8
Calculation:		
$R = \left(\frac{0.0002}{0.045}\right) + \left(\frac{0.01}{0.4}\right) + \left(\frac{0.305}{50}\right) + \left(\frac{0.0125}{0.033}\right) + 0.1 + \left(\frac{0.1}{0.8}\right) = 9.128\text{m}^2\text{K/W}$		
$U = \left(\frac{1}{9.128}\right) = \mathbf{1.110\text{W/m}^2\text{K}}$		

After:

Material	Length (m)	Thermal Transmittance (W/mK)
New DPM	0.0002	0.039
New Cavity Tray	0.01	0.25
Steel	0.305	50
Insulated Plasterboard	0.035	0.033
Cavity	0.1	-
Brick	0.1	0.8
Calculation:		
$R = \left(\frac{0.0002}{0.039}\right) + \left(\frac{0.01}{0.25}\right) + \left(\frac{0.305}{50}\right) + \left(\frac{0.035}{0.033}\right) + 0.1 + \left(\frac{0.1}{0.8}\right) = 13.552\text{m}^2\text{K/W}$		
$U = \left(\frac{1}{13.552}\right) = \mathbf{0.073\text{W/m}^2\text{K}}$		

Sources:

Cavity Closer: Manthorpe G240 uPVC Cavity Closer Double Flange 100mm x 2440mm.

Galvanised Steel Lintel: Catnic CG90/100 3000mm.

DPM: Visqueen EcoMembrane.

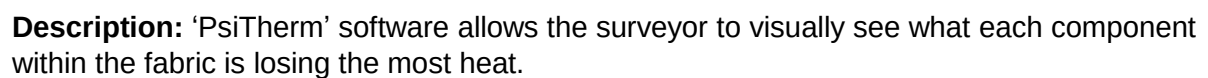
Cavity Tray: Manthorpe Horizontal Cavity Tray 900mm.

Brick: Figure 2.3.

Steel: Figure 2.3.



Accessed: 14th March 2019.



Date: 30th October 2018.

