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Urea Formaldehyde cavity wall insulation, after many years of service is it still insulating adequately and was it ever fit for purpose?

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Abstract.

With the current drive towards energy efficient refurbishment and the promotion of grant subsidized loft and cavity wall insulation it is vital that any insulation is carried out correctly with materials that will stand up to the ravages of time. Cavity wall insulation cannot be seen once installed and is generally assumed to be performing as specified and forgotten about.

This thesis looks at UFFI which, although rarely used today, has played a significant role in retro fitted cavity wall insulation since its introduction in the late 1950's.

The intention of this work is to determine if Urea Formaldehyde Foam Insulation (UFFI) is or was a material suitable for the purpose of retro fitting cavity wall insulation and able to achieve the long term energy saving goals it was intended for.

An overview of the British Standards and building regulations associated with UFFI is detailed followed by an investigation into 5 houses insulated with UFFI uncovering a small area of each cavity to expose the foam enabling samples to be taken and a view of the condition of the otherwise hidden insulation. Referring to the standards, the investigations try to determine whether the standards were adhered to or whether the standards were high enough to ensure correct installation.

A 16 week period of cavity monitoring is carried out gaining an insight into the environment within a cavity and an analysis comparing external environmental data from a local MET office is made. Historical weather data from 1970 to 2010 is compared to the current investigation results giving an indication of the conditions the cavities may have been subjected to during the life of the installed UFFI.

Coordinating previous and current research into UFFI produces an analysis of how predicted long term performance of the foam compares with the current condition of actual installed foam.

The outcome is a conclusion that UFFI has so many factors that can cause detrimental effects for installation and long term performance that it's suitability for the intended purpose raises further questions.

Acknowledgements.

Firstly, and it goes without saying, I would like thank all the dedicated staff at the Graduate School of the Environment and particularly the AEES staff and tutors for all their hard work through some pretty hard times over the last couple of years. Special acknowledgements must go to; Mike Thompson, for giving me a place on the AEES course and for having the drive and enthusiasm to lead a truly inspirational group of people, and my tutor Jason Hawks for his dedication and enthusiasm towards his students and the whole AEES ethic. Thanks must also go to Frances Hill my thesis supervisor for just being there when I needed a bit of advice.

Special thanks must go to the brave people who were willing for me to part demolish their homes in the name of research, without their trust (or gullibleness) a large part of my research could not have been done; Mr and Mrs Dangerfield, Mr and Mrs Coker, my Mum and Dad, Mr and Mrs Bryden and Mr and Mrs Collins. A mention also must go to Mark Humphreys for his subsequent professional repair of the afore mentioned homes and my previous employer, Ultralife Batteries UK Ltd, for the use of their scales to weigh the samples!

And lastly, but by no means least, my long suffering, supportive and very tolerant wife Andrea, (who has threatened to shoot me if I talk about UFFI or insulation once this paper is handed in!) and my two daughters Erin and Annie who have had to put up with a ‘grumpy old dad’ for the last two and a half years. And a final one to Lottie my Jack Russell who has seen her quota of walks and ball chasing drastically reduced over the last 6 months!

Contents.

Abbreviations.

BBA – British Board of Agrément.

BPI – British Industrial Plastics.

CIGA – Cavity Insulation Guarantee Agency.

CMHC – Canada Mortgage and Housing Corporation.

CSIRO – Commonwealth Scientific and Industrial Research Organization.

CWI – Cavity Wall Insulation.

DECC – Department of Energy and Climate Change.

EPS – Expanded Polystyrene.

NMR – Nuclear Magnetic Resonance.

RH – Relative Humidity.

UF – Urea Formaldehyde.

UFFI – Urea Formaldehyde Foam Insulation.

WDR – Wind Driven Rain.

Figures.

(All photographs and thermal images were taken by the author.)

Tables.

1. Introduction.

Wall cavities have been constructed in buildings since 1945 although many older buildings also have them. Cavity walls were initially constructed as a moisture barrier to prevent water penetration from the exterior wall leaf to the interior, insulating these cavities can reduce heat loss through the walls by up to 40%, BRECSU (1993). Retro fitted cavity wall insulation (CWI) has been available in the UK since the late 1950's but, until the oil shortages resulting from the Arab-Israeli war of 1973, was rarely installed, Barret (1984). After 1973 there became an awareness of the cost and security of energy resources and consequently people started considering energy efficiency. Cavity wall insulation was seen as the ultimate energy saving upgrade for dwellings and, when combined with loft insulation, home owners could expect to save around 10% of their heating costs, Hong, Oreszczyn, Ridley (2006).

With the increasing awareness of climate change, CO_2 emissions and dwindling energy resources, cavity wall insulation has probably never been as relevant as it is today, it is a cheap and quick system for reducing heat loss from dwellings. The first CWI material used was urea formaldehyde foam insulation (UFFI), installed predominantly from the early 1970's it was given a 20-30 year guarantee and sold with the premise that it would last for the lifetime of the building. In 2011 the guarantees have long since expired and it is assumed that the insulation is still up to standard nearly 40 years after installation.

Cavity wall insulation is a *stealthy* insulation that cannot be seen once it has been installed, the ideal system for attracting 'cowboy installers'. The homeowner has to put faith in the skills and honesty of the installer because it is virtually impossible to verify the integrity of the insulation without removing walls to expose it. Once it is installed it is generally accepted that the walls are insulated sufficiently and are forgotten about.

"........many people are sceptical about cavity wall insulation, because the product is unseen and its benefits are not directly measurable – a potential dreamboat for a cowboy operator." Barret (1984).

"........*many 'cowboys' on a get-rich-quick path were installing UFFI. Larger companies were claiming the cowboys used sub-standard resins or didn't know how to formulate UFFI & this was where problems arose."* Brown (2011).

There is significant evidence to suggest that UFFI can degrade over time due to varying temperature and relative humidity levels, both of which are highly likely to occur within a cavity wall annually. Over a period of time, up to around 40 years currently, UFFI subjected to these annual temperature and relative humidity fluctuations is highly likely to have degraded to such an extent that buildings once insulated with this system are potentially now effectively uninsulated.

There are probably up to 3 million dwellings installed with UFFI in the UK, and assumed to be fully insulated. If this insulation has become degraded, some method of refurbishment might be necessary in order to help meet government plans of 80% energy reduction by 2050.

2. CWI Standards and Best Practice.

2.1 Overview.

This chapter summarizes the Building Regulations and British Standards associated with retro-fitted UFFI cavity wall insulation that should be adhered to by installers, manufacturers and suppliers. Sections most relevant to this paper have been included.

2.2 Building Regulations.

Urea formaldehyde CWI is covered in two sections of The Building Regulations 2000;

Part C – Site preparation and resistance to contaminants and moisture.

Part D – Toxic substances.

2.2.1 Part C2.

Section 5.15 Cavity Insulation.

d. This states that the foam should meet the requirements of BS 5617:1985 (*See section 2.3*) and should be installed to BS 5618:1985 (*See section 2.3*). The overall responsibility for the suitability of the wall to be filled lies with a surveyor from the installation company, and the installer should work under an Approved Installer Scheme. Beyond the installation there is no further building regulation requirement.

e. This refers to the condition of the outer leaf of the cavity wall and its condition and type of pointing giving BS 8208-1:1985 as guidance, stating that some cavity fill materials may have differing levels of risk of moisture being carried over to the inner leaf of the wall.

It sets out a method of assessment in section 15.6 but says that this method may be replaced "in cases where a third party assessment of such a cavity fill material contains a method of assessing the construction of the walls and exposure risk".

Section 15.6.

The UK is divided into wind driven rain (WDR) exposure zones ranging from high to low exposure risk. *Figure 1* below is a map showing these zones, it is used to determine which zone a dwelling falls into.

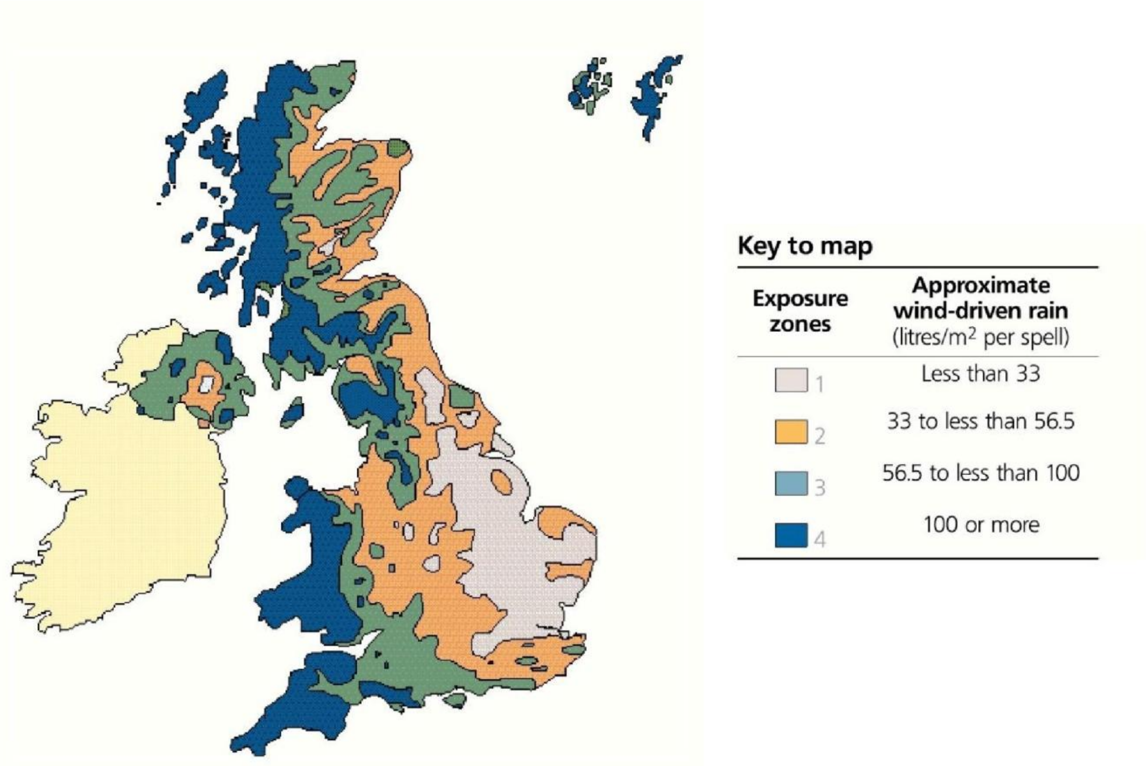


Figure 1. UK wind-driven rain map indicating suitability of ` CWI in different areas, EST (2002).

Wall construction

Insulation method	Min. width of filled cavity or clear cavity (mm)	Impervious cladding		Rendered finish		Facing masonry		
		Full height of wall	Above facing masonry	Full height of wall	Above facing masonry	Tooled flush joints	Recessed mortar joints	Flush sills and copings
Built-in full fill	50	4	3	3	3	2	1	1
	75	4	3	4	3	3	1	1
	100	4	4	4	3	3	1	2
	125	4	4	4	3	3	1	2
	150	4	4	4	4	4	1	2
Injected fill not UF foam	50	4	2	3	2	2	1	1
	75	4	3	4	3	3	1	1
	100	4	3	4	3	3	1	1
	125	4	4	4	3	3	1	2
	150	4	4	4	4	4	1	2
Injected fill UF foam	50	4	2	3	2	1	1	1
	75	4	2	3	2	2	1	1
	100	4	2	3	2	2	1	1
Partial fill								
Residual 50 mm cavity	50	4	4	4	4	3	1	1
Internal insulation								
Clear cavity 50 mm	50	4	3	4	3	3	1	1
Clear cavity 100 mm	100	4	4	4	4	4	2	2
Fully filled cavity 50 mm	50	4	3	3	3	2	1	1
Fully filled cavity 100 mm	100	4	4	4	3	3	1	2

Table 1. Maximum recommended exposure zones for insulated masonry walls, BRE (2001).

Table 1 shows the cavity width and exterior wall finishes that are suitable to be filled with different CWI methods for each particular exposure zones.

Using the map and table together, determination of which CWI material and method is suitable for any construction type and exposure zone can be made.

Formulations to adjust the application under different site conditions are also given;

i) “where local conditions accentuate wind effects, such as open hillsides or valleys where the wind is funnelled onto the wall, add one to this exposure zone value.”
ii) “where walls do not face into the prevailing wind, subtract one from this exposure zone value.”

This section gives BS8104:1992 (*See 2.3.4*) for more accurate and detailed area and zone mapping and calculation of exposure zone values, Crown copyright[1] (2006).

2.2.2 Part D – Toxic substances.

This regulation states that the UFFI insulation must be installed in such a way that any toxic fumes are prevented from penetrating into an occupied building.

As with Part C2 above it gives BS 5617:1985, BS 5618:1985 and BS 8208-1:1985 for further reference and guidance, Crown Copyright[2] (2006).

2.3 British Standards.

2.3.1 BS 5617:1985 - Specification for Urea-formaldehyde (UF) foam systems suitable for thermal insulation of cavity walls with masonry or concrete inner and outer leaves.

This standard sets out the suitability of the UF material for use as an insulating material for cavity walls. Appendices A-G describe the methods required to test each property of the foam end product to prove its overall suitability for use in the application. Tests D, E, F and G could be carried out on site prior to installation. The tests determine;

A) Effective density by measuring a sample, allowed to dry for a minimum of 24 hours, and relating its dried mass to its original volume. The system supplier should specify a target value, the final result must be within ± 25% of the original target value in kg/m^3.
B) Linear shrinkage by measuring the circumference of a sample piece allowing it to dry naturally for a minimum of 3 weeks and re-measuring the circumference. The shrinkage should be less than of 8% for type tests and 10% for quality control.
C) Water absorption by floating a test piece of foam on water for 24 hours and measuring before and after weights, the maximum absorption should be $2kg/m^3$.

D) The wet density of the foam by weighing a known volume of the foam system, as it would be injected into a wall cavity, by filling a container with foam directly from the injector nozzle. This test is designed to be suitable for use on site prior to installing the insulation system and should be within ±20% of the supplier's given target value.
E) Gel time of the system, the time taken for the foam to become non fluid. This should be within the limits specified by the supplier.
F) Foam system stability by carrying out a test to prove the absence of oil carryover from the system compressor. This is a drop test carried out using a 5 litre container, filled with foam, from a height of approximately 100mm, 1 minute after the foam has gelled. If oil is present the foam will collapse and reduce in height, there should be no collapse.
G) Appearance of the foam by cutting a sample and visually inspecting the material for any sign of non uniformity to the structure.

Tests H-M (appendices H-M) are carried out on the individual components of the UF foam under laboratory conditions, BSI[1] (1999).

2.3.2 BS 5618:1985 - Code of practice for Thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with urea-formaldehyde (UF) foam systems.

This standard covers the assessment of the building and its suitability to be filled with CWI and the installation of the UF foam system.

Section 3 – Suitability of cavity walls for insulation.

3.1. The onus is put on the installation contractor to determine whether the building is, or can be made suitable for CWI installation.

3.2. The walls to be filled should be structurally sound, the insulant cannot remedy defects and can, in fact, exacerbate existing faults, any necessary rectification work should be included as part of the installation contract.

This section gives Appendix A for details.

Appendix A;

A.1. This details different conditions and construction materials of the external wall leaf that may be present and gives wind driven rain exposure index limits for some types. If the wall is protected from rain penetration by methods such as weather boarding, slate, tile, timber or metal cladding, the installation will not be subject to an exposure index limit.

For some conditions such as the wall having been treated with a very low vapour permeable coating, the wall is not suitable to be filled with CWI.

The rest of the appendix details instances where likely areas of water penetration may be present, these areas should be thoroughly checked to determine if water penetration is present and if so these should be rectified before installation of CWI.

A.2. This covers the internal wall leaf, if it is of random rubble construction the whole wall is not covered by this standard.

The cavity must be isolated from occupied areas of the building to prevent formaldehyde gas penetration.

Any holes or areas where services enter the building should be sealed as part of the installation.

Any signs of damp other than caused by condensation should be investigated and remedial work carried out prior to installation. If the external leaf continues above the top floor ceiling and the inner leaf does not, such as a gable, any possible water penetration must not be able to pass to the inner leaf via the cavity fill.

On the survey report, any areas of inner leaf that are likely to make adjacent cavities unsuitable for filling and the position of ducts, chimneys and service entry points should be recorded.

A.3. This covers the nature and condition of the cavity for surveys.

The cavity should be determined to be at least 40mm wide over the whole area to be filled. The survey should identify construction details such as cavities capped by concrete gutters, which would cause the wall to be rejected for CWI fill if not water tight, and where standard bricks have been used as wall ties which would make the wall unsuitable for filling.

If the cavity extends 0.5m or more below ground level this should be reported in the survey as the foam should not be installed below ground level. If the cavity is greater than 100mm wide it should be inspected to ensure that there are no frames within the cavity that could cause water penetration or allow formaldehyde to ingress the building.

A.7. Services within the cavity. If services such as cables or gas pipes are found to be in the cavity, their position should be noted in the survey and taken into consideration when planning the drilling pattern for filling.

A.8. Any essential ventilation points through the cavity for appliances, etc, should be trunked to ensure they remain fully open after filling with foam.

Section 4 – Material composition.

This section states that the material must comply with BS 5617 (*See chapter 2.3.1*).

Section 5 – Thermal performance of installed foam.

This gives a recommended thermal conductivity design value of 0.04W/(m·K), compared with BS 5617:1985 which gives 0.035W/(m·K) as a maximum thermal conductivity, BSI[1] (1999).

Section 6 – The filling process.

(*See chapter 3 Urea Formaldehyde Foam, 3.4 The installation process.*)

Section 7 – Installation of the UF foam system.

(*See chapter 3 Urea Formaldehyde Foam, 3.4 The installation process.*)

Section 8 – Post-installation activities.

This section covers all post installation checks that should be carried out before the installer departs the site.

At the end of the section is the following caution;

"CAUTION. There is a slight possibility that a fuel-burning appliance could malfunction after the installation team has left the premises. It is therefore essential for the installation contractor to leave a WARNING CARD with the householder advising him to switch off all such flued appliances should a malfunction be suspected and giving the appropriate emergency telephone number(s).

During the drying process, a small amount of free formaldehyde is evolved from the foam system, which is normally dissipated through the outer well. Occasionally some vapour may enter the building which can cause irritation to the eyes, nose and throat. The WARNING CARD should also advise that this transitory situation can normally be alleviated by additional temporary ventilation, but, should the problem persist, the householder should notify the installation contractor." BSI[2] (1999).

2.3.3 BS 8208-1:1985 - Guide to Assessment of suitability of external cavity walls for filling with thermal insulants — Part 1: Existing traditional cavity construction.

This is a general standard for assessing buildings and their suitability to be filled with any CWI, not specifically UFFI. It covers many of the issues covered in the previous standards BS 5617:1985 and BS 5618:1985 concerning the condition of the building.

It lists the following factors that need to be taken into consideration when assessing a building for suitability:-

a) Form of construction and site conditions.
b) Age of the building.
c) Condition of cavity.
d) Extent of cavity to be filled.
e) Nature and condition of the outer leaf.
f) Nature and condition of the inner leaf.
g) Services within the cavity.
h) Ventilation through the cavity.

For each of these factors a flow chart is featured which guides the surveyor through the assessment process, *Figure 2* is an example of these.

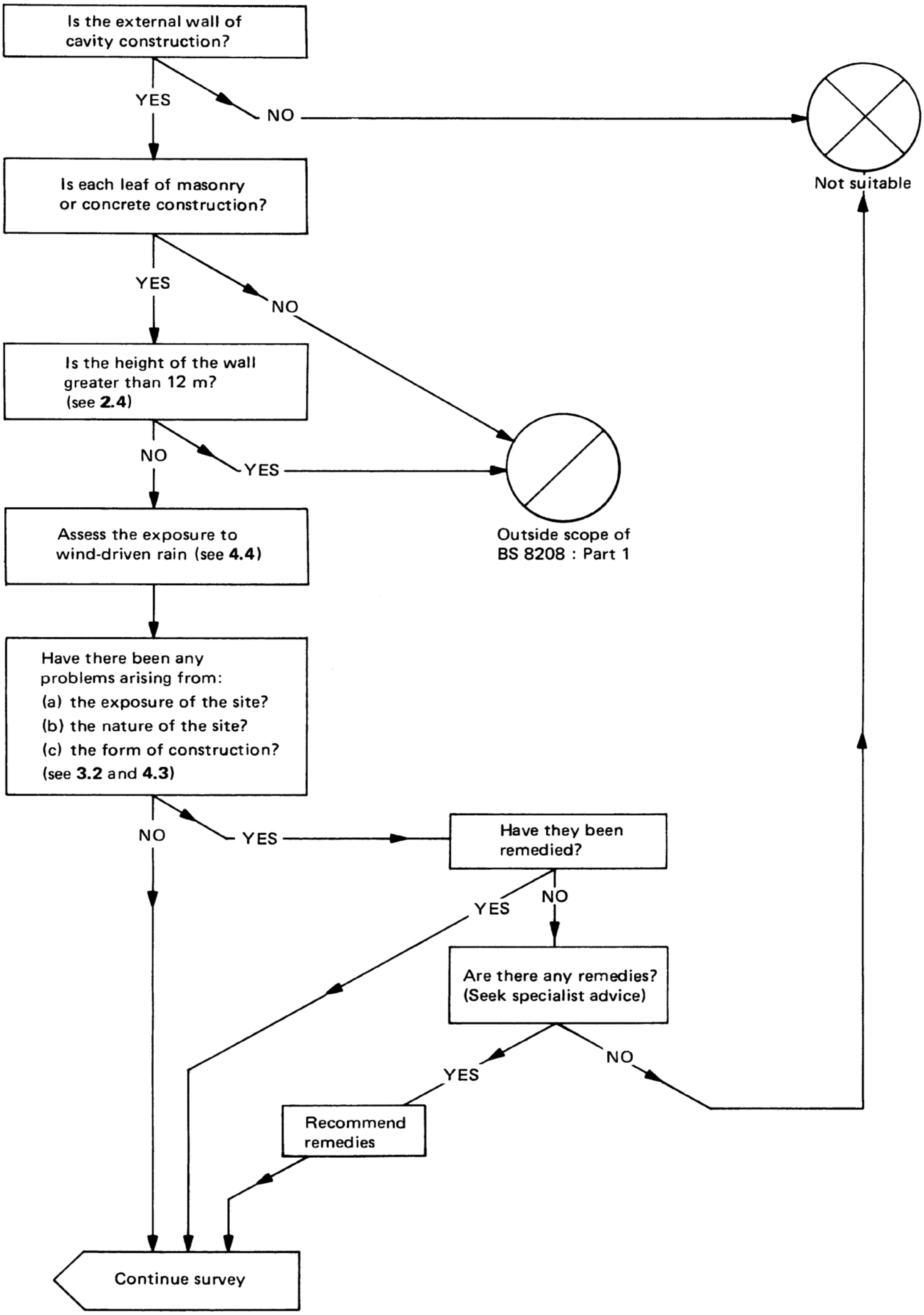


Figure 2. Flow chart to guide the surveyor through the assessment of 'form of construction and site conditions', BSI[1] (2008).

2.3.4 BS 8104:1992 - Code of practice for assessing exposure of walls to wind driven rain.

This standard provides detailed information and area data for wind driven rain calculations.

Each area or zone is considered to have its own unique set of geographical considerations which need to be taken into account when assessing a building for CWI suitability. If a wall is subjected to WDR, the water can penetrate through the external wall leaf and, if the cavity has been filled with an unsuitable material or filled when the risk of penetration is too high, the water can track through the CWI and penetrate the internal wall leaf and cause internal damp.

Figure 3 is a typical worksheet for wind driven rain calculations and is used to assess the suitability of a building to be filled with CWI.

Location:
Grid reference:
Orientation:
Map subregion:

		Spell index	Annual index
Geographical increment	i	....	....
Rose value	r	....	....
Map value (i + r)	m	....	....
Airfield indices (table 1 or 2)		D_S =	D_A =
		l/m² per spell	l/m² per year
Terrain roughness factor (table 3)	R	....	
Topography factor (table 4)	T	....	
Obstruction factor (table 5)	O	....	
Wall factor (table 6)	W	....	
Wall indices for the appropriate		D_{WS} =	D_{WA} =
direction of wall		l/m² per spell	l/m² per year

Figure 3. Sample of typical worksheet for wind-driven rain calculations.

For the purpose of this paper the writers' home has been used to demonstrate the use of this worksheet.

Location Abingdon, Oxfordshire.

Grid reference [4)]510E [1)]980N

The grid reference was determined by using a map supplied with the standard which covers the area concerned, in this case *Map 5*. (SU510980 is the standard OS reference)

Orientation 326°

This was obtained using a compass, the wall in question is the most northerly facing wall of the property.

Map subregion OX1

Each map is divided into zones, or subregions, the property falls within zone OX1 of Map 5.

The next section looks at the *spell index* and *annual index*.

The *spell* is a period or series of periods where wind driven rain hits a vertical wall of a given orientation, a spell has no specific length but can be a mixture of wind driven rain and periods of up to 96 hours where no significant wind driven rain has been experienced.

The wall *annual* index is the litres of wind driven rain that hits a square meter of wall per year.

	Spell index	*Annual index*
Geographical increment	i = 0	= 0

On the provided maps there are a series of contour lines with an increment number within them, these can be negative or positive values, the higher the number the greater the risk of wind driven rain. In the case of the subject property this increment is 0, very low risk.

	Spell index	*Annual index*
Rose value	r = 15	= 4

Supplied with each map is a set of 'roses' each rose gives 12 values for different wall orientations, the subject has an orientation of 326° which is slightly west of north. It does not specify on the table which orientation is north so this was assumed as indicated, (*See Figure 4*.). The orientation of the subject building is shown on the table on the OX1 Oxford row, this gives a spell rose value of 15 and an annual rose value of 4.

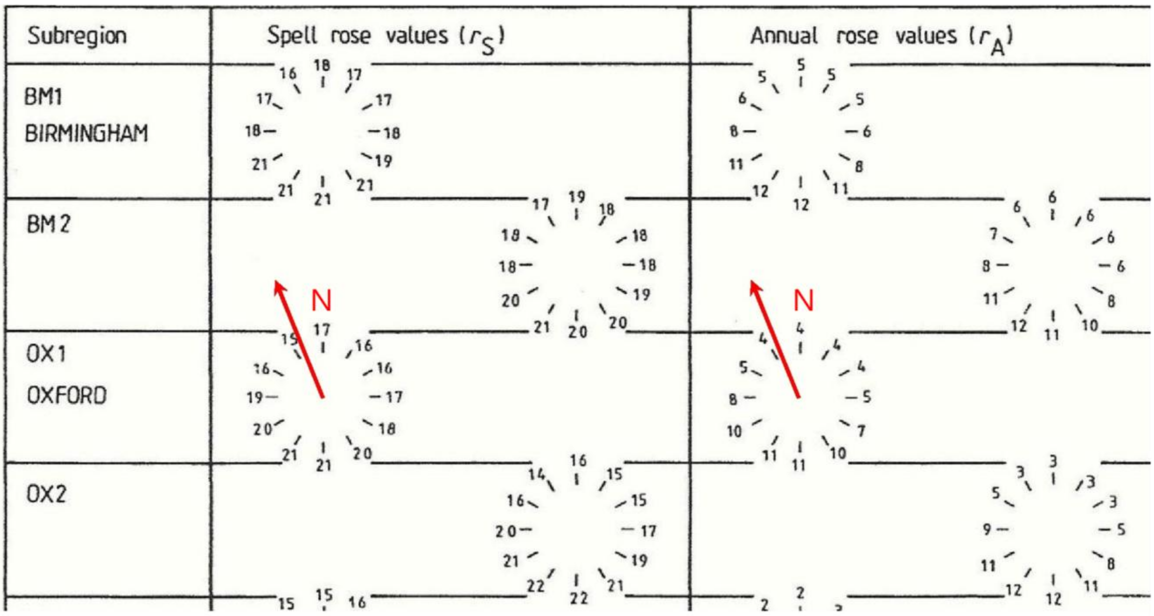


Figure 4. Scan of rose value table.

	Spell index	*Annual index*
Map value (i + r)	m = 15	= 4

The Map value is the sum of the geographical increment (i) and the rose value (r).

	Spell index	*Annual index*
Airfield indices (table 1 or 2)	D_S = 35.6 l/m² per spell	D_A = 160 l/m² per year

If the geographical location of the subject wall was on an airfield, the airfield index would be the quantity of rain likely to occur 10m above ground level at that point.

Terrain roughness factor (table 3) R = 0.75

The terrain roughness factor is the terrain upwind of the subject wall, this considers, hills, trees, buildings and other features that could give some degree of shelter from wind driven rain, table 3 on the standard gives 4 categories for this ranging from 0 (no shelter and a factor of 1.15) to 3 (significant shelter and a factor of 0.75). The subject wall has buildings in close proximity providing significant shelter giving it a category of 3 and factor of 0.75.

Topography factor (table 4) T = 1.0

This considers the topography of the location and determines whether there are slopes or valleys that could potentially funnel the wind onto the wall or, in very rare cases, shelter the wall from wind. Table 4 gives 3 factors, in the case of the subject wall there are no nearby slopes of a 1 in 20 gradient or more giving a factor of 1.0.

Obstruction factor (table 5) O = 0.4

This is the distance of obstructing objects from the subject, in this case, between 15 and 25m giving a factor of 0.4.

Wall factor (table 6) W = 0.4

The wall factor considers the layout of the subject wall, for example if the wall is of gable end construction or has an overhanging pitched roof. The factor is a ratio of the average quantity of rain falling on the wall and the quantity falling in a similar unsheltered area.

Wall indices for the appropriate $D_{WS} = D_S \times R \times T \times O \times W$ = 4.272 l/m² per spell

direction of wall $D_{WA} = D_A \times R \times T \times O \times W$ = 19.2 l/m² per year

The resulting wall indices can be assessed using the wind driven rain map (*Figure 1.*) and the exposure zone table (*Table 1.*) in chapter 2.2.1. to determine which CWI method and material would be suitable for the particular application. In this case, the subject wall falls into exposure zone 1, less than 33 l/m² per spell, it has facing masonry with tooled flush joints and a cavity of around 75mm, UFFI would be a suitable material for CWI, BSI² (2008).

Had the orientation been different, the terrain more open and the property in a less sheltered location it could have been pushed into a higher zone. The maximum exposure zone for similar properties is 2.

2.4 Omissions from the standards.

Factors which are not considered within the standards, but are reported to have an impact on the material, are; water hardness and environmental temperature and RH at the time of installation, Brown (1988).

2.5 UFFI limitations.

The building example used in 2.3.4 is of a very common construction type and similar properties can be found all over the UK, but in a different geographical location it is highly likely that it would fall into a different exposure zone. Referring to *Table 1*, this type of building with a 75mm cavity is only suitable to be insulated with UFFI up to exposure zone 2, most other facing masonry walls are restricted to zone 1 therefore the use of UFFI in similar properties will be limited.

Properties of other construction types where the wall has some form of external protection such as render or impervious cladding can be insulated with UFFI up to exposure zone 4.

3. Urea Formaldehyde Foam.

3.1 Overview.

This chapter looks at urea formaldehyde foam insulation, the number of properties insulated with the material, a brief insight into its chemical makeup, how it insulates the cavity and the process of installation. There were a lot of concerns over health issues in the 1970's and 80's, this chapter also offers a brief summary of these concerns.

3.2 The extent of application.

It is estimated that there are 26.6 million dwellings in the UK and 18.7 million of these are of cavity wall construction, at the time of writing, 10.76 million of these were estimated to have had cavity wall insulation installed, DECC[1] (2011).

The statistics department of DECC was contacted, via e-mail, to determine if there were any statistics available on CWI materials, a reply e-mail recommended contacting CIGA stating that no information on materials had ever been collected by DECC in the production of their statistics, Oxley (2011). The only statistics available have a starting date of 2008 and were taken from a 2008 housing survey and other known data at that time. These statistics are, at the time of writing, currently undergoing evaluation before being assessed as National Statistics and are classed as Experimental Statistics, DECC[2] (2011).

According to CIGA (2011), UFFI insulation was used extensively until 1985 when it was all but replaced by alternative materials, although there were one or two companies that continued to install it up until quite recently, no date was given or names and contact details of the companies.

CIGA was only established in 1995, according to a reply e-mail, and as such no data before this is available and other data also seems rather limited, Miller (2011). In a further e-mail the name of a UFFI manufacturer was supplied, BPI (British Industrial Plastics (Oldbury) Limited), indicating that they may have some statistics regarding the number of UFFI installations.

BPI was purely a chemical supplier of UFFI and not involved with the installation of the CWI system so do not have any information on the number of properties insulated, they no longer manufacture it. They estimated that about 90% of their UK material was supplied to a company in Somerset called Everwarm and recommended contacting them, Whyley (2011).

Everwarm were set up in 1980 and were one of 96 companies installing UFFI at that time, they believe they are the only company still using the system for new installations in the UK. The proprietor has worked in the industry since 1969 and estimates that he has personally been involved with around 40,000 UFFI installations and believes that the total number of installations in the UK could be as high as 2.5 - 3 million. Everwarm also install EPS beads as a CWI material although they believe UFFI to be a better system but more expensive than other materials and requires a higher level of training to become an installer so is used less, Hulin (2011). At the time of writing, they are currently supplied with UFFI by a company called Dynea.

Dynea were contacted via telephone, they believe they are the only supplier of UFFI in the UK and only supply to a total of 3 companies, two of them being in Belgium, the other in the UK, DeWolf (2011). The UK customer is an agency based in Bristol called Alansons that supply the material to the installers.

Alansons currently supply one company for new installations, Everwarm, and one company for occasional remedial work. They also have a potential customer who intends carrying out future remedial works, beyond this they have no figures on the number of properties insulated, Nunn (2011).

With no official statistics or figures available and estimates of between 0.5 and 3 million installations, it is impossible to determine a definitive figure for buildings insulated with UFFI, Whiteside, et al (1980), Barret (1984), Brown, Crump, Gardiner (1990), and Hulin (2011).

3.3 Chemical makeup.

Urea formaldehyde foam is a thermosetting polymeric product consisting of a water based urea formaldehyde resin solution combined with an acidic foaming hardener. It is supplied as components which need to be prepared and mixed in controlled quantities and rates on site just prior to installation using a suitable foam generating system. The foam has a cell structure created by bubbles, formed by mixing compressed air with the hardener, becoming coated with the resin during the injection process. Once mixed with the hardener and compressed air the resin starts to react to form a polymer, Brown (1988). These reactions can continue for some time after the installation as the foam cures and dries into its final state. During the curing process the foam releases formaldehyde gas and some of the acidic content until the curing process has completed, this can take several weeks and can continue, to a lesser degree, for many years after this. It has been found that if the foam dries too quickly it can result in the occurrence of cracking and shrinkage, Adderley, Probert (1990).

Each foam system supplier will have their own chemical compounds and material specification which will include; thermal conductivity, dry product density and an Agrément Certificate number.

Brown (1988), referenced a paper, [**Everett,L.H. (1983, October) A contribution to the Formaldehyde Workshop. *Little Rock, Arkansas.*]** (could not be located) claiming that the calcium content of hard water can have an effect on the resin polymerisation. Using hard water during the mixing stage of UFFI can cause precipitation of the hardener / surfactant, effectively weakening the foam structure and reducing its effectiveness at initiating the polymerisation. It is also mentioned that other ionised particles, such as magnesium above 6ppm, can also have a detrimental effect on the foam.

(There is no mention of water hardness or other waterborne minerals in any of the British Standards associated with UFFI).

3.4 How it works.

A wall cavity is a void filled with air which is free to circulate within the cavity via convection currents and draughts, this air movement will effectively remove heat from the building. Heat radiation and thermal conduction also contribute to the total heat loss through the cavity.

Injecting UFFI into a wall cavity fills the void with foam preventing air circulation and reducing heat loss through radiation. The performance of the insulation is mainly dependent on the extent to which the cavity is filled, density variation of the material will have limited effect assuming the cavity if fully filled, BSI[1] (1999).

Any cracking, shrinkage or gaps in the installation will allow air movement within the cavity and seriously reduce the foams insulation effectiveness.

3.5 The installation process.

3.5.1 The survey.

The first part of the installation process is the initial survey of the property to determine if it is suitable to be insulated with CWI. If all the requirements of the British standards and Building Regulations set out in *chapter 2* are adhered to for the survey, there should be no reason for any problems to occur. However, there are a lot of factors to take into consideration when carrying out a survey and, from a commercial point of view, will take time and cost money when the company will only make money from the actual installation. It is very likely that the surveyor will only carry out part of the survey with the sale being the most important factor.

The following quote was found on an internet forum written by an electrician who gives an indication of the perceived integrity of the CWI survey system;

“Don't worry about the cavity walls as I believe the building regulations do not allow cavity filling when cables are present. The installers use a small camera to check the cavities for cables and cavity ties with cement on them which can cause problems. However, if you really believe that happens, you are thicker than I am.” Cutting (2009).

3.5.2 The injection holes.

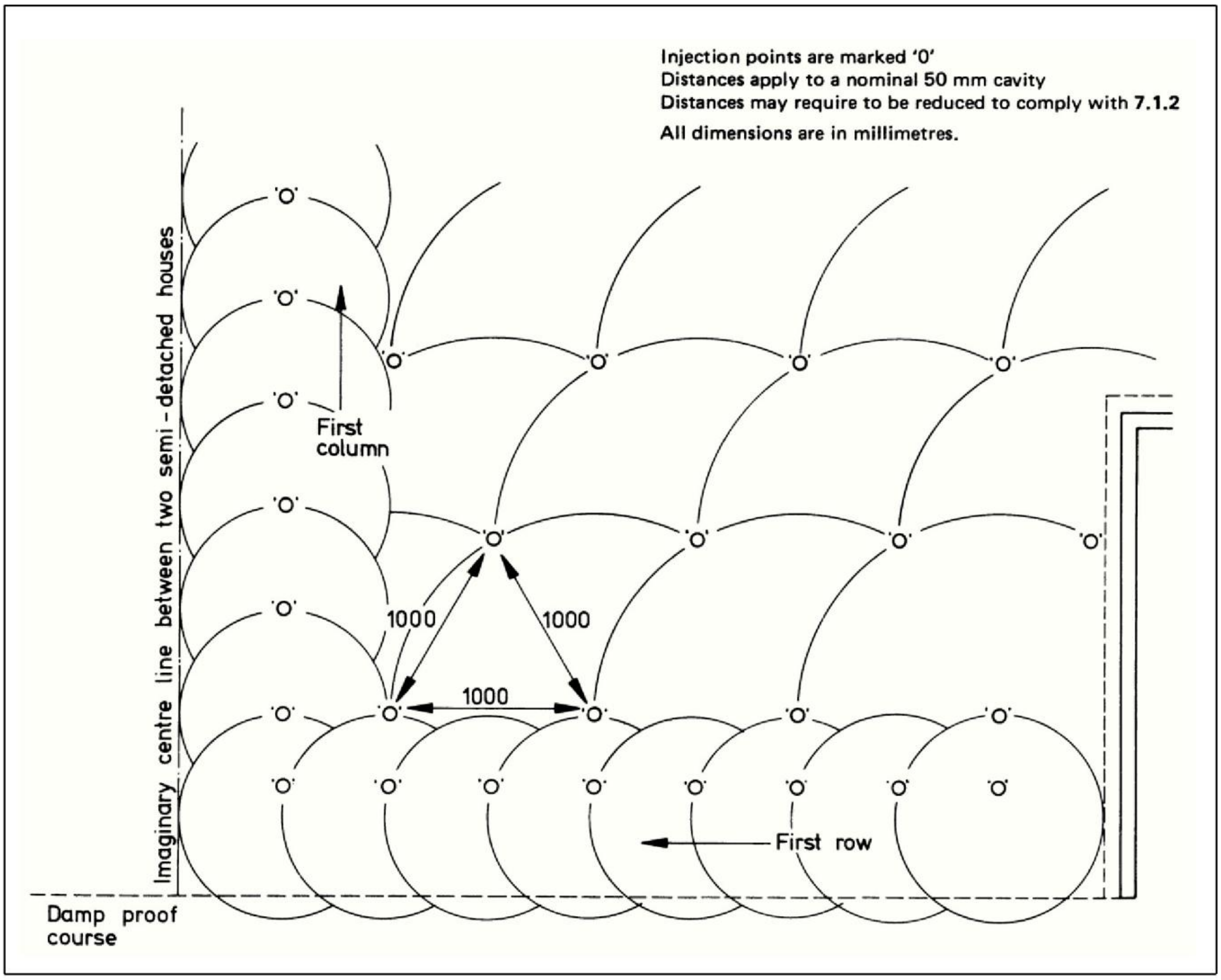


Figure 5. Overall pattern of filling for a nominal 50mm width cavity, BSI² (1999).

A series of holes in a triangular staggered pattern with a spacing of approximately 1m are required to ensure that an even fill is achieved, an example of this is shown in *Figure 5.* The pattern varies when the installation of a semi–detached/ terraced house meets the next property to form a barrier between the two and also along the line of the damp proof course. Around doors and windows there is a requirement to put in additional holes where necessary to ensure a full fill is achieved around these areas.

Additional sight holes should also be drilled (*not shown in Figure 5.*) along the limits of the installation such as the line between two semi–detached properties so that the foam can be seen when it reaches these limits and the injection stopped.

3.5.3 Injecting the foam.

On site quality checks D, E, F and G (*See chapter 2.3.1*) should be carried out prior to or during the injection of the foam if;

i) the resin has had a temperature rise above 20°C since its initial delivery,
ii) the resin is more than 3 months old,

iii) the equipment has been adjusted,
iv) there is a fault or suspected fault with the equipment.

A sample should also be produced by the operator in order that effective density – A and linear shrinkage – B tests (*See chapter 2.3.1*) can be carried out for each installation, BSI[3] (1999).

The foam should be injected in such a way as to ensure each injection bonds with a previous one (notice the arc of each injection). Indicator sticks should be put into the holes adjacent to the injection hole, when the foam is injected and reaches the indicator sticks they should move to indicate that the foam has reached this limit.

3.6 The health issues with UFFI.

Urea formaldehyde CWI is rarely used today due in part to health concerns about the release of formaldehyde gas into buildings, T-Zero (2009). It was banned for use as a building insulation material in Canada (December 1980) under the Hazardous Products Act, Crawford, Shirtliffe (1982/3?), and the US (1982) due to these health concerns. The ban was lifted in the US, however, in April 1983 when the US court of appeal over turned the ban because no conclusive evidence was found to substantiate the detrimental health claims against UFFI. It was never banned in the UK because British houses were built differently to those in the US and Canada where the health issues in the buildings were more apparent, Eakes (2002), All Around the House (1998), Perry (1982).

There has been considerable research into the health issues associated with UFFI and the release of formaldehyde gas but the general conclusion, from the many papers considered during the writing of this paper, is that the risks are minimal. UFFI releases the majority of its formaldehyde content within the first few weeks after installation and the amount of the gas emitted reduces significantly over time to such an extent that it can be difficult to measure due to the very small quantities. Many household products and materials contain formaldehyde, such as new carpets and furniture, which all contribute to the overall formaldehyde levels experienced within buildings. The research has shown that readings of inhabited space formaldehyde levels before and after the installation of UFFI show very little difference and the levels are so low that it is not considered to be of a significant health risk.

Despite the evidence indicating there is little or no significant health risk from UFFI it is still a concern to homeowners in Canada, up until 1993 a UFFI declaration was required for mortgage insurance purposes. This is no longer a requirement but a declaration can still be requested for a purchase agreement or real estate property listing, CMHC (1996).

4. UFFI Investigation.

4.1 Overview.

This chapter looks at evidence to suggest that the UFFI material is likely to have degraded since its initial installation, possibly as long as 40 years ago. It looks at previous research that has been carried out since the 1970's and also research and investigations conducted during the writing of this paper.

There is very little research available from the UK on UFFI other than health issues associated with the release of formaldehyde gas. There is, however, suggestion that UFFI can degrade over time, but the industry insists that once it has been installed *"it will last for the lifetime of the building",* CIGA (2011). CIGA also stated that *"UFFI shrinks by a few percent during the first few days or weeks after installation as it dries and cures, then stabilizes and will not shrink further or degrade."* The views of CIGA are likely to be biased in favour of the material because they have a vested interest in the longevity of it, *"CIGA is a trade association funded by the insulation industry. Like all trade associations, its purpose is to protect its members from the public."* Howell (2011).

It is very difficult to fully assess retro fitted CWI once it has been installed because it cannot be seen and 'out of sight, out of mind' means it is generally forgotten about under the assumption that the building is insulated.

Determining which buildings have been insulated with UFFI is difficult because there is no external indication of the type of CWI that has been installed, all retro fitted CWI will leave similar filled holes where the material was injected. In some cases the material can be seen in the loft space where it has escaped through holes in the cavity structure or the top of the cavity. Some home owners may have an idea of when the CWI was installed, if it was during the 1970's and early 1980's it is likely that UFFI was used. In many cases the owners will only be able to confirm that they believe their home has been insulated because they were advised as such when they purchased the property.

Since 1995, the year CIGA was set up, a completion certificate has been issued to the home owner confirming that CWI has been installed correctly and guaranteed by CIGA for 25 years,. Previously the installation guarantee was given by the installer covering 20 – 30 years. In many cases this certificate becomes misplaced or lost, not passed on by vendors to new owners when they buy the property and generally forgotten about. There does not appear to be any register to refer back to in order to find out the details of the insulation other than the installers own records, the installers contact details or name are also rarely known by the owner, and in many cases the installers no longer exist.

4.2 Previous research.

Research into the long term performance of UFFI is very limited, one study carried out in Australia used manufactured foam samples from a number of suppliers under laboratory conditions. A later study in the UK used similar laboratory tests on a mix of manufactured samples and samples removed from buildings, some from loft spaces and some from wall cavities. These give an indication of how UFFI can behave under controlled laboratory conditions with set temperature and RH levels but were mainly speculative exposing the samples to *likely* wall cavity environments rather than *actual* environments.

This research was carried out in the late 1980’s/ early 1990’s and very little, if any, appears to have been carried out since. UFFI was all but replaced by alternatives in the UK and elsewhere in the mid 1980’s and is rarely used today, as a result, further up to date research would likely be seen as irrelevant or redundant.

Research on the wall cavity environment is very limited (*See 4.4*).

4.2.1 Laboratory tests.

UFFI is initially produced as a liquid foam which is injected into the wall cavity where it cures as a “wet set foam” with a high water content, the initial density of this foam is between 40 and 48kg/m³. After installation the foam will form a “dry set foam” by evaporating away the water content and releasing formaldehyde gas over a considerable time period, which can be from weeks to years in duration, to produce an acidic insulating material with a dry density of between 8 and 13kg/m³, Crawford, Shirtliffe (1982/83?). This dry set foam has a structure that can break down by *hydrolysis*, a reaction caused by the addition of moisture to the dry set foam.

In Australia research experiments were carried out with UFFI samples being exposed to varying levels of relative humidity (32% – 96%) and temperature (35°C - 60°C) under laboratory conditions. Reports give differing degrees of linear shrinkage from 6.5% to 39% for time periods of up to 1 year. At higher temperatures and RH levels of 96%, this shrinkage was seen to occur much more rapidly. At higher temperatures the shrinkage was found to occur within a few days.

The samples that exhibited the greatest shrinkage were noted to have a high acidic content above the tolerance level of the proposed Australian standard (a proposed Australian standard gave acceptable acidic values for each individual product, the British Standard gives a tolerance of ±2% of the manufacturers specification). Samples with a lower acidity were subject to less shrinkage, even when subjected to severe test conditions, Brown (1990).

Brown (1990) also stated that the effects on UFFI by temperature and RH exposure are very complex with many variables, RH levels above 85% have been seen to increase the moisture absorption of the material and 96% RH and above is termed as severe. UFFI products can be very susceptible to environmental conditions and even short exposures to extremes can cause deterioration.

In conclusion Brown (1990) states that UFFI with an acid value of more than 0.5 will shrink rapidly by up to 39% at a RH of 96% while lower acid values will shrink to a much lesser degree. All product sample tested had significantly different chemical formulations but all exhibited similar degradation when exposed to higher temperature and RH levels. Brown made recommendations that UFFI products should be able to withstand exposure to a temperature of 50°C and RH of 96% for 28 days to comply with the proposed Australian standard.

In a previous study Brown (1986) concluded that hydrolysis will promote the release of formaldehyde gas from UFFI through degradation due to temperature and humidity within its environment, however very little is known about the environment within a wall cavity.

All the above research was concerned with exposing samples to high temperatures of between 30°C and 60°C, however there was no study into the effects of low temperatures below 0°C which could be present within a cavity during very cold weather spells.

A Canadian report published during the development of a Canadian Standard for UFFI, Bowles, Shirtliffe (1980), referred to three reports including, [**Vaughan,J.L.B. Shimizu,T.Y. (1974, Oct) "Properties of Urea Formaldehyde Foam Thermal Insulation,"** ***Department of Public Works Canada, Research and Development Laboratories*****],** which detailed a number of tests that subjected fresh foam samples to cycles of freezing and thawing. According to Bowles, Shirtliffe (1980), the samples were subjected to seven cycles which involved immersion in water for 10 minutes followed by 22 hours at -18°C and then a thawing period. The other two reported similar experimentation and results (these reports could not be located so further analysis was not possible).

The study concluded that there was no evidence of resulting damage and that UFFI installed in accordance with the Canadian standard would remain in a stable condition for an acceptable time period.

4.2.2 Installed UFFI.

A later study in the UK took a total of 27 samples of UFFI, 6 were fresh samples produced for the experiment and 21 were taken from buildings, 12 were in good condition while the remaining 9 were in poor condition.

This study used NMR (Nuclear Magnetic Resonance) Spectroscopy, to look at the polymeric structure of the foam samples and digestion with phosphoric acid to determine their formaldehyde content.

The aged UFFI samples, removed from building cavities and loft spaces, were found to have significantly lower formaldehyde levels than the new test samples, the samples with the lowest formaldehyde content were in the poorest condition. The NMR spectroscopy concluded that these older samples showed signs of structural simplification which was consistent with the degradation found in the samples, Brown, Crump, Gardiner (1990).

4.2.3 Referenced research.

Brown (1986) referenced some further research, which could not be readily sourced in the UK, According to Brown, the following were noted;

i) **[Dunlap,L. (1981) The use of Urea Formaldehyde Foam for Insulation.** ***Technical Record 472, Experimental Building Section, Department of Housing and Construction, North Ryde, Australia.***]

Dunlap refers to the BBA in the UK who found that 16 years after installation, UFFI within a wall cavity showed no sign of deterioration and was still in good condition. In contrast to this Dunlap also refers to a Canadian study that indicated partial collapse of installed UFFI was evident where prolonged periods of high RH levels had been seen, 5 to 15 years after installation shrinkages of up to 33% with surface degradation were noted.

ii) **[Rossiter,W.J. Mathey,R.G. (1985) Urea-formaldehyde foam insulation: a review of their properties and performance.** ***NBS Technical Note 1210, National Bureau of Standards, Washington, DC.*****]**

Rossiter and Mathey indicated that a 5% thermal resistance could be lost for every 1% of linear shrinkage. According to this study, the shrinkage found in the study by Dunlap (1981) would result in 100% reduction in thermal resistance.

iii) **[Mayer,B. (1979) Urea-Formaldehyde Resins.** ***Addison – Wesley Publishing Co. Massachusetts.*****]**

Mayer noted that UFFI was found to be a stable product for 10 years.

iv) **[Weidt,J.L. Saxler,R.J. Rossiter,W.J. (1980) Field investigation of the performance of residential retrofit insulation.** ***Technical Note 1131, National Bureau of Standards, Washington, DC.*****]**

A study of 25 houses in the US surveyed by Weidt, Saxler and Rossiter found no deterioration of UFFI within walls due to temperature and RH, concluding that the properties were *not* in a region of the US that is subject to long periods of warm, humid conditions.

v) **[Chown,G.A. Bowen,R.P. Shirtliffe,C.J. (1981) Urea Formaldehyde Foam Insulation.** ***Building Practice Note No. 19, Division of Building Research, National Research Council of Canada.*****]**

According to Chown, Bowen and Shirtliffe, UFFI will deteriorate continuously at a significant rate, depending on exposure to temperature and RH, giving it a limited service life compared to other building materials.

4.2.4 Word of mouth.

During the writing of this paper, informal discussions were made with a number of people ranging from home owners to building control officers. Comments such as;

‘When fitting replacement windows the cavities were exposed around the window frame and they were mostly empty even though we know UFFI had been installed.’

‘We took a wall down when we had our extension built and found loads of white dust in the bottom of the cavity but no foam.”

‘Very often when I break into a wall to build an extension I find loose lumps of white foam that just get blown around and turn to dust when you touch them.’

These comments cannot be verified but give an indication of what has, or what is likely to be found in cavities. Of the people spoken to, none said they had found foam in good condition within a cavity.

4.3 The Investigation.

The investigation was in two parts;

i) This looked at five properties that had been insulated up to 40 years ago. A number of bricks were removed from the outer wall leaf of each building to expose the cavity and their contents. Photographs were taken of the holes and insulation material to provide evidence. A sample of the material was removed and analyzed.

ii) A data logger was installed in a wall cavity to monitor the environment within the cavity over a 4 month period measuring relative humidity, temperature and the dew point. During the same period local weather data was obtained for relative humidity and temperature. Local weather data from 1970 – 2010 was also obtained.

4.3.1 House 1.

The trigger point for this thesis research was the result of a thermal imaging survey carried out on House 1 in December 2010 which showed the external walls to be very patchy, (*See Figures 6. and 7.*). After analyzing the images an assumption was made that the CWI had either deteriorated or was never installed correctly from the outset. The patches appeared to correspond to a pattern that would have been used to inject the insulant into the walls during the installation process.

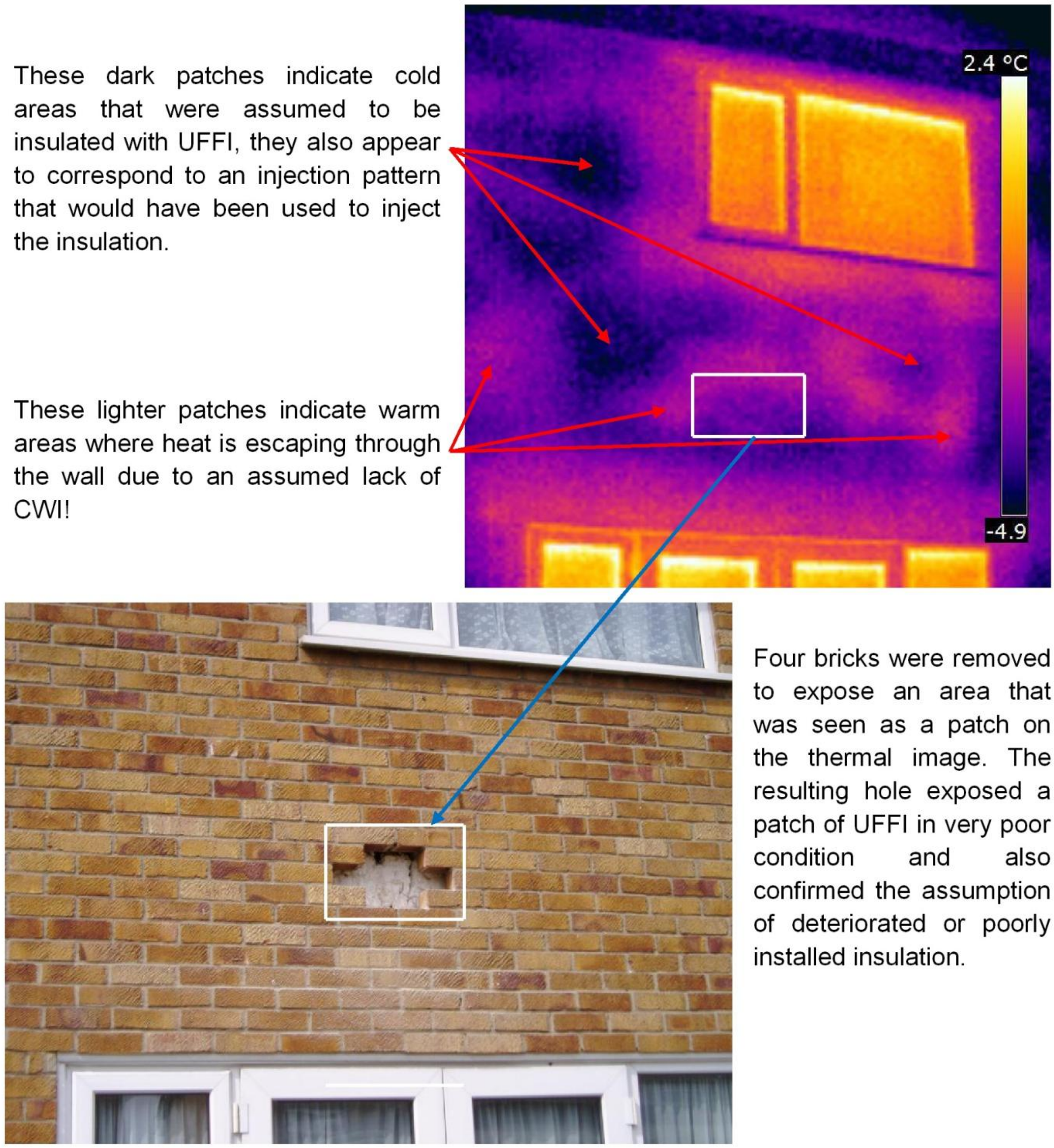
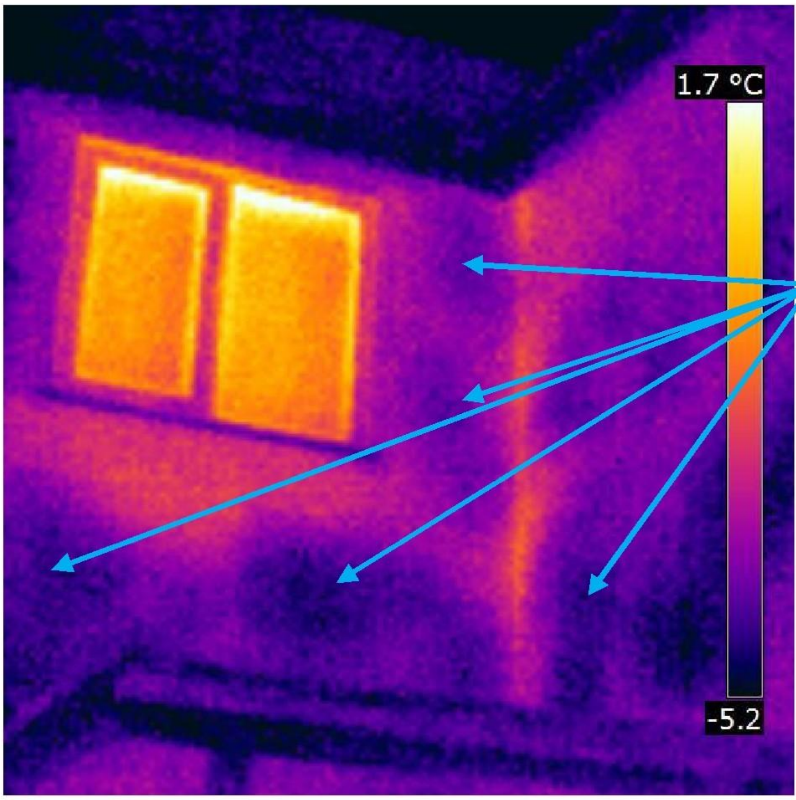


Figure 6. The two images here show the patch indicated by the thermal imaging and the corresponding hole where the bricks were removed.

The owners have lived at the property for nearly 20 years and assumed that the walls were not insulated because the house always felt cold during the winter months. They had recently had a survey carried out by an insulation installer, with the intention of having the loft insulation topped up and the cavity walls filled to take advantage of the government insulation grant scheme. On inspection they were told that the walls already had CWI installed. It was assumed, from this information that due to the age of the property and the time scale of when CWI was likely to have been installed that the insulant was UFFI. It was clear from these initial findings that further investigation was required to determine the material used and to prove the theory of deterioration or poor installation.

The walls were carefully examined to determine whether the patches did actually correspond to the injection holes but, despite a thorough search, the holes could not be located. The holes may have been filled and hidden very well or the walls may have been re-pointed at some time, it is also possible that the building was insulated during its construction and may have been filled from the inside before the building was internally finished. This initially raised the question of ‘had insulation actually been installed’?



Another view of House 1, again showing light areas indicating heat loss and dark areas assumed to be insulated. (Note the apparent pattern of the dark areas that could indicate the installation injection holes!)

Figure 7. This is a view of the front of the house, again showing patches.

An area on the wall where a patch was highlighted by thermal imaging was chosen for the investigation (*See Figure 6*), four bricks were removed from the east facing wall to make a hole to expose the cavity with the intention of trying to bridge the dark and light areas. The dark areas indicated that the wall was cold as a result of insulation in the cavity reducing heat transfer to the outside, the light areas indicated a warm wall where insulation was lacking and heat was escaping.

When the bricks were removed it was quickly confirmed that the walls were insulated and that UFFI was the material used. The condition of the foam was very poor, full of holes, very powdery, no structural strength and showed signs of shrinkage (*See Figure 8.*). There was a large void directly above and to the left of the hole, (*See Figures 9. and 10.*) the gap to the next patch of insulation was approximately 250mm wide which corresponded very well to the patch indicated on the thermal image.

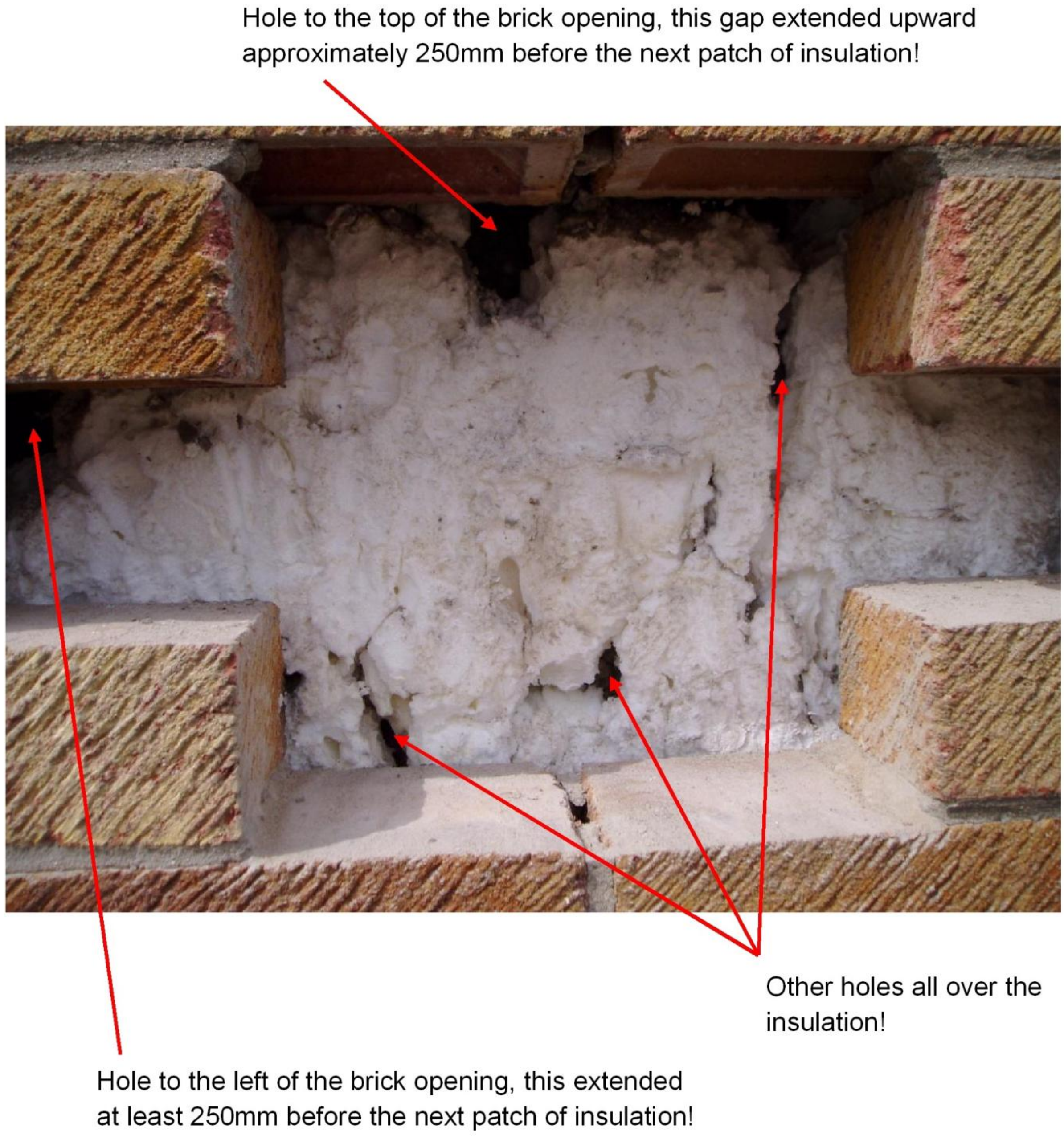


Figure 8. This shows the poor condition of the UFFI and the holes within the material and around the patch of insulation.

Figure 9. This image shows the hole at the top of the brick opening.

Figure 10. This image shows the hole to the left of the brick opening, the gap between this insulation patch and the next was approximately 250mm.

It is difficult to prove conclusively without removing further bricks but all the evidence suggests that the patches do correspond to where the insulation was likely to have been injected (*See chapter 3.5.2 Figure 5.*), which brings into question the installation and in fact the installer. It appears very likely that insufficient and poor quality insulation was injected into the cavity.

The cavity was approximately 55mm wide and there was a gap of around 15mm between the insulation and the inside of the exterior wall leaf giving an approximate shrinkage of around 27%. (*See Figure 11.*).

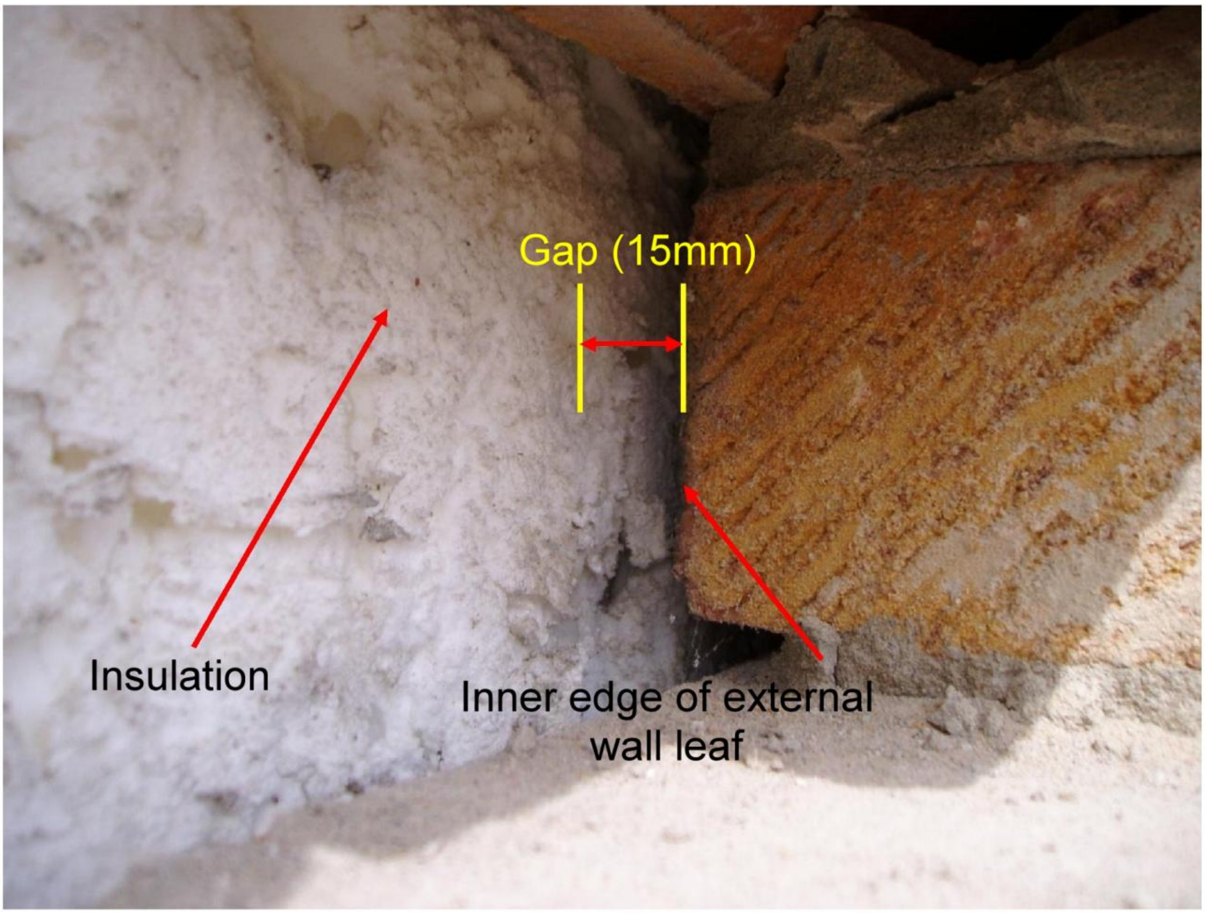


Figure 11. A close up view showing the gap between the foam and the external wall leaf.

Sample 1. *(See Figure 12.)* Taken from House 1;

Condition - This sample was very delicate and 'powdery' making it easily damaged just by trying to pick it up. Compressing the foam caused it to colapse leaving dents where contact with the material was made.

Volume = 87mm x 73mm x 40mm = $2.54 \times 10^{-4} m^3$

Weight = 2.75×10^{-3}kg (weighed using 'Sartorius PRO28/3BC' counting scales which are calibrated annually)

Density = $1m^3 \div 2.54 \times 10\text{-}4m^3 \times 2.75 \times 10^{-3}kg = 6.98kg/m^3$

The density of installed UFFI should be between 10 and 12kg/m³, CIGA (2011), Wilkinson,M.A. (2001). BS 5618:1985 appendix J gives a desired minimum density of 6kg/m³, BSI² (1999).

The sample has a density deficiency of approximately 30% of its target value (this target value was defaulted as 10kg/m³ because no information was available on the supplier or specification of the material), the tollerance is ± 25% of the suppliers specification, (*See chapter 2.3.1*). The sample weighs in at 5% below the minimum tollerance allowed but is still within the BS 5618 desired minimum density of 6kg/m³.

Photographs 1, 2 and 3 show the dimensions of sample 1, these measurements were used to calculate the density of the sample.

Figure 12. Sample 1.

The thermal images of House 1 showing very patchy CWI (*See Figures 6. and 7.*), prompted a search to find a company who would be prepared to refill the void areas of the cavity using further thermal imaging to identify these areas. One response received was;

"The stock answer is that once a cavity wall has been insulated it cannot/shouldn't be 'topped up' or displaced. The situation is that you are not permitted to mix materials in a wall and identifying precisely any areas requiring remedial work is very difficult. The option of removal is also very expensive and any re-fill shouldn't receive the benefit of the current subsidies available as the property has already received the improvement." Roberts (2010).

4.3.2 House 2.

The second building investigated was built in the early 1970's and had CWI installed, possibly in the 1970's, (an exact date for the installation could not be determined, the current owners have only lived in the property for a few years and have no information on the installation).

Four bricks were removed from the south facing wall on the ground floor. As can be seen in *Figure 13.* there were gaps in the insulation to the left and the bottom of the hole.

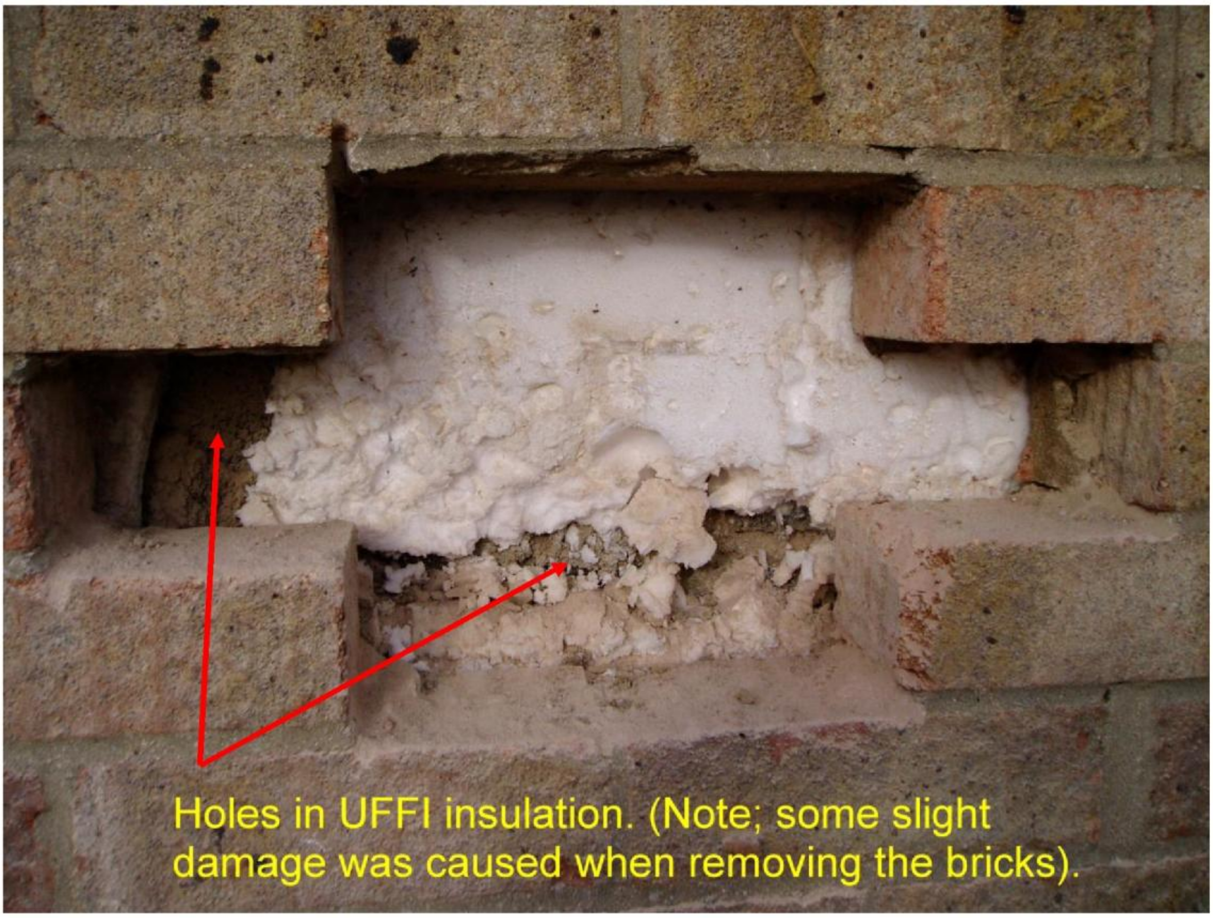


Figure 13. Hole where 4 bricks were removed showing the UFFI within the cavity.

Figure 14. shows a close up of the left hand hole in the insulation. On further inspection the hole appears to be a crack, the edges of the material are parallel so were presumed to have pulled apart along a weak line, most likely where two injections met during installation.

Figure 14. Close up of the crack running vertically to the left of the Investigation hole.

The assumption from finding these cracks is that the foam has been subjected to shrinkage which has effectively produced patches of foam by pulling the foam apart. It would appear that the cracks have developed at the joint where two injections meet, this is likely to be a weak point in the structure of the foam. *Figure 15.* is an impression of how the foam may appear if the UFFI was fully exposed, the centre of each patch being the point of injection. This would be very difficult to prove conclusively without removing the whole of the outer wall leaf, if this did prove to be the case, it would indicate that the wall was incorrectly filled because the foam pattern would not be as specified in BS 5618:1985 and shown in *Figure 5,* chapter 3.

Figure 16. is a photograph of the wall investigated showing the area where the bricks were removed, the location of the cracks and the position of the injection holes. This provides evidence to support the assumption that the foam may have cracked between the injections.

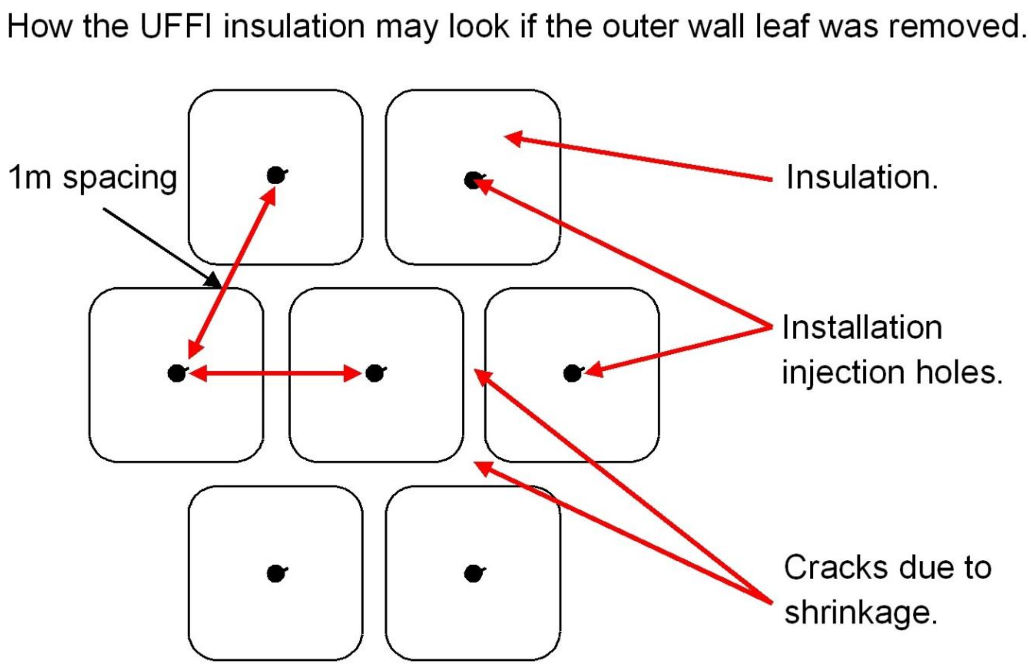


Figure 15. An impression of how the UFFI may appear if fully exposed.

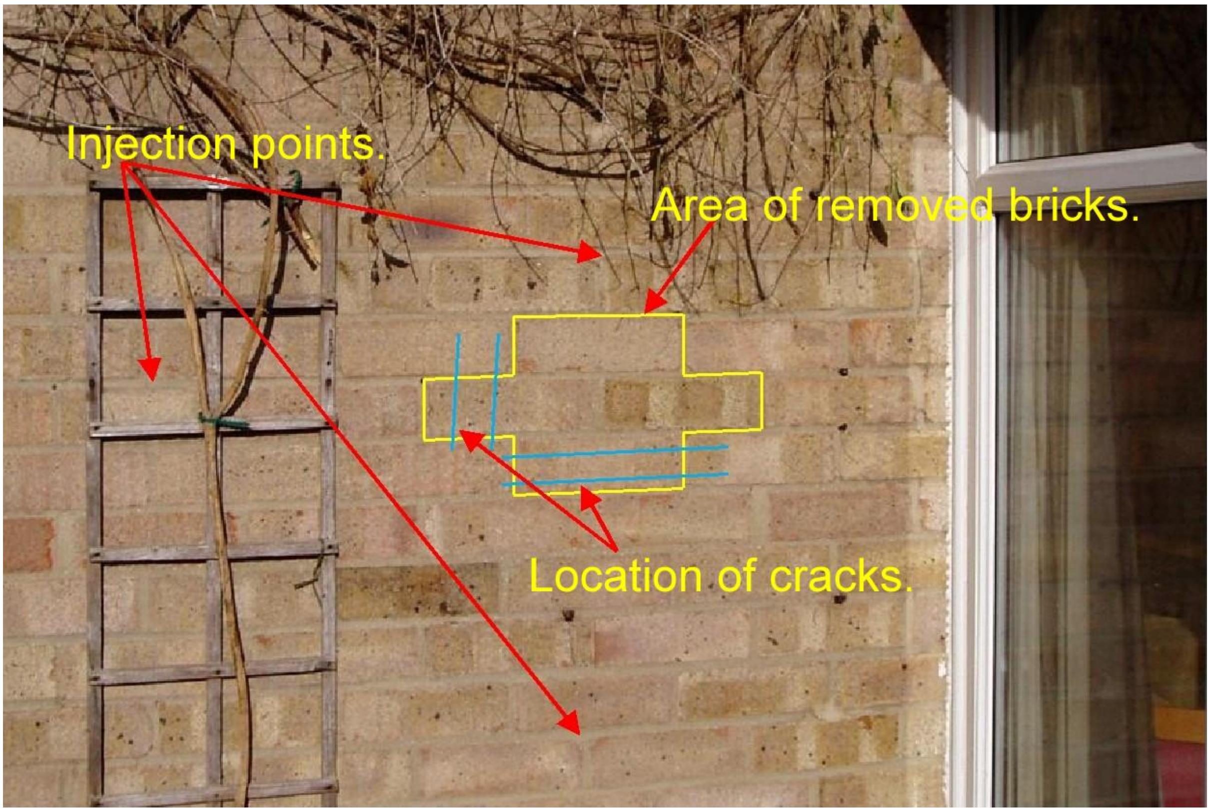


Figure 16. Photograph of House 2 investigation wall.

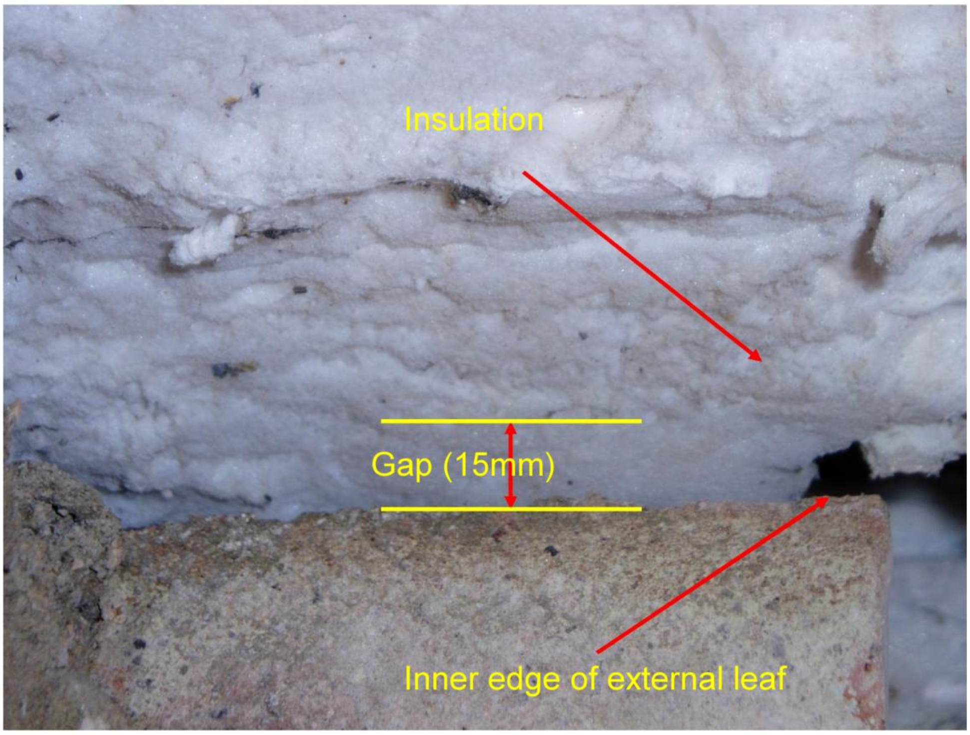


Figure 17. Gap between the inner edge of the outer wall leaf and the insulation.

Figure 17. illustrates a gap between the inside of the exterior wall leaf and the insulation of around 15mm, the cavity was approximately 55mm wide with the insulation being around 40mm thick which indicates an approximate shrinkage of 27% assuming the cavity was fully filled on installation.

If the insulation has suffered 27% shrinkage over the entire installation this could have resulted in a linear shrinkage of up to 270mm per meter, without exposing a square meter of cavity and insulation this is only an assumption based on the evidence available. The cracking seen in figure 2 was approximately 50-60mm wide over a range of around 460mm, there is likely to be further cracking within a square meter so in this case it could result in a gap of at least 100mm.

Sample 2. (*See Figure 18.*) This was taken from House 2;

Condition - This sample had a spongy feel to it, when compressed very lightly it returned to its original shape although handling it also caused it to flake.

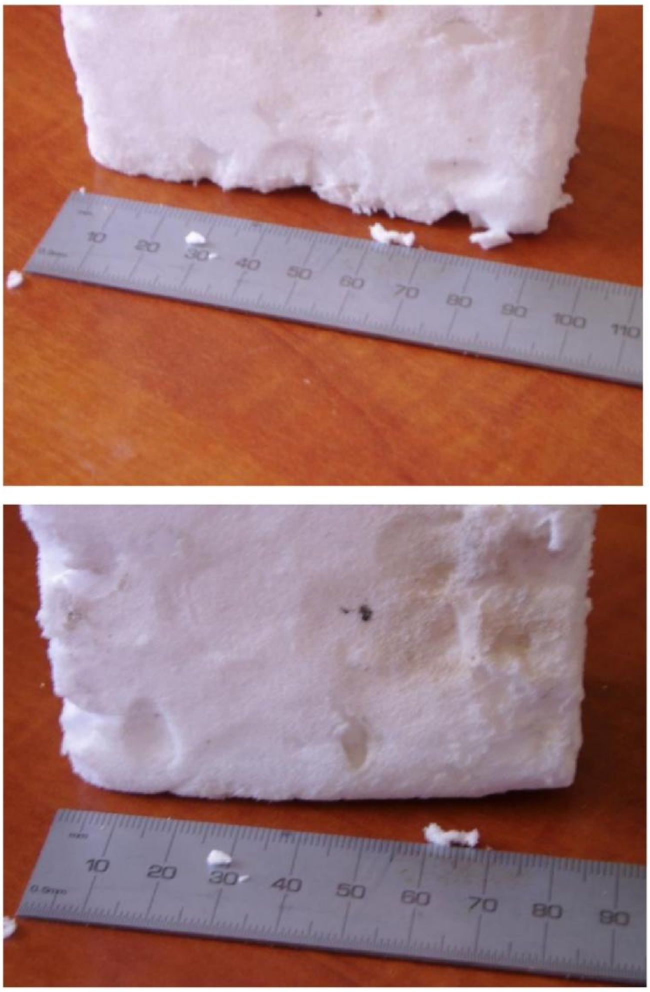
Volume = 80mm x 90mm x 40mm = $2.88 \times 10^{-4} m^3$

Weight = 2×10^{-3}kg (weighed using ‘Sartorius PRO28/3BC’ counting scales which are calibrated annually)

Density = $1m^3 \div 2.88 \times 10\text{-}4m^3 \times 2 \times 10^{-3}kg = 6.9kg/m^3$

The sample has a density deficiency of approximately 31% of its target value (defaulted to 10kg/m³ *See 4.2.1 Sample 1*) .

The sample weighs in at 18% below the minimum tollerance allowed.



Photographs 1, 2 and 3 show the dimensions of sample 2, these measurements were used to calculate the density of the sample.

Figure 18. Sample 2.

4.3.3. House 3.

The third building investigated was built in 1968 by the present owner, it had CWI installed in the early 1970’s but no date or further details were available. Four bricks were removed from the north facing wall on the ground floor. *Figure 19.* shows the wall and the original injection holes that were used during the installation.

Figure 19. Photograph of House 3 investigation wall.

There was a similar crack in the insulation to that found in **House 2,** as can be seen in *Figure 20.* From the injection holes indicated in *Figure 19.* it would appear that the crack has formed half way between the injection holes which would correspond to where the join in the insulation from the separate injections would be. This is evidence that points to the possible cracking pattern illustrated in *Figure 15.* for **House 2** above.

Similar to **House 2**, *Figure 21.* shows a significant gap between the inner edge of the external wall leaf and the insulation of around 20mm, the cavity was approximately 70 - 75mm wide so shrinkage of around 15% is evident.

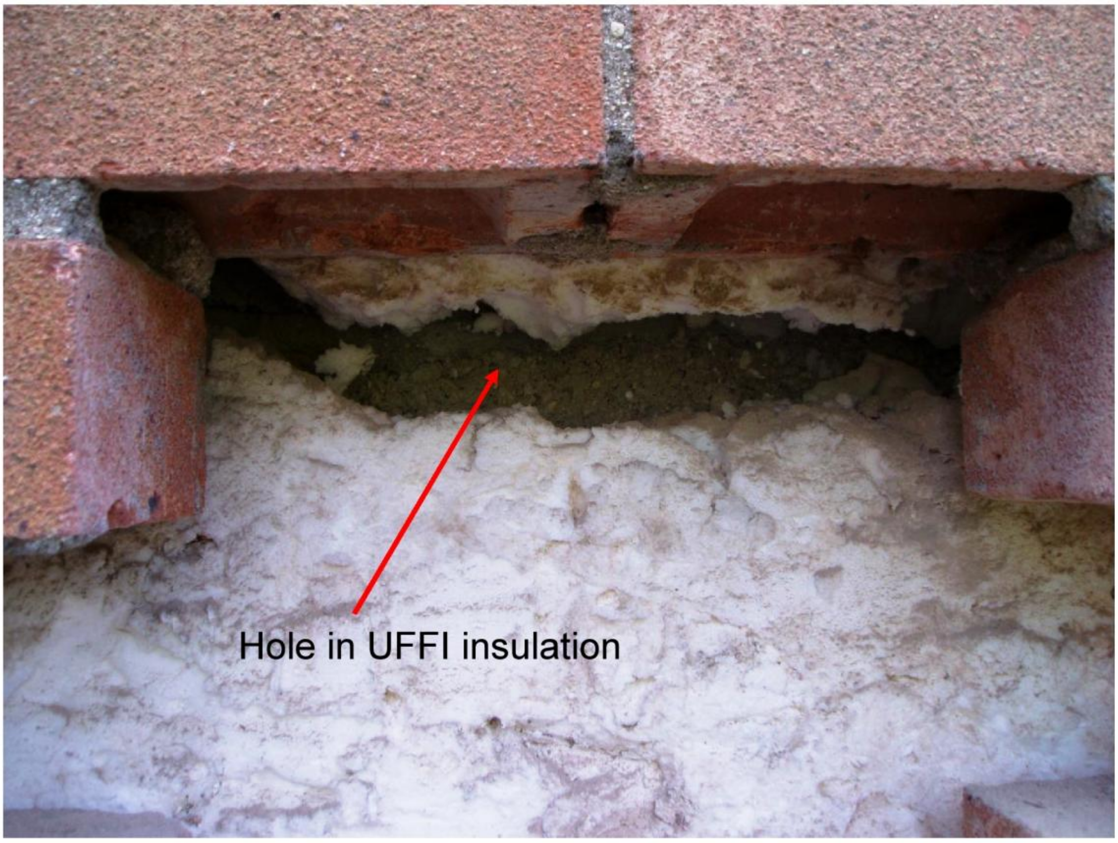


Figure 20. Photograph showing similar cracking to that found in House 2.

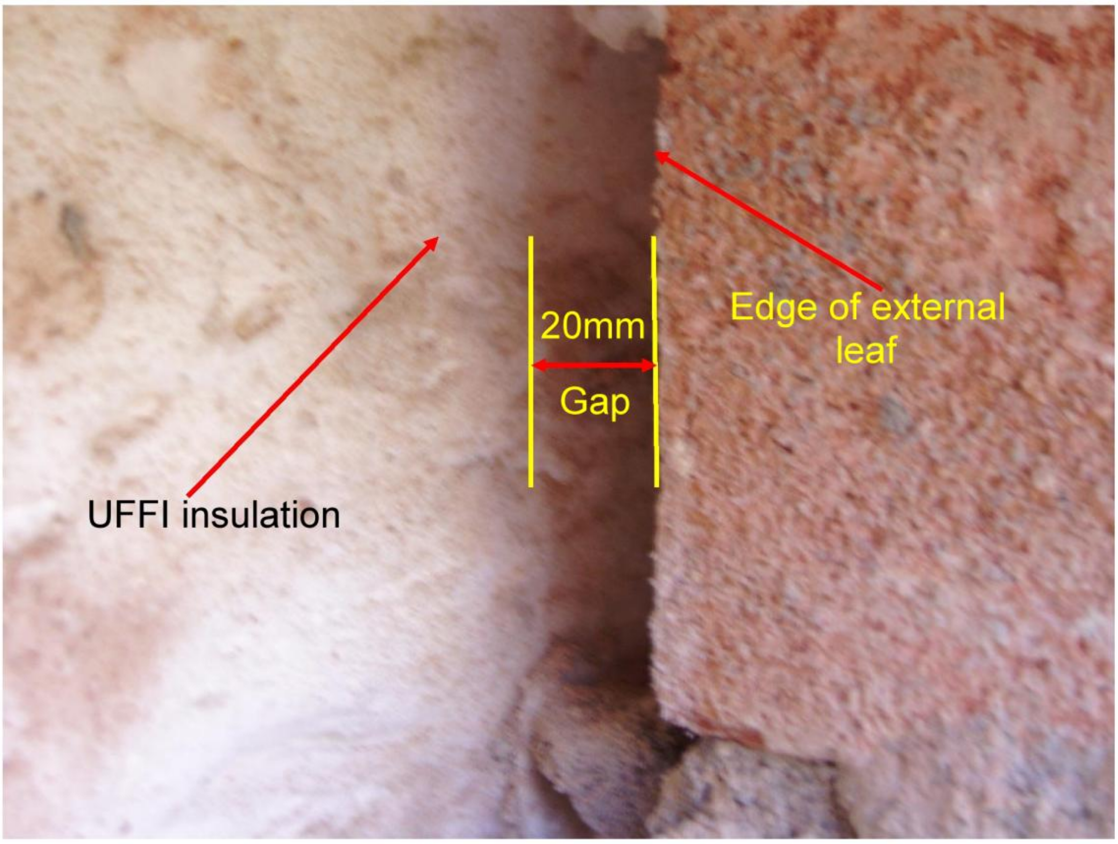


Figure 21. Photograph showing shrinkage gap.

Sample 3. (*See Figure 22.*) This was taken from House 3;

Condition - This sample had reasonable structural strength which when compressed very slightly (on the side which faced the exterior wall leaf), returned to its original shape, compressing more heavily resulted in denting. The side that faced the internal wall leaf showed evidence of possible chemical damaged as shown in *Figure 23.* this side was very brittle and had a 'crunchy' feel to it when compressed causing the material to powder. Without further investigation it is not possible to determine the cause of this damage, however, this sample was taken from a kitchen wall and could possibly be due to moisture and oils from the kitchen environment breaching the inner wall over many years and coming into contact with the foam. (None of the other samples displayed similar damage however one other was taken from a kitchen wall).

Volume = 135mm x 75mm x 55mm = $5.67\times10^{-4}m^3$

Weight = 6.8×10^{-3}kg (weighed using 'Sartorius PRO28/3BC' counting scales which are calibrated annually)

Density = $1m^3 \div 5.67\times10\text{-}4m^3 \times 6.8\times10^{-3}kg = 11.99kg/m^3$

The density of installed UFFI should be between 10 and 12kg/m³, CIGA (2011), Wilkinson,M.A. (2001).

The density of this sample is well within the allowable tollerance of ± 25% assuming the suppliers specification was 10 – 12kg/m³ (again due to no available installation data this cannot be verified).

Photographs 1, 2 and 3 show the dimensions of the UFFI sample taken from House 3. These measurements were used for calculating the density of the material.

Figure 22. Sample 3.

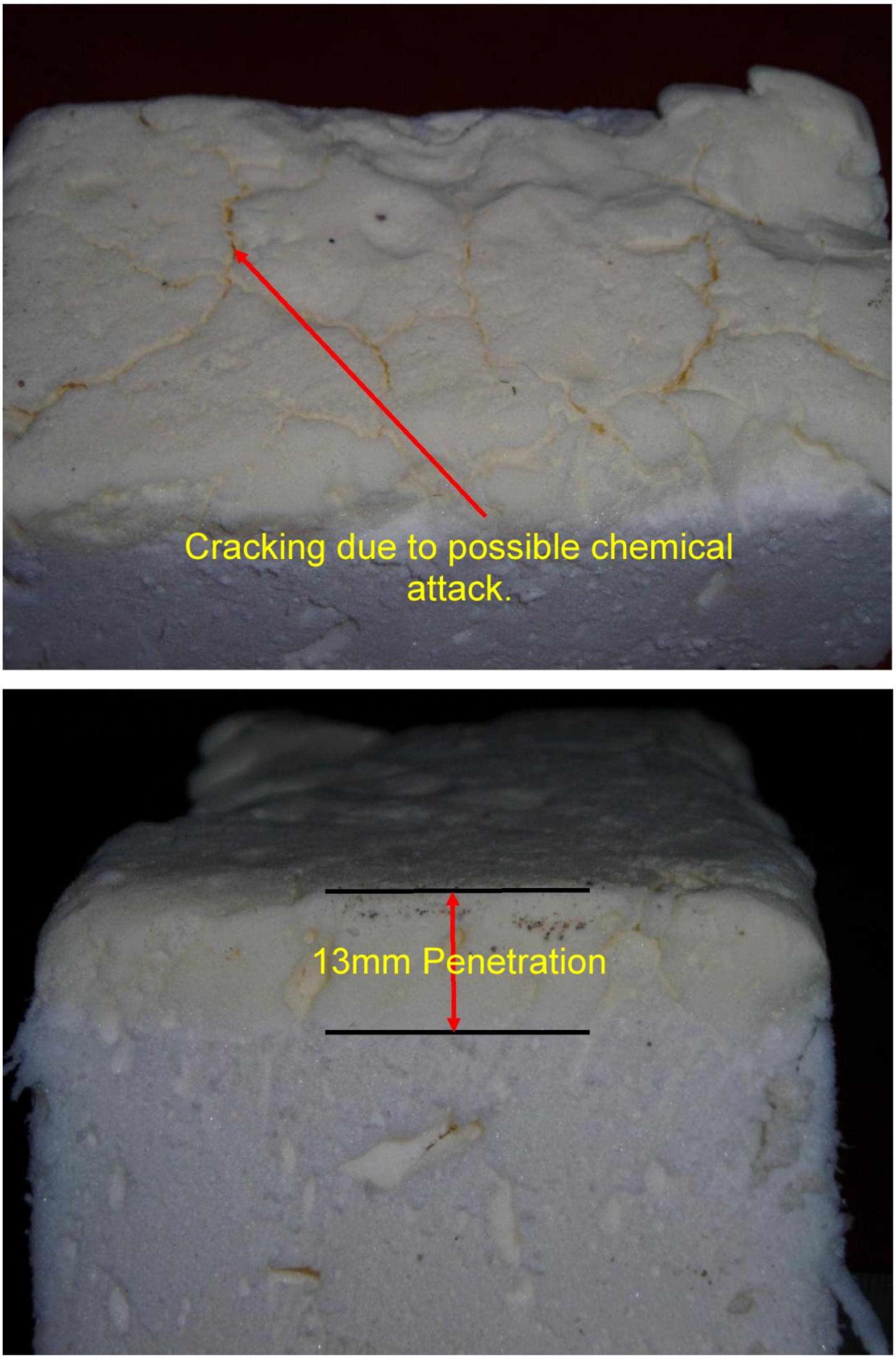


Figure 23. Sample 3 showing signs of chemical damage.

4.3.4 House 4.

This house was built in the late 1960's and had CWI installed on the 25th November 1975, the current owners had the insulation installed and still have the original documentation with a guarantee for 20 years.

The installation was carried out before all the relevant British Standards associated with UFFI were published and as a result will not have been carried out according to any official standards.

BS 5617 – (*See 2.3.1*) *first published August 1978.*
BS 5618 – (*See 2.3.2*) *first published August 1978.*
BS 5628-3:2001 – Code of practice for use of masonry — Part 3: Materials and components, design and workmanship. *First published March 1985.*
BS 8104:1992 – (*See 2.3.4*) *first published 15th August 1992.*
BS 8208-1:1985 – (*See 2.3.3*) *first published 31st July 1985.*

Four bricks were removed from a south facing wall, the UFFI was in a poor condition with cracks running through and around the inspection area, a large piece of the foam had actually broken away and was only held in place by the bricks that were removed (*See Figure 24.*).

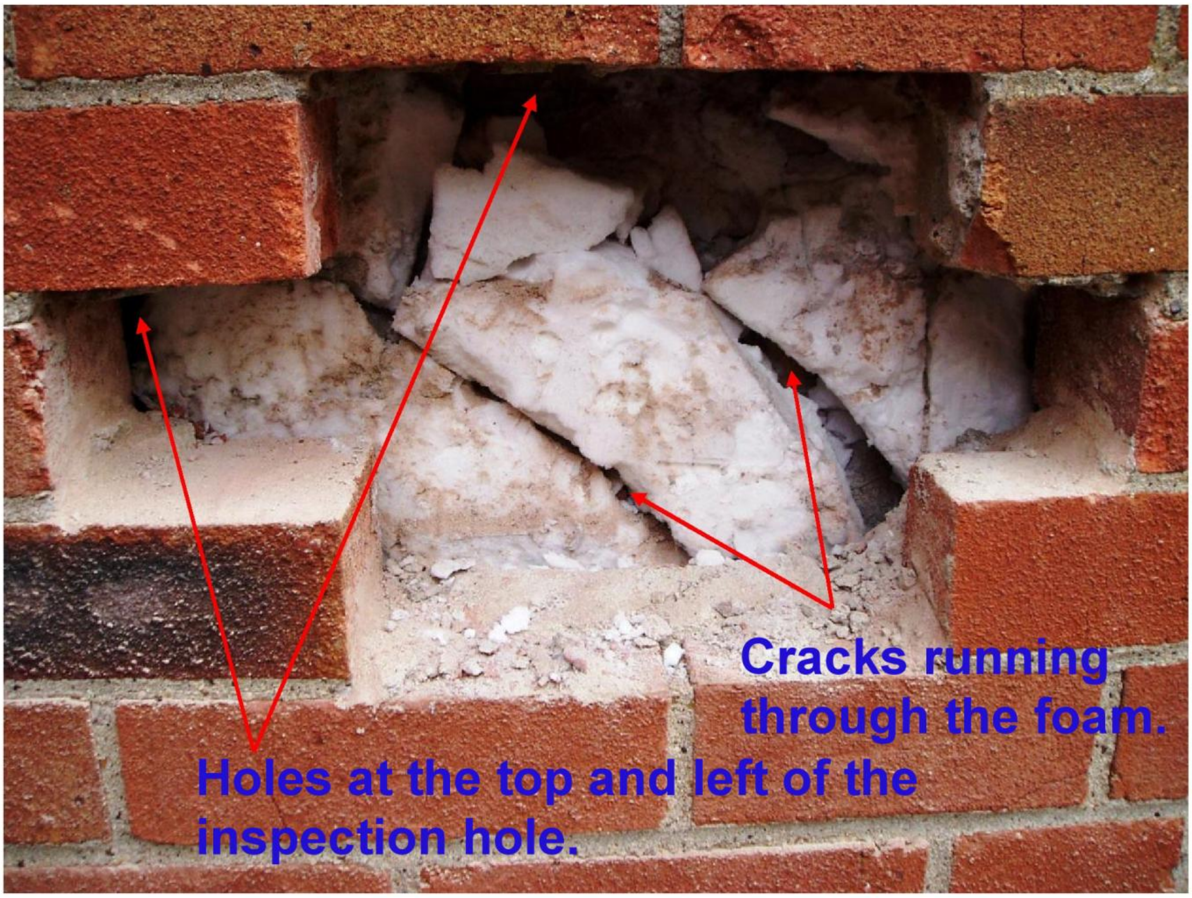


Figure 24. A view of the investigation hole showing cracks in the foam and holes at the top and to the left.

Figure 25. Close up of the hole at the top of the inspection hole, notice the remains of UFFI on the brickwork at the back of the hole.

The hole at the top of the inspection area was measured and was found to extend upwards by at least 250mm before any further UFFI was found.

The back of the hole has traces of UFFI remaining on the brickwork indicating that the cavity had previously been fully filled, due to the cracking found it is believed that the foam has shrunk considerably and been pulled apart during this shrinking leaving these remnants.

There was evidence of further cracks around the edge of the investigation hole extending vertically as illustrated in *Figure 25*.

An extension was built adjacent to this wall some time ago, approximately 2m to the left of the investigation area. It is possible that the foam could have become damaged during the construction of this, however with a distance of around 2m to the extension this is thought to be unlikely, further investigation would need to be carried out to verify this.

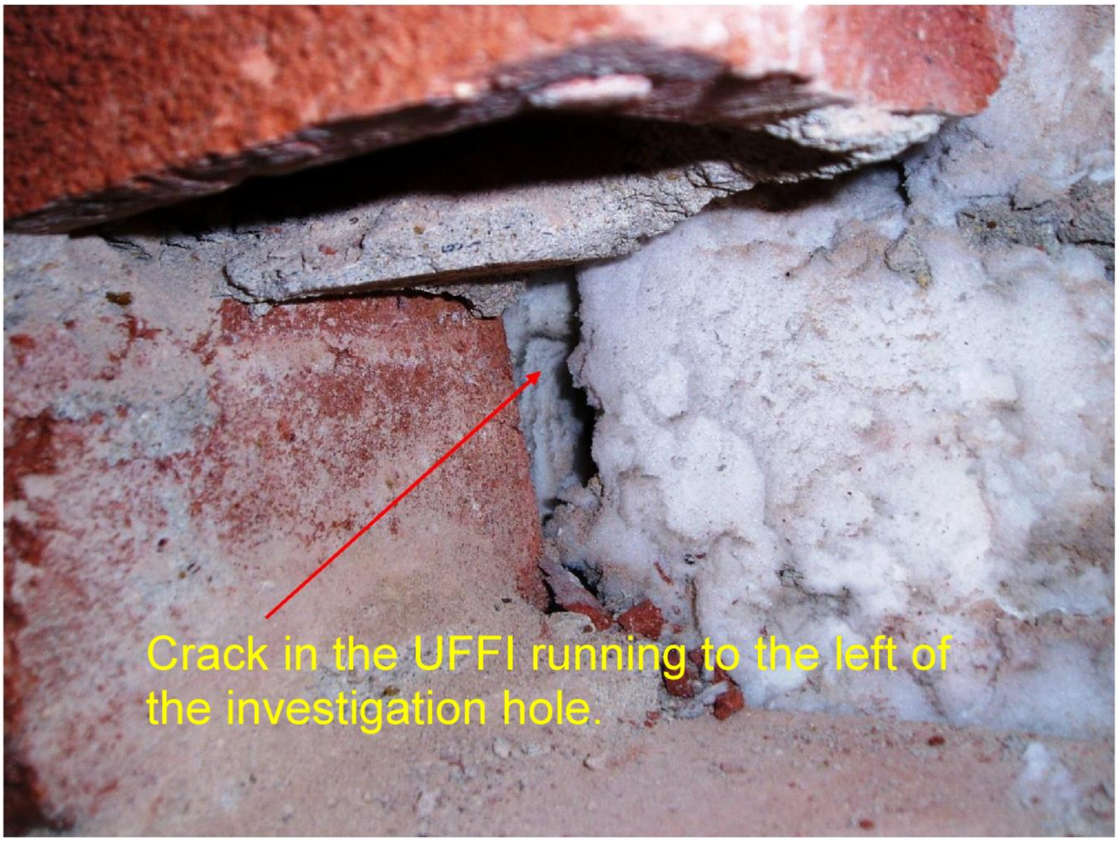


Figure 26. Evidence of further cracks.

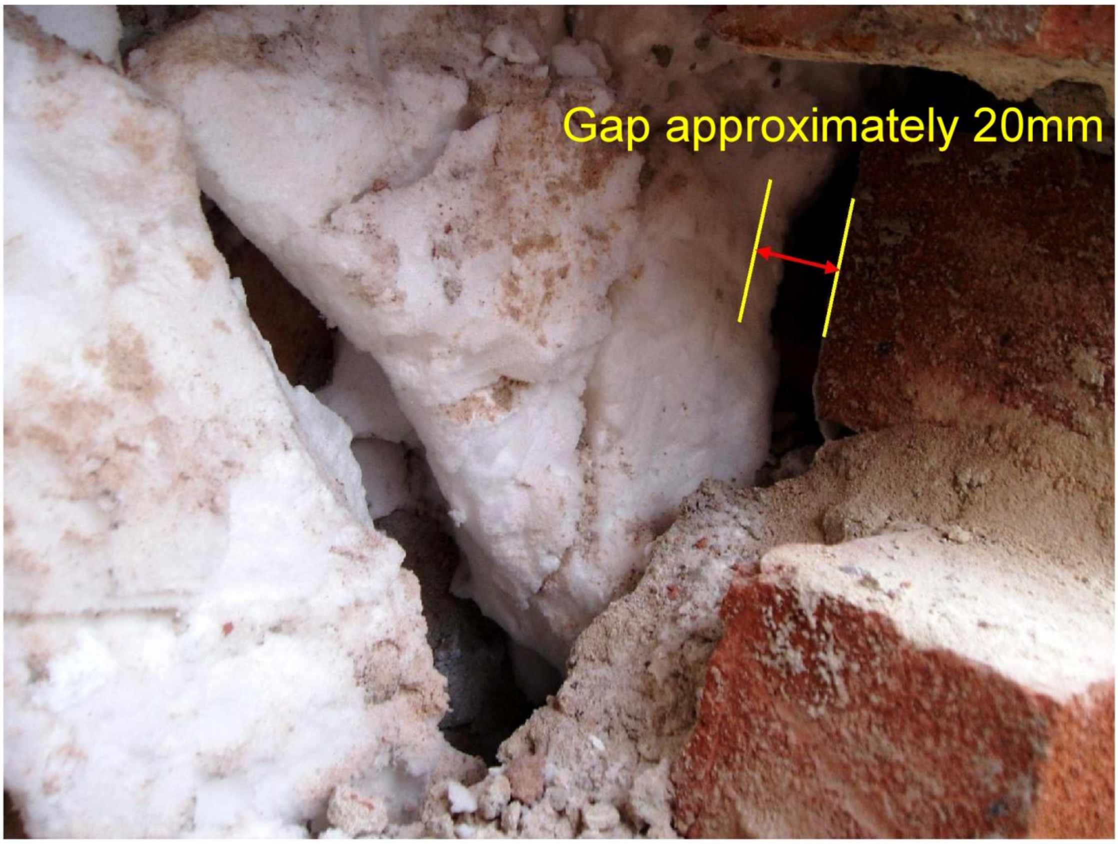


Figure 27. Gap indicating a 20mm gap and approximately 30% shrinkage.

The cavity was about 60mm wide with a gap of around 20mm between the inner side of the external wall leaf and the foam representing shrinkage of approximately 33%.

Sample 4. (*See Figure 28.*) This was taken from House 4;

Condition - This sample was very brittle and felt ‘crunchy’ when compressed, turning to dust.

Volume = 85mm x 75mm x 40mm = $2.55 \times 10^{-4} m^3$

Weight = 2.55×10^{-3}kg (weighed using ‘Sartorius PRO28/3BC’ counting scales which are calibrated annually)

Density = $1m^3 \div 2.55x10\text{-}4m^3 \times 2.55 \times 10^{-3}kg = 10kg/m^3$

The sample has a density well within the limits set out in BS 5617:1985.

The original paperwork for the UFFI installation was available for this property, the product was ICI ‘Ufoam Plus’ and, according to the ICI data booklet, *“Developed by ICI and installed only by ICI Insulation Service”*. The manufacturers data sheet specifies;

Density = 8 – 10kg/m³.

Thermal conductivity = 0.031W/mk

Agrément certificate number 74/209-75/AM12 (this certificate no longer exists).

It also gives a predicted ‘U’ value of 0.57W/m²k for normal cavity wall structures. There is no mention of the acidity of the product.

There is a quote on the front of the manufacturers data booklet, ICI (1975);

“........ we consider a cavity filling to be a perfectly safe method of providing thermal insulation as long as it is done in the right way to the right house. We have, in fact, specified it as one of the ways in which our new thermal insulation standards can be met”. - Mr Gerald Kaufman MP, Under Secretary of State for the Environment, House of Commons 4/2/75.

Photographs 1, 2 and 3 show the dimensions of sample 4 that were used to calculate the density.

Figure 28. Sample 4.

4.3.5 House 5

This house was built in the 1940's/50's and had CWI installed on 5th July 1977, the owner still has the original paperwork including a 20 year guarantee.

Four bricks were removed from a west facing wall on the side of the property. As can be seen in *Figure 29.* there was a significant crack discovered over 150mm wide in some places, running vertically through the investigation hole. The crack was measured upwards from the hole (*See Figure 30.*) and was found to extend at least 250mm, and downwards (*See Figure 31.*) extending to over 500mm.

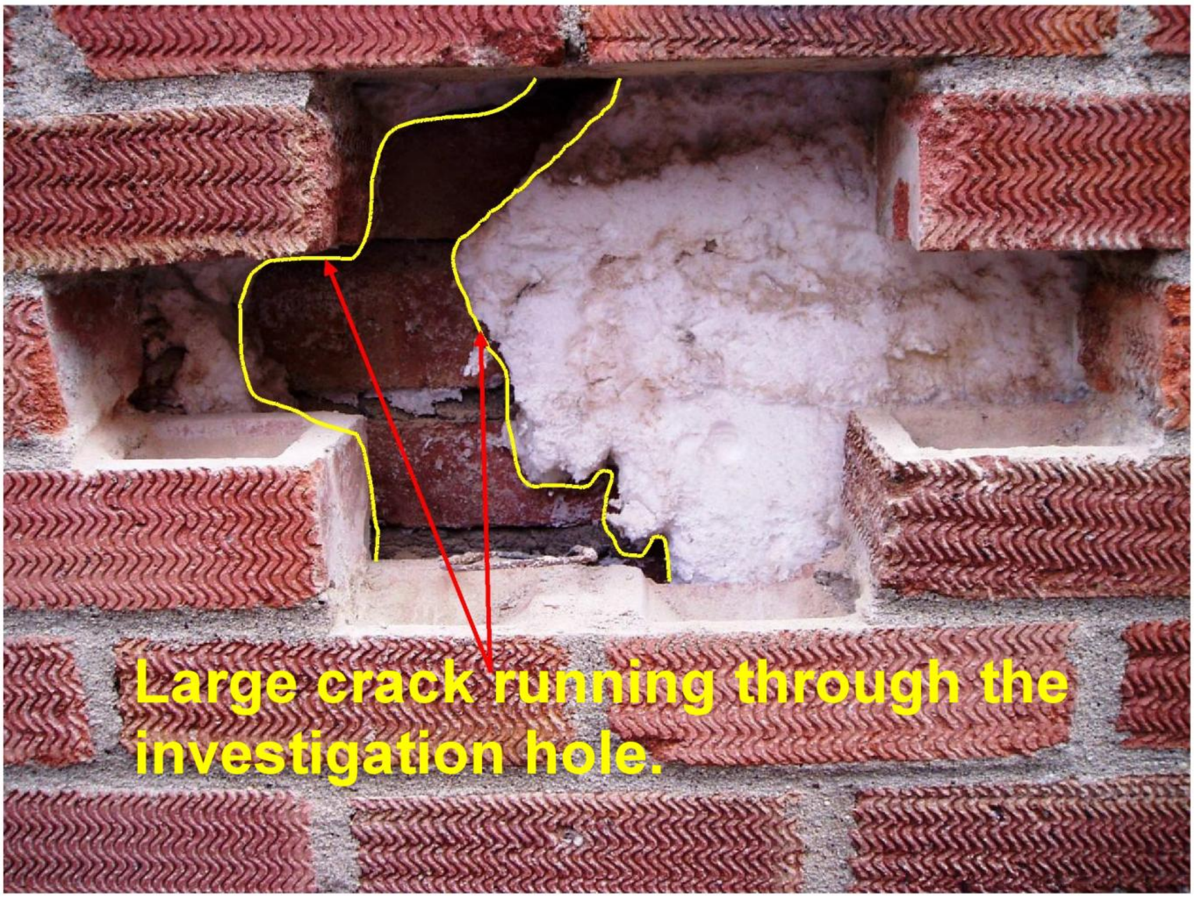


Figure 29. View showing the investigation hole and the large crack that was present.

Figure 30. A view of the hole at the top of the investigation hole.

Figure 31. A view down the hole at the bottom of the investigation hole.

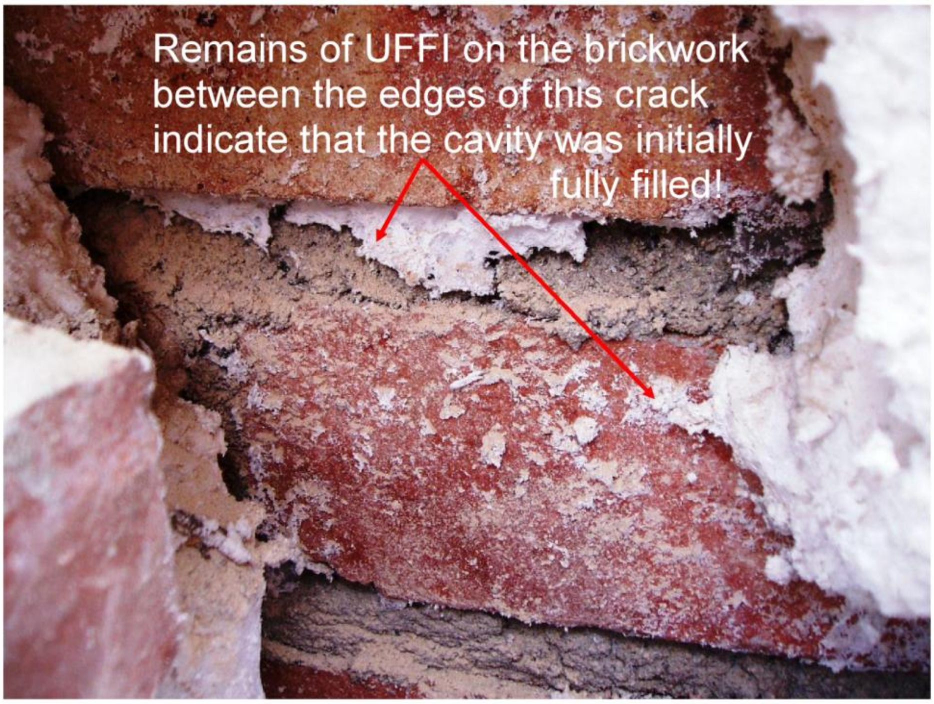


Figure 32. Remnants of UFFI stuck to the brickwork.

Figure 32. shows remnants of UFFI stuck to the brickwork within the crack in the foam which indicates that the cavity was originally fully filled. This crack is likely to have developed due to shrinkage but it is not known how long it took for the crack to form, this may have happened over many years or could have occurred during the first year or two after installation. If cracking occurred during the first few years (within the 20 year guarantee period), which is highly likely, a claim could have been made against the guarantee but as it cannot be seen this was never likely to happen.

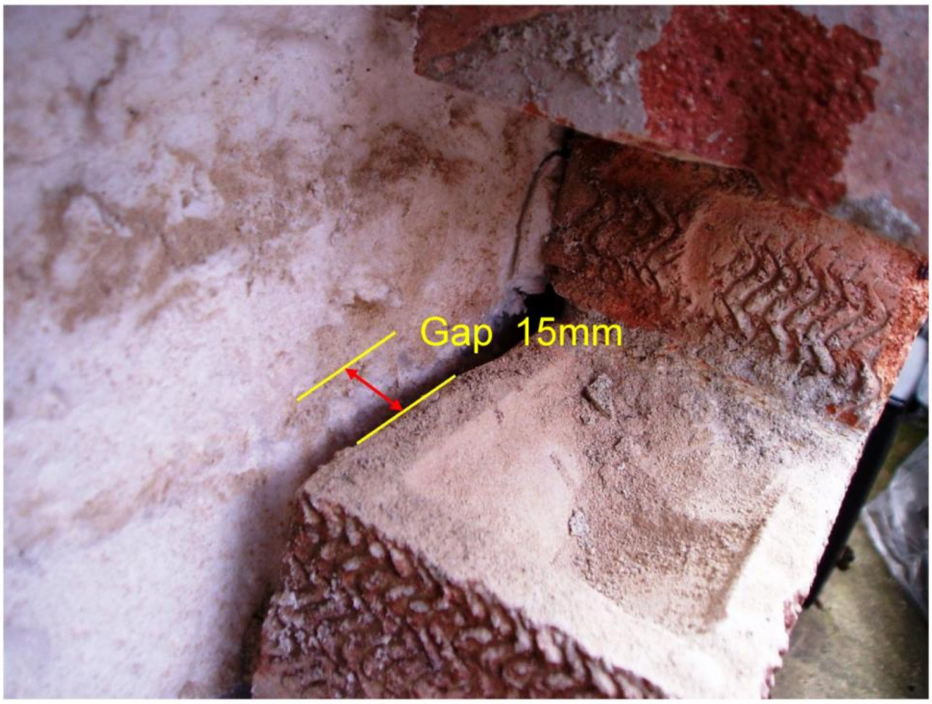


Figure 33. Gap between outer wall leaf and UFFI.

The cavity was approximately 65mm wide, *Figure 33.* shows a gap of approximately 15mm between the foam and the outer wall leaf indicating 23% shrinkage.

Sample 5. (*See Figure 34.*) This was taken from House 4;

Condition - The UFFI was in relatively good condition and had a ‘springy’ flexible texture to it although it flaked during handling.

Volume = 95mm x 110mm x 50mm = $5.23x10^{-4}m^3$

Weight = $5.37x10^{-3}kg$ (weighed using ‘Sartorius PRO28/3BC’ counting scales which are calibrated annually)

Density = $1m^3 \div 5.23x10\text{-}4m^3 \times 5.37x10^{-3}kg = 10.27kg/m^3$

The sample has a density well within the limits set out in BS 5617:1985.

Although the original paperwork was available for this sample there were no manufacturers details with it only the installers stating “Approved Installers under the terms of Agrément Certificate no. 74/261” (this certificate no longer exists). The information sheet claimed *“treatment with UF foam can reduce the loss of heat through the walls by as much as 75%.”* and *‘total heat loss can be reduced by 30% by installing UFFI’*, Foam Insulation (<1977).

Photographs 1, 2 and 3 show the dimensions of sample 5 that were used to calculate the density.

Figure 34. Sample 5.

4.4 Cavity monitoring.

One of the most important factors that can have an effect on the UFFI installation is the environment within a cavity. It is subjected to large temperature changes throughout the year and varying levels of relative humidity which have been proven to cause damage and shrinkage to UFFI samples under laboratory conditions (see 4.2). The only research that could be found during the writing of this paper was from a study of three properties in Australia which were monitored for 1 year each. This study found that there can be large fluctuations in temperature and RH on a daily basis within a wall cavity, Cole (1994).

A Lascar EL-USB-2 data logger which measures temperature and RH with a range of -35 to +80°C (accuracy ±0.3°C) and 0 to 100%RH (accuracy ±2.0%RH) set to take readings at 30 minute intervals, was placed in a west facing wall cavity in the writers home, *Figure 35.* for 16 weeks. The period monitored was 24th February to 16th June 2011.

Figure 35. Cavity monitoring.

The local MET office weather station is at RAF Brize Norton which is approximately 16 miles to the west of the property. Weather data covering temperature and RH for the same period as the monitoring was obtained from the met office to enable a comparison between the external environment and the internal cavity environmental conditions. Comparing these figures could determine how weather conditions can influence the cavity climate.

Weather data was also obtained for the same area for the period 1970 – 2010 to assess how the climate within a wall cavity could have varied since UFFI was installed during the 1970's. Using this data an assumption of how likely serious UFFI degradation could have occurred, influenced by climatic conditions, within wall cavities.

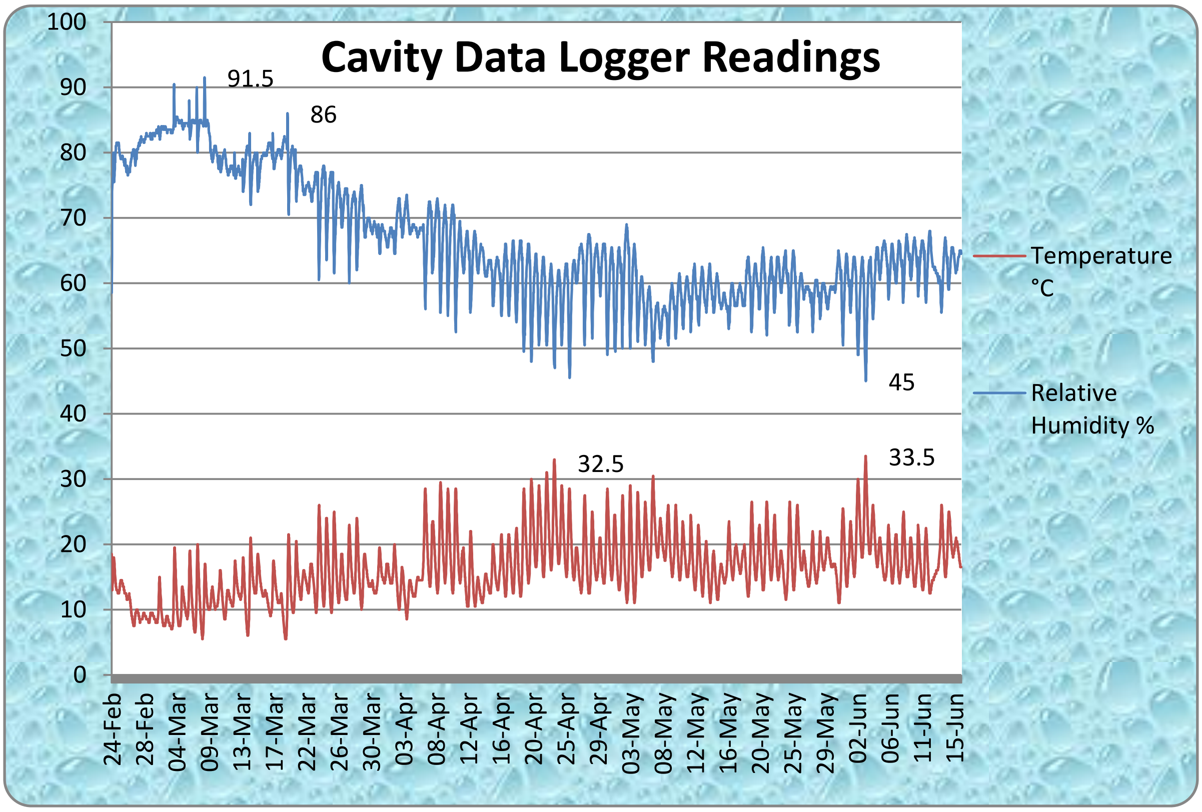


Figure 36. Cavity data graph.

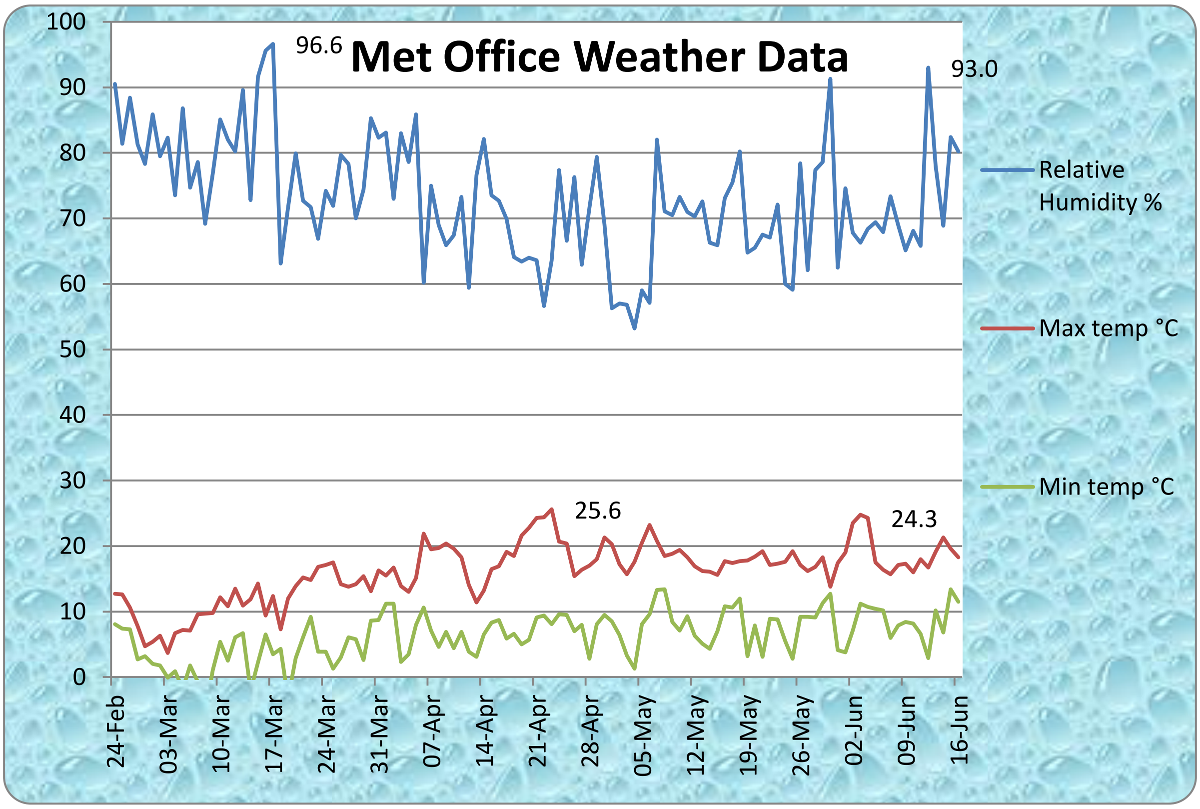


Figure 37. Local weather data from the Met office at Brize Norton, Met Office[1] (2011).

4.4.1 Weather summary.

Figure 36. is a graph showing the temperature and RH readings obtained from the data logger, inserted into the cavity of the writers home, covering the period 24th February to 16th June 2011 a total of 16 weeks.

Figure 37. is a similar graph using data for the same period obtained from the Met office at RAF Brize Norton, it shows daily maximum and minimum temperature readings and the daily mean RH readings.

Weather summary and statistics for the monitoring period.

February 2011 – February was a relatively mild month, the 9th mildest since 1911 with the average temperature being 2°C above the 1971 – 2000 averages. The weather was predominantly from the west with around average rainfall for the Oxfordshire region, BBC[1] (2011).

March 2011 – March was a particularly dry month with over 80% less rainfall than usually experienced and although the average temperature was around 0.6°C above the 1971 – 2000 average, there were some very warm (19.8°C recorded in southern England) and sunny days particularly in the latter part of the month, BBC[2] (2011).

April 2011 – April was an exceptionally warm month with temperatures 3.7°C above the average for this time of year and the warmest in central England for over 350 years. The highest temperature recorded was 27.8°C. Less than 10% of the average rainfall was seen during the month, the 6th driest since 1910 with well above average sun shine, BBC[3] (2011).

May 2011 – May was again a very dry month with less than 30% of the average rainfall for the month and an average temperature 1°C above 1971 – 2000 averages. It was a relatively dull month with heavy cloud cover much of the time and strong winds experienced at times over the Oxfordshire area, BBC[4] (2011).

June 2011 – June began with some periods of prolonged rainfall, around average for the month, the temperature was also about average, although it was the coolest June since 2001. Following the exceptionally dry spring, on the 10th, some parts of the UK were declared to be in drought conditions, BBC[5] (2011).

4.4.2 Historical weather data.

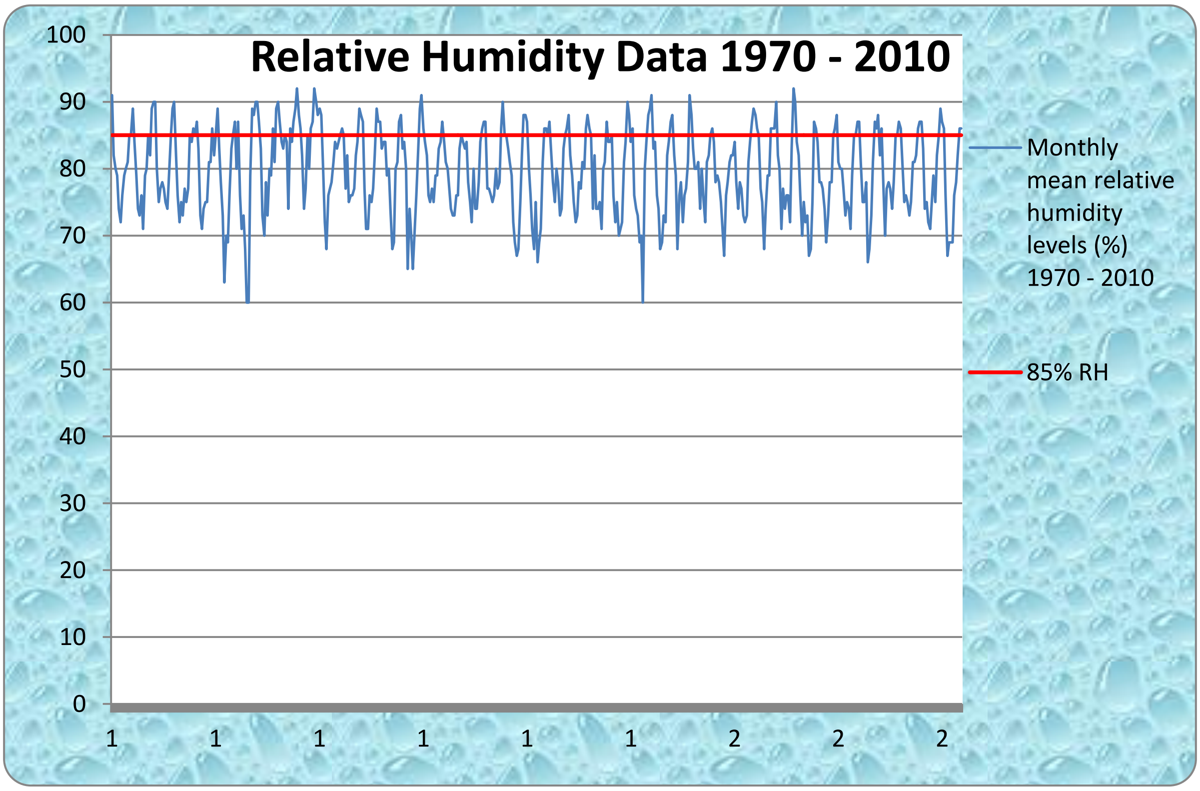


Figure 38. Recorded relative humidity levels for Brize Norton from 1970 – 2010, Met Office² (2011).

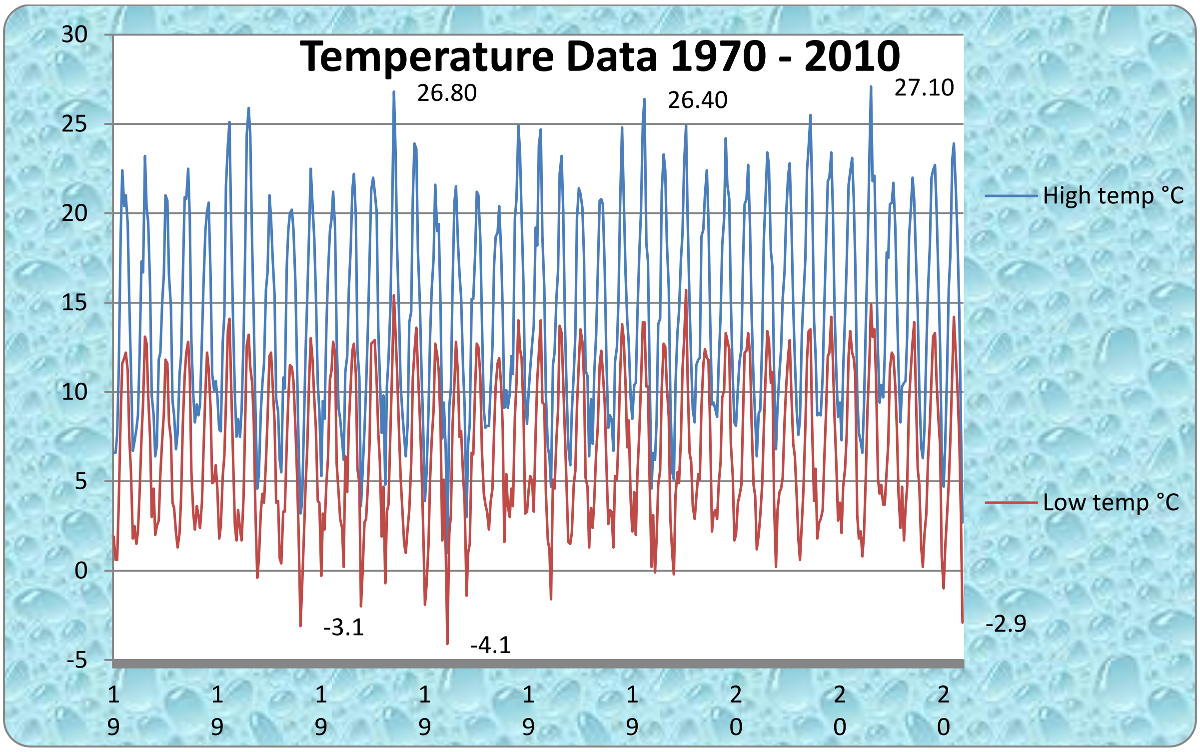


Figure 39. Recorded monthly High and low temperature levels for Brize Norton from 1970 – 2010, Met Office[3] (2011).

UFFI in the UK has predominantly been installed since the early 1970's although some properties were insulated before this. For this study, historical weather data for the local area to the author's home was acquired from the Met Office at Brize Norton covering the period January 1970 to December 2010. Assuming an installation was carried out in 1970 using this data, in comparison to that collected during the monitoring period, an assumption of long term environmental conditions within a cavity can be made.

Figure 38. is a graph showing monthly mean RH levels, an indication line has been added to show 85% RH where moisture absorption has been seen to increase.

Figure 39. is a graph of average monthly high and low temperature readings, much higher and lower individual daily readings have been recorded during this period.

4.4.3 Data analysis.

Comparing the two graphs it can be seen that the internal cavity RH readings are approximately 5 – 10% lower than the external environmental readings, they also display a level of stability compared to the external readings. This stability is likely to be a result of the building fabric acting as a buffer by regulating the moisture penetration. There also appears to be a correlation between temperature and humidity, as the temperature rises the humidity drops and likewise as it drops, the humidity rises.

The cavity temperature is 5 – 10°C higher, (assuming the data logger is working correctly to within its stated accuracy). The wall was facing in a south westerly direction in direct sun light for a large part of the day which will subject it to solar gain and raise the temperature.

During the previous laboratory testing (*See 4.2.1*) it was found that RH levels above 85% cause the moisture absorption to increase while levels of 96% are considered severe. During the early part of the cavity monitoring, late February to mid March, RH levels above 85% and up to 91.5% were recorded for a considerable part of this period. During the same period the external RH levels were similar, but less stable, and peaked higher at 96.6%, from mid March onwards, the temperature started to rise and the RH dropped although later in the period the RH rose sharply a couple of times peaking at 93%. During this later period there were some periods of relatively heavy rain which is likely to have caused these peaks.

The laboratory experiments used temperatures of between 35°C and 60°C, at the higher temperatures degradation and shrinkage were significantly greater compared to the lower temperatures, however, even at lower temperatures with humidity levels set at 96%, degradation was considerable, Brown (1990). Throughout the period of monitoring, the climate within the cavity was recorded as having an average RH of 66.4% peaking at 91.5% with an average temperature of 16.4°C peaking at 33.5°C.

The Met Office data for the same period recorded an average RH of 73.2%, peaking at 96.6% and an average maximum temperature of 16.1°C peaking at 25.6°C.

Within this period there were high levels of RH within the cavity, although for only relatively short periods, and generally low temperature levels. Further long term monitoring of at least 12 months would be required to obtain a better understanding of how the environment of a cavity behaves.

During this period the RH has averaged above 85% for a total of 132 months the majority of this time has been between November and February each year when the temperature has been low. It is unknown how the cavity RH behaves during these periods but if prolonged levels of high RH are experienced the wall fabric could absorb moisture and consequently raise the cavity level. The temperature of the cavity is likely to be influenced by the building heating so the lowest temperatures could be well above the external readings.

Highest monthly temperatures on record within the period 1970 – 2010, Met Office[4] (2011).

Date	Temperature
27th January 2003	17.6°C
13th February 1998	19.7°C
28th June 1976	35.6°C
19th July 2006	36.5°C
10th August 2003	38.5°C
1st October 1985	29.4°C
2nd December 1985	21.1°C
11th December 1994	17.7°C

Table 2. Highest recorded monthly temperatures.

Referring to *Figure 36.* if the cavity temperature can be up to 10°C higher than the external readings this could push the cavity temperature up to almost 50°C at times which is in the high temperature region used during the laboratory testing, (*See 4.2.1*).

Table 2. shows the highest monthly temperatures recorded for the period 1970 – 2010 giving an indication of the extremes of climate that have been experienced during the last 40 years, the majority of installed UFFI will have been present during this time. August 2003 saw temperatures above 30°C for a prolonged period of around 10 days in some areas although the average RH level for the same period was 67%, Met Office[6] (2011). July 2006 again saw high temperatures for a prolonged period of around 10 days and an average RH of 68% for the month, Met Office[7] (2011).

Lowest monthly temperatures on record within the period 1970 – 2010, Met Office[5] (2011);

Date	Temperature
10th January 1982	-26.1°C
28th August 1977	-2.0°C
17th October 1993	-10.6°C
24th November 1993	-15.5°C
13th December 1981	-25.2°C

Table 3. Lowest recorded monthly temperatures.

The lowest temperatures recorded could have other implications on the UFFI.

None of the previous research found has looked at the effect of low temperatures and frost on UFFI, some of this research was carried out in Australia where the risk of very low temperatures occurring under real conditions is negligible.

During the period very low temperatures were recorded that could have caused the UFFI within a cavity to freeze, December 1981 and January 1982 had recorded temperatures of -25.2°C and -26.1°C respectively. Many other extremes of low temperature are certain to have occurred over the 40 year period, the temperatures shown (*See Table 3.*) are the lowest recorded monthly figures on record for the period. Assuming the cavity temperature was 5 – 10°C above these levels, as recorded at the higher temperatures by the data logger, the temperature within the cavity could have been around -15°C, the average RH for the months were 89% and 88% respectively.

With these high RH levels there was likely to have been some moisture within the structure of the foam which would have frozen at these temperatures, with the expansion caused by freezing the foam could have been subject to cell structure damage. Without data recorded for winter conditions the actual cold temperature extremes likely to be found within a cavity cannot be determined.

Research into very low temperatures and frosting of UFFI is very limited so the effect this could have on the foam is not known but likely to be detrimental.

With the potential of high cavity temperatures around 50°C and potential low temperatures of around - 20°C, the UFFI within the cavity is likely to have been exposed to severe temperature ranges during its lifetime.

4.5 Summary of investigation.

Of the five properties investigated, none of them had UFFI in good condition, they all exhibited shrinkage and cracking, severe in most cases.

House 1 displayed very patchy walls when surveyed with thermal imaging, the patches appeared to correspond to where the foam was likely to have been injected, the assumption was that UFFI had been installed but had either severely degraded or not been correctly filled. When the wall was opened up the assumption from the thermal imaging was confirmed, the foam was in very poor condition and large uninsulated areas were discovered. Although it could not be confirmed, it was concluded that the patches did represent the injection points and the most likely cause of this was poor installation.

House 2 showed evidence of around 27% shrinkage and cracks of approximately 60mm width. The density of the foam was approximately 18% below the minimum tolerance for UFFI based on a target density of 10kg/m³.

House 3 displayed similar cracking to that of house 2 with around 15% shrinkage evident, the density however was well within tolerance. The sample had evidence of some kind of chemical damage to the internal side of the foam which created yellowing and a 'crazy paving' effect, penetrating the surface by 13mm. This sample was removed from the kitchen wall and the damage may have been due to moisture and oils from the kitchen environment.

House 4 had the original paperwork from the installation which was carried out on the 25th November 1975 using ICI Ufoam Plus by an ICI Insulation Service installer. The information sheet backs up the installation and the installer by saying *"........satisfactory results depend very much on the experience and resources of the installing company.*

ICI Insulation Service sets itself rigorous standards from the outset, and has a first-class technical and commercial reputation." ICI (1975). This quote would build consumer confidence in the installer and the product, however, 36 years later the foam was found to be in very poor condition. There were large cracks in the foam which had caused pieces of it to break away, above the investigation hole was a large hole in the foam which extended upwards by at least 250mm. The UFFI also displayed approximately 30% shrinkage allowing the foam to move within the cavity. Traces of foam were seen on the brickwork within the hole which indicated that the foam originally filled this area and has been pulled away over time, more than likely due to the shrinkage, leaving this hole unfilled.

House 5 also had the original paperwork for the installation which was carried out on 5th July 1977, no information was available on the material used. 34 years later the foam was found to have a very extensive crack extending vertically by at least 1m and up to 150mm wide within the investigation area. Similar foam traces to those found on the brickwork in house 4 were evident within the crack indicating an initial full fill of the cavity.

The Oxfordshire region where all the investigation properties were located is in a hard water area with a calcium carbonate ($CaCO_3$) reading of 286ppm, Thames Water (2010). The $CaCO_3$ content of the water used to mix the foam at the time of injection can have a detrimental effect on the quality of the foam (*See 3.5.3*). This could be a significant factor accounting for the very poor condition of the foam samples found during this investigation.

Cavity monitoring, using a data logger buried in the cavity of the author's home, was carried out over a 16 week period to gain an indication of the environmental conditions that can occur within a wall cavity. Weather data for the same period was collected from the Met Office located within 20 miles of the subject cavity to enable a comparison of internal and external conditions.

The recorded RH levels for the period concluded that the internal and external levels correlate to each other, however the cavity RH is generally 5 – 10% lower than that recorded externally. The temperature readings also correlated but the cavity temperature was generally 5°C – 10°C above the external readings.

Weather summary, this is an overview of the weather conditions during the period of monitoring, it offers a comparison of the rainfall and temperature levels of the period with historic average levels for each month.

Historical weather data looks at the recorded monthly average RH levels and high and low temperatures for the area from 1970 – 2010. This data compared to the cavity monitoring data gives an indication of the environmental conditions that the UFFI may have been subjected to since original installation into a wall cavity.

Data analysis, *Figures 36. and 37.* show a correlation between RH and temperature, the RH decreases as the temperature rises, much of the previous research was concerned with high RH and high temperatures combined. Assuming the pattern shown on the graphs is a good indication of actual cavity environmental conditions it could be concluded that high RH and temperature levels would be unlikely to occur together. *Figure 38.* indicates that the highest RH levels were predominantly recorded during the period November to February annually while *Figure 39.* indicates that this is also generally the coldest period.

The graphs are the average monthly records for the period, however much higher and lower temperatures were recorded on a daily basis, figures for the highest and lowest monthly temperatures on record were obtained from the Met Office to give an indication of the extreme temperatures that have been experienced in the past 40 years. A maximum temperature of 38.5°C was recorded on 10th August 2003 which could potentially have accounted for a cavity temperature of around 50°C while on 10th January 1982 a minimum temperature of -26.1°C was recorded which could have produced a cavity temperature of around -16°C. With a combination of an average RH of 89%, this could have created ice crystals within the UFFI with the potential to cause structural damage to the foam.

Limitations of study.

Previous research.

There has been limited research into this topic and much of it has repeated previous experimentation using similar material samples and varying laboratory conditions. Since the late 1980’s there does not appear to have been any further research into UFFI and it has been all but forgotten about.

There is no data, other than a study carried out on three properties in Australia, that could be found on wall cavity environments.

UFFI is rarely used today with possibly only one manufacturer in the UK and one installer regularly carrying out installations. With this very limited usage there is very little requirement for ongoing research into what is virtually an obsolete material as a retro fitted cavity wall insulant.

Cavity monitoring.

The cavity monitoring carried out for this paper was limited in that it only covered a short period of 16 weeks due to time constraints. The data logger was placed in a cavity filled with Rock Wool insulation, although a section of insulation was removed to expose the external wall leaf and provide a clear space. An empty cavity or one filled with UFFI may have been more appropriate for this study, locating a suitable property for monitoring proved to be difficult so a compromise had to be made.

The wall monitored was a south west facing wall subject to direct sunlight for a large part of the day, further data loggers placed in walls of other orientations would have provided more balanced data. A north facing wall, for example, would not be subjected to direct sunlight and would experience lower temperatures and possibly higher RH levels.

The study covered only a small geographical area with low exposure risk of WDR, monitoring a selection of properties of differing ages, construction types and WDR exposure risk zones would have produced a comprehensive view of the conditions UFFI would have been exposed to.

Investigations.

Only a small number of properties were investigated, due to time constraints and the reluctance of many homeowners to allow semi-demolition of their homes in the name of research.

A larger number of properties being opened up would have given a much better overview of how UFFI has performed in situ since installation. Houses within different WDR exposure zones would have enabled a clearer assessment of UFFI and provided more comprehensive evidence of the potential condition of up to 3 million installations nationwide.

Conclusion.

There are many aspects to UFFI that can influence the material and its performance, from the earliest introduction of the material as a cavity wall insulator it has been almost impossible to predict or calculate its longevity. Many installations had been carried out between the late 1950's and 1978, without regulation, before the British Standard for UFFI was released. Even with the standards in place there is little known about the long term performance of the material, UFFI is a 'once only' application and should last and perform adequately for the lifetime of the building.

The standards set for the manufacture of UFFI are likely to have been adhered to under controlled conditions by the manufacturer within the factory during production but that was only a small part of the process. The most critical part of the process was the onsite mixing and application which was open to abuse and error.

The weather data and cavity monitoring did not produce conclusive evidence that similar temperature and RH levels, found to be detrimental to the foam in laboratory tests, could actually occur within a cavity environment. It did, however, prove that the foam could potentially have been subjected to a temperature range of approximately -20°C to 50°C and RH range of 50% - 100% within a 12 month cycle (*See Data analysis 4.4.3*). If this cycle repeated every year for almost 40 years since the UFFI was installed it is highly unlikely that the foam will have remained in good condition.

The investigation was limited to only 5 properties, apart from House 2, all the walls investigated were in relatively sheltered locations in built up areas. The wall investigated on House 2 was south facing with an open field beyond. It was expected that foam in very good condition would be found in some of the houses, however each house exhibited shrinkage of between 15% and 33% with very obvious large cracks. The area of walls uncovered were mostly chosen at random, apart from House 1 where the position was influenced by thermal imaging, mainly for ease of access and in a position that would not be too prominent due to the repair being visible once the bricks were replaced. Only four bricks were removed from each which uncovered a very small area of approximately 0.1m², the defects found within this small area are highly likely to extend to the entire installation.

UFFI works by preventing air circulation within the cavity but only if the cavity is fully filled, the evidence found proves that the cavities within this investigation are far from fully filled and air circulation around the foam and through the cracks is certain rendering the insulation mostly ineffective.

In conclusion, the evidence collected would suggest that all of the sample properties in this study are no longer effectively insulated due to a combination, in some cases, of poor installation and foam degradation due to aging and environmental conditions. All houses insulated with UFFI, potentially as many as 3 million, will have been subjected to similar environmental conditions and, in many cases, poor installation due to lack of initial standards and the likelihood of ‘cowboy installers’.

It is very likely that most properties insulated with urea formaldehyde cavity wall insulation are now no longer, and possibly never were, insulated to any significant level. This could equate to between 20% and 30% of all properties believed to have been insulated with CWI.

Once UFFI has been installed it cannot be topped up and it is very difficult to identify and remediate any areas that have not been adequately filled or have become uninsulated due to shrinkage or degradation. To reinsulate a cavity with UFFI the foam first has to be removed, at great expense to the homeowner, and then refilled with CWI. If the UFFI was originally installed under a government grant scheme the building will not be eligible for a further installation grant because the building is only entitled to one grant.

If the UFFI cannot be topped up or replaced and any remedial work not eligible to benefit from any government grant scheme, by definition, the material should be fit for purpose for the lifetime of the building.

With so many elements acting against UFFI from manufacture, on site preparation, installation and environmental conditions, it brings into question whether the material was ever fit for purpose from the beginning. It has all but disappeared from the UK market today, possibly as a result of the industry being aware of the issues surrounding it and encouraging its replacement. UFFI may have left a legacy of up to 3 million properties which need remedial work to remove and replace the ineffective insulation in order to work towards future government energy saving targets. The cost of this work could run into hundreds of millions of pounds.

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