Energy Efficiency Best Practice in Housing

Scotland: Assessing U-values of existing housing

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Housing in Scotland

This document offers guidance to designers and energy auditors on how to assess the U-values of existing dwellings. With the Energy Performance of Buildings Directive being implemented in Scotland during the next few years, it will aid the process of certifying buildings.

A U-value is a measure of the rate at which heat is lost through a roof, wall, floor or window; the higher the number, the greater the heat loss. So a building with low U-values is likely to have lower heating bills – and better indoor comfort levels – than an equivalent structure with high U-values.

This publication gives details of typical, as-built, U-values for Scottish housing prior to the retrofitting of any insulation materials. These are 'typical' or default values for different types of dwelling: if more accurate information on a specific building is available, this should be used in preference.

The housing stock

Table 1 summarises the prevalence of different construction methods within the Scottish housing stock. The figures are based on the 2002 Scottish House Condition Survey.

Table 1: Types of construction found in the Scottish housing stock, 2002.

Type of housing	Proportion of total (%)
Traditional, sandstone walls	18
Traditional, whinstone/granite walls	5
Brick/block cavity walls	67
Non-traditional timber walls	5
Non-traditional concrete walls	4
Non-traditional metal-frame walls	1

Age and construction method

In general, U-values can be determined by age and style of construction. Any assessment of the likely U-values for the walls of an existing building requires an appreciation of these factors.

The Scottish housing stock can be usefully classified according to the following construction periods:

1. Pre-1919
2. 1919-1944
3. 1945-1954
4. 1955-1964
5. 1965-1975
6. 1976-1983
7. 1984-1991
8. 1992-1998
9. 1999-2002

1. Pre-1919

Stone was used for nearly all the walls (96%) of properties built before the First World War. Sandstone was the predominant choice, although granite/whinstone can also be found.

There are large numbers of tenement flats from this period still in use. They feature high ceilings and thick, exposed stone walls. The detached and semi-detached houses that survive from this period also tend to have these exposed stone walls. In some instances, there is a stone façade at the front with brick at the back and sides. A small proportion of properties are rendered, usually with a wet cast (harled) finish.

The roofs from this period are usually slated and have half-inch sarking board. This would not originally have been ventilated, but eaves ventilation may have been added later.

Figure 1: A typical pre-1919 red sandstone tenement

2. 1919-1944

Following the war, cavity wall construction grew in popularity and brick/cavity/brick or brick/cavity/block methods took over from sandstone or whinstone/granite. Cavity walls account for 83% of dwellings from this period.

There were also a significant number of 'non-traditional' constructions during this time. These involved labour systems and materials not common in housebuilding. As such, they marked a departure from the stone or brick-cavity walls of traditional methods. Most of these non-traditional dwellings incorporated timber or concrete-based walls, while a much smaller percentage employed metal-frame construction, such as steel and aluminium.

Figure 2: Stone-fronted housing with brick at the sides and back

3. 1945-54

Cavity wall construction continued to be the traditional type of construction in this period. Stone was seldom seen, but the non-traditional methods developed between the wars were used as well – and continued later still in the case of no-fines concrete.

Ceilings were generally made of plasterboard and sarking board was still used in roofs.

Figure 3: A terraced house from the early 1950s

4. 1955-64

Cavity wall construction was still the traditional method for dwellings. In general, building in this period was carried out in accordance with the 1954 Model Building Byelaws.

Figure 4: Typical Scottish housing of the late 1950s

U-value requirements for Scottish housing

Regulations - implementation date	Standard wall U-value (W/m^{2}K, to two significant figures)
Model Building Byelaws 1954	1.7
June 1964	1.7
April 1975	1.0
March 1983	0.60 (thermal bridging ignored)
April 1991	0.45 (thermal bridging ignored)
December 1997	0.45 (Proportional Area method)
March 2002	0.30 (BS EN ISO 6946 'combined' method)

Once granted, building warrants have a duration of three years, so a house constructed shortly after a change in regulations may in fact be built to earlier requirements. For example, a building for which a warrant application was submitted in February 2002 might not be completed till 2005. It would therefore be constructed to 1997 standards, not those of 2005.

To allow for this, it is recommended that an average time lag of a year is assumed between warrant application and construction. So a dwelling completed in March 1992 is assumed to be built to the 1983 regulations.

5. 1965-75

The Building Standards (Scotland) Regulations 1963 were implemented in 1964 and retained the U-value requirements of the Model Building Byelaws. They put an effective upper limit on the U-values of walls and roofs (see box). An unimproved roof typically had a U-value of 1.1 W/m^{2}K. However, many dwellings were constructed with 25mm of mineral fibre insulation in lofts, placed between the ceiling ties.

System-build housing and no-fines construction accounted for a significant proportion of the total in this period. One popular system-build method employed block/cavity/block construction with large diameter steel connecting rods serving as wall ties. In the late 60s and early 70s, cavity wall construction was also undertaken with aerated concrete blockwork on the inner leaf.

No-fines walls have U-values comparable to brick walls with unfilled cavities. They typically featured render-coated, in-situ cast concrete, or alternatively in-situ cast concrete with stone aggregate (e.g. whinstone) and timber straps, and an internal plasterboard lining.

Some medium-rise housing and tower blocks used concrete no-fines systems. A popular choice for tower blocks from the mid-60s was to have double concrete panels separated by 25mm of expanded polystyrene.

6. 1976-83

With new Building Standards implemented in 1975, wall U-values were reduced to 1.0 W/m^{2}K and roof values to about 0.6 W/m^{2}K (if thermal bridging is ignored). U-values were still high by modern standards, so thermal bridging still had a relatively low impact on overall heat loss.

7. 1984-91

During these years, timber-frame construction with brick façades became increasingly common. It generally utilised 89mm studs with 80mm mineral wool quilt fixed against the sheathing plywood.

Some cavity walls were built with exterior masonry but no insulation; this could still satisfy the regulations with the use of 'high performance' 100-125mm aerated concrete blocks for the inner leaf.

The Technical Standards were now placing an upper limit on wall U-values of 0.60 W/m^{2}K and on roofs of 0.35 W/m^{2}K, although the impact of thermal bridging was still not taken into account when calculating the values. Mineral fibre insulation to a depth of 100mm was commonly installed in lofts between the ceiling ties.

8. 1992-98

The simplest way to comply with the 1997 Technical Standards, Part J, was to construct walls with a U-value of 0.45 W/m^{2}K and install single glazed windows. Many house builders chose to meet the regulations by opting for higher wall U-values, typically 0.60 W/m^{2}K, coupled with double glazing.

Timber-framed housing, with its 89mm studs fully filled with mineral wool quilt, generally achieved lower U-values than cavity walls. However, the calculations did not include the effect of thermal bridging, so the 0.60 value achieved becomes slightly higher when recalculated using modern methods.

In fact, the effect of a number of components, such as timber joists, timber framing, wall ties, mortar bedding and the air gaps between insulation sections, were routinely ignored in U-value calculations during this period. In reality, these could have a significant impact: in partial-fill cavity walls, mild steel wall ties and mortar joints could impair performance by some 20%, increasing the U-value from 0.45 to 0.55 W/m^{2}K. In clear-cavity construction, though, the effect is relatively small and can be ignored.

Figure 5: Traditional-style housing from the 1990s

9. 1999-2002

Partially-filled cavity walls with brick-faced outer leaf still predominated, but timber-framed housing accounted for about 29% of post-1997 dwellings, according to the Scottish House Condition Survey.

In order to comply with the 1997 revision of Part J via the Elemental Standards Method, walls normally have to achieve a U-value of 0.45 W/m^{2}K.

U-values in this period were calculated using the Proportional Area Method. This meant that calculated U-values more realistically reflected actual heat loss. However, the 'Combined Method' (introduced in 2003) is more accurate still and U-values for buildings from this period should be recalculated if a very accurate assessment of heat loss is required.

Typical U-values for existing housing

The tables in this section give default U-values for the major building elements of Scottish housing, according to construction method and age. Unless otherwise stated, they have been calculated using BS EN ISO 6946, with the exception of floors where BS EN ISO 13370 has been used. Due to their greater accuracy, these calculation methods may give different U-values than those found in the Technical Standards of the period concerned.

A. Walls

This guide does not cover any upgrade measures that may be encountered in buildings that have been refurbished or have had energy efficiency improvements. However, there are ways to identify whether improvements have been made which would alter the U-value of the wall:

- a regular drill hole pattern in the outer leaf may indicate the addition of cavity wall insulation
- window sill extensions are common when external wall insulation has been added
- deep internal window reveals often signal the presence of internal wall insulation.

Table 2. Default U-values for walls

Period	Construction type	U-value (W/m²K)
Pre-1919	Traditional sandstone (or granite) dwellings with solid walls: stone thickness typically 600mm with internal lath and plaster finish	1.7
1919-1944	Cavity walls involving brick and block with external render	1.7
	Non-traditional housing, predominantly timber or concrete based, with smaller numbers of metal-framed dwellings (steel or aluminium)	1.7 (concrete) 1.2 (timber) 1.2 (steel)
	Some stone construction	1.7
1945-1954	Cavity walls of brick and block, with external render	1.7
	Non-traditional housing, predominantly timber or concrete based, with smaller numbers of metal-framed dwellings (steel or aluminium)	1.7 (concrete) 1.2 (timber) 1.2 (steel)
1955-1964	No-fines concrete	1.7
	Tower blocks (e.g. Bison and Reema systems): typically 25mm EPS between system build double concrete panels. For example: 20mm stone chip finish on 80mm cast concrete; 25mm EPS bridged by metal ties; 80mm cast concrete; 10mm plaster finish. There may be some thermal bridging at the perimeters of the panels.	1.7
	Cavity walls of brick and block	1.7
1965-1975	Mainly brick/block cavity walls	1.7
	Timber frame	1.2
	No-fines construction	1.7
	System build: block/cavity/block walls with large steel connecting rods serving as wall ties (e.g. Wilson Block System)	1.7
1976-1983	Mainly brick/block cavity walls	1.0
	Some other types	1.0
1984-1991	Mainly brick/block cavity walls with insulation or AAC (Aircrete) blocks used	0.60
	Timber-frame walls with 89mm studs and approximately 80mm mineral wool quilt	0.43
	Some other types	0.60
1992-1998	Mainly brick/block cavity walls (with single glazing). Predominant type: facing brick; partially-filled cavity; inner leaf concrete blockwork. Effect of wall ties and mortar joints ignored.	0.45 (nominal) 0.55 (actual)
	Brick/cavity/block walls. Cavity partially filled with insulation. (Used in conjunction with double glazing to satisfy Part J.)	0.60
	Timber frame walls with 89mm studs fully filled with mineral wool quilt	0.42
1999-2002	Mainly brick/block cavity walls with insulation. Predominant technique: facing brick; partially-filled cavity; concrete block inner leaf.	0.45
	Timber frame walls with 89mm studs fully filled with mineral wool quilt insulation	0.42
2003 to present	Brick/block cavity walls with insulation. Predominant technique: facing brick, partially-filled cavity, concrete block inner leaf.	0.30
	Timber frame with variable stud depth and variable insulation materials. 140 mm studs fully filled with mineral wool is commonly used.	0.30
	Some use of insulated dry-lining	0.30

B. Roofs

Most dwellings have a pitched roof with a tiled or slated covering, according to the Scottish House Condition Survey. Closer examination of the housing stock shows that some dwellings use sarking board while others use sarking felt.

In older houses, sarking board (half an inch or 13mm thick) was originally installed without ventilation and in many cases eaves ventilation was added later. Ventilation tends to raise the U-value slightly: this is incorporated in the values quoted in the tables.

Table 3 gives the default values based on loft insulation thickness. In Table 4, values are given for the various periods considered in this guide: the figures are based on known levels of loft insulation or – where roof insulation levels are not known – on the requirements of the Technical Standards of the time.

Table 3: Default U-values when loft insulation thickness is known

Insulation thickness (mm)	U-value (W/m^2K), assuming sarking felt or ventilated sarking board	U-value (W/m^2K), assuming unventilated sarking board
None	2.3	1.6
12	1.5	1.1
25	1.0	0.8
50	0.68	0.60
75	0.50	0.45
100	0.40	0.37
150	0.29	0.27
200	0.20	0.19
250	0.16	0.16
≥ 300	0.13	0.13

Note: the thermal resistance of sarking board is assumed to be 0.2 m^2K/W. This was usually installed in the absence of eaves ventilation.

Table 4: Default U-values for roofs by age, with known quantities of loft insulation thickness or unknown levels of roof insulation. Values are based on current calculation methods.

Period	Pitched roof (with depth of insulation between joists in mm)	Pitched roof with insulation between rafters	Flat roof
Until 1954	1.6 (sarking board only)	1.6	1.6
1955-1975	1.1 (12mm, sarking board)	1.1	1.1
1955-1975	1.5 (12mm, sarking felt)	1.5	1.5
1976-1983	0.68 (50mm, sarking felt)	0.68	0.68
1984-1991	0.40 (100mm, sarking felt)	0.40	0.40
1992-1998	0.29 (150mm, sarking felt)	0.35	0.35
1999-2002	0.26 (150mm, sarking felt)	0.35	0.35
Post 2003	0.16 (250mm, sarking felt)	0.20	0.25

C. Floors

Until 1991, there were no formal targets for the insulation performance of floors. So the values for pre-1992 properties are simply calculated from perimeter-to-area ratio. A typical U-value would be in the region of 0.60 W/m^2K, but would tend to be higher for detached dwellings and lower for mid-terrace dwellings.

In the absence of better information, the values in Table 5 may be used for both solid and suspended ground floors.

Table 5: Default U-values for solid or suspended floors

Period	U-value (W/m^2K)
Until 1991	Typically 0.60 but see text
1992-1998	0.45
1999-2002	0.45
2003 to present	0.25

D. Windows

Table 6: Default U-values for windows		
Period	**Predominant type**	**U-value (W/m²K)**
Until 1991	Single glazed, timber frames	4.8
1992-1998	Single glazed	4.8
	Double glazed	3.1
1999-2002	Double glazed (uncoated glass)	3.1
2003 to present	Wood/PVC-U frames	2.0
	Metal frames	2.2

References

Christie A (1987) A Guide to Non-Traditional Housing in Scotland 1923-1955. Scottish Office Building Directorate

BSI (1997) BS EN ISO 6946:1997 Building components and building elements – Thermal resistance and thermal transmittance – Calculation Methods.

BSI (1998) BS EN ISO 13770:1998 Thermal performance of buildings – Heat transfer via the ground – Calculation methods.

The Scottish House Condition Survey, 2002. Communities Scotland.

Further Reading

Energy Efficiency Best Practice in Housing publications

These publications can be obtained free of charge by telephoning the Helpline on **0845 120 7799** or by visiting the website at **www.est.org.uk/bestpractice**

Cavity wall insulation in existing housing (GPG 26)
Domestic Energy Efficiency Primer (GPG 171)
Effective use of insulation in dwellings (CE23)
Energy efficiency in new housing: Summary of specification for England Wales and Scotland (CE12)
Energy efficiency in new housing: Summary of specification for Northern Ireland (CE24)
Energy efficient refurbishment of existing housing (GPG 155)
Energy efficient refurbishment of existing housing – case studies (GPCS 418)
External insulation systems for walls of dwellings (GPG 293)
Internal wall insulation in existing housing – a guide for specifiers and contractors (GPG 138)
Post-construction testing – a professional's guide to testing housing for energy efficiency (GIR 64)
Refurbishing cavity-walled dwellings: A summary of Best Practice (CE56)
Refurbishing dwellings with solid walls: A summary of Best Practice (CE58)
Refurbishing timber-framed dwellings: A summary of Best Practice (CE59)
Refurbishment site guidance for solid-walled houses – ground floors (GPG 294)
Refurbishment site guidance for solid-walled houses – windows and doors (GPG 295)
Refurbishment site guidance for solid-walled houses – roofs (GPG 296)
Refurbishment site guidance for solid-walled houses – walls (GPG 297)

Other publications

BRE (2002) Non-traditional housing CD: a collection of BRE publications.

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