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Construct Ireland - Partial Fill Cavity Walls

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Partial Fill Cavity Walls:

Have we reached the limits of the technology?

An examination of whether it still deserves its best practice status in the Irish Construction Industry in light of higher U-Values, construction practices, recent research and cultural pressures.

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'Radical abatement measures must be implemented immediately to offset further growth in these emissions over the next ten years and to prepare for much more onerous obligations in the longer term'.

EPA Newsletter Vol 7 No 2 October 2000 [13]

'U-values are used in the prediction of fuel consumption for the building stock as a whole and regulations are laid down concerning the U-values for new building works. It is therefore important to examine the reliability of existing methods of calculating U-values'.

Field Investigations of the Thermal Performance of Construction Elements as Built [12]

PART 1

1.1 Introduction

There is a strong focus in this course on the environmental and thermal benefits of alternative technologies, which is clearly a good thing. One downside of this is that I believe there may be a lack of focus in dealing with the huge environmental issues mainstream construction technology can throw up. These issues can be huge by virtue of the number of buildings constructed using this technology alone. In Ireland for instance 50,000 houses will be built this year, 25% in timber frame and the vast majority of the rest in some form of insulated blockwork wall construction. It is clearly essential therefore that we grapple with the thermal performance issues mainstream technologies throw up and try to resolve them, *alongside* developing and promoting technologies that may in the future replace them. With this in mind I chose to follow the environmental assessment theme of Unit B1 by assessing one of these mainstream forms of construction.

Partial fill cavity walling has been regarded as the best-practice form of wall construction in Ireland for at least two decades. I have seen this first hand as a student of a School of Architecture in the early and mid 1990s, and as an architect in practice. It is for instance the first construction form any architectural or technology student is taught, it is the first detail presented in the *Technical Guidance Document L: Conservation of Fuel and Energy: Dwellings* (TGD L) for the Building Regulations (2002) [1] and its details dominate the '*HomeBond' House Building Manual.* [2] The latter is the 'bible' for those constructing dwellings in Ireland.

However cavity wall technology may be reaching its limit. Wider and wider insulation batts are pushing the masonry leafs further apart and making wall ties longer with structural implications, several studies point to marked difference between predicted and measured U-values, while certain issues that were highlighted as long ago as 1990 have not been taken on board by the Building Industry or the legislators. This paper aims to look at:

1) Why cavity walling became and has remained a leading technology

2) Whether this position is justified in an era of higher thermal standards and

3) If the standards themselves need to be re-examined.

Part 2

TECHNOLOGY, GROWTH & THE NEED TO CHANGE

2.1 Origin of cavity wall technology

It is important to understand that cavity walls were promoted in the Post-War era as a technological answer to two key problems associated with the most popular wall construction of the Inter-War years, the externally rendered (uninsulated) 215mm solid block wall. The 215mm solid block wall has good load bearing and lateral stiffness characteristics; it's also simple and fast to construct. Yet another advantage was that there was a clear and sensible division of trades during its construction: blockies built the structure and plasterers provided the weatherproofing (and limited insulation) in the form of external render and internal plaster.

It's problems were insulating and weatherproofing. For weatherproofing the wall construction relied primarily on the external cast two-coat render, and secondarily on the width of the block and a fully-filled mortar joint to prevent moisture penetration. Sand/cement renders, made increasingly by the emerging concrete industry, began to supplant the more flexible lime render at this

TABLE 1 & 2

External wall to my parents' house (1953): 215mm solid block wall (uninsulated)

Layer/ Surface	Thickness (m)	Conductivity (W/mK)	Resistance (m^2K/W)
ext. surface	-	-	0.040
render	0.019	0.57	0.033
conc. block	0.215	1.33	0.162
int. plaster	0.013	0.18	0.072
int. surface	-	-	0.130
Total Res.			0.437
U-value of construction = 1/0.437 =			2.290 (W/m^2K)

Table 1

External wall to City Quay School (1973): 300mm cavity wall (uninsulated)

Layer/ Surface	Thickness (m)	Conductivity (W/mK)	Resistance (m^2K/W)
ext. surface	-	-	0.40
conc. block	0.100	1.33	0.075
cavity	0.050	-	0.180
conc. block	0.100	1.33	0.075
int. plaster	0.013		0.072
int. surface	-	-	0.130
Total Res.			0.572
U-value of construction = 1/0.572 =			1.750 (W/m^2K)

Table 2

time which inadvertently increased the risk of failure of this wall technology. Risk of failure also increased greatly when exposed to high winds. My own parents' house built in 1953 in a sheltered Dublin suburb has never had a moisture penetration problem to my knowledge: fuel bills however have always been high. Given a U-value of 2.29W/m2K this is not surprising, see table 1.

Cavity walls solved these problems in a simple, effective way. By building two masonry leafs side by side a set distance apart but carefully tied together, the leafs act together structurally, but separately in terms of moisture penetration. As long as the ties slope down, the bottom of the cavity can drain and the cavity is kept clear the inner leaf should remain entirely dry, even when rain is dribbling down the cavity face of the outer leaf. I contend that this is the original reason for the popularity of cavity walls. I believe the fact that the walls were also warmer was considered a secondary advantage.

I base this view on my reading of Foster [3] and my understanding that the until recently a well-built building meant one that had structural integrity and good resistance to moisture penetration: good thermal performance was not considered as significant. City Quay Primary School in Dublin's inner city, on which I worked for a re-glazing contract is a good example. It was built in the early 1970s before the Oil Crisis. It's external wall was made up of two 100mm leafs with an un-insulated 50mm cavity, plastered only on the inside. It's U-value of 1.75W/m2K, while poor by today's standards, is a marked improvement on my parent's house, see table above. Note for instance that the Resistance of the air cavity is greater than the two blocks combined.

2.2 Modern cavity wall and the impact of U-values

it became clear during the Oil Crises in the early 1970's that the best way to mitigate spiralling fuel costs was to add high-performing insulants to construction thereby reducing the heating requirement. The inherent insulating characteristics of the materials themselves was no longer sufficient. This change seems to be so significant to me as to constitute a cultural shift. Even so it took time to become mandatory: it was only in 1976 that specific regulations dealing with energy efficiency in housing came into force in Ireland. [13]

For cavity wall technology the higher thermal performance was met by building insulation

FIGURE 1

An image from Mitchell's Building Series: Structure and Fabric Part 1[3]

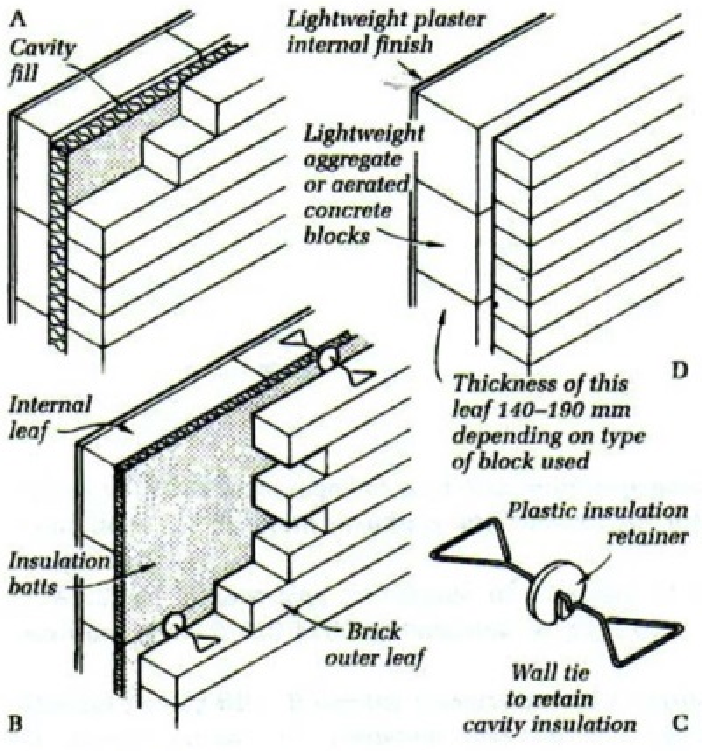


Figure 5.12 Thermal insulation of cavity walls

An image from *Mitchell's Building Series: Structure and Fabric Part 1* [3] into an increased cavity width. Initially 40mm of insulation was judged sufficient resulting in an 80 or 100mm cavity. Significantly blockies were given the task of installing the insulation while they built the leafs, not a specialist installer. In the early '90s, while I was studying to be an architect, a partial fill cavity wall of 50mm insulation in a 100mm cavity was taught as best practice following the introduction of the 1991 Building Regulations. Interestingly there was no emphasis placed on which insulation was specified at the time: all (modern) insulations met the standard.

In 1997 *Technical Guidance Document L: Conservation of Fuel and Energy* to the Building Regulations set the 'maximum average elemental U-Value' for an external wall as 0.45W/m2K. It listed eight insulants and gave an example of a partial fill cavity wall that exceeded the standard by 0.05W/m2K using 65mm of the lowest performing insulant (glass wool quilt) in an overall cavity of 105mm wide. The latest TGD L [1] (2002) sets the external wall U-value as 0.27W/m2K. It shows an example of a partial fill cavity wall that exceeds the standard by 0.01W/m2K using 80mm of a high-performing insulant (extruded polyurethane) in an overall cavity of 105mm wide.

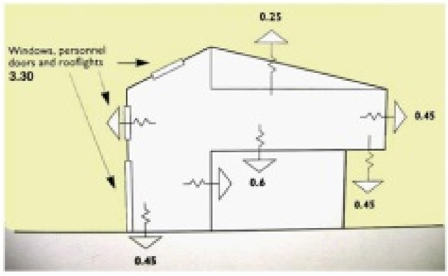
It is noteworthy in my view that four of the seven insulants listed are now ruled out at this width. This is because it shows how specifications are becoming more exact and the components higher performing, and more expensive, for the technology to function satisfactorily. We will see below whether the construction standards also need to become more exact.

2.3 Building technology for the housing sector

Homebond's 'GoldShield Homes' construction certifying scheme is the only such scheme in the State: its link with insurers is so strong that it has a marked effect on the willingness of builders, architects and clients to pursue non-standard, i.e. non-Homebond, forms of construction in the housing sector. Added to this Ireland's concrete industry, which is very healthy and markets aggressively ('concrete built is better built'), dominates the entire construction sector. This position was originally fostered by the State: as Ireland is blessed with good supplies of lime, water, sand and aggregate, key Post-War politicians promoted concrete as a native technology. The largest firm, supplying cement, concrete, blocks & paving is so big it has long been a key player in the UK construction industry also.

In contrast to the rude health of the concrete industry the timber industry is small. Due to almost complete deforestation of the country in the 17th and 18th Centuries there is no tradition, little understanding and much distrust of building in timber let alone other innovative technology. There is only one mill in Ireland that supplies a limited amount of native hardwoods (oak, beech sycamore etc.) to the market. Large supplies of softwood timbers (planted since the foundation of the State in 1922) are only slowly becoming available and are often poor quality due to fast growth. Therefore a large percentage of timber is imported. It is not surprising that the construction industry has been conservative and that a marked bias towards masonry and concrete construction still exists.

In the last five years things have begun to change perceptibly however. In a climate of spiralling land prices and increased trade with Europe many have looked beyond the cement industry for building solutions that reduce costs and increase standards. A new acceptance of higher density design has also broadened the housing types built, with a direct impact on the technology used. Timber frame housing production, albeit of suburban semi-d's with a reassuring brick skin, has growing very quickly. From 10% of the housing



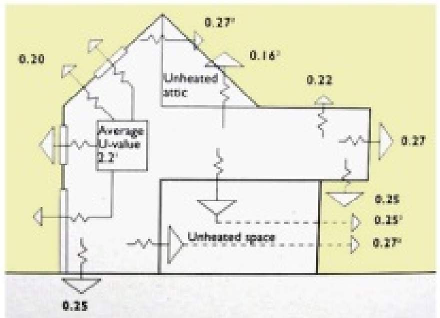


FIGURE 2

Maximum Average Elemental U-Values: TGD L 1997 and 2002

market in 1990 it now accounts for 25%. It will however take longer for people in general to accept housing without masonry elements at all.

In the last few years several new wall systems have been introduced to the market. I have broken these into four classifications:

FIGURE 3

Kingspan TEK haus system

1. prefabricated structural panels or frames (such as pre-finished concrete panels or timber frame) to which insulation is applied internally or externally.

2. Insulated wall panels. These panels can be structural or non-structural. Examples are 'Tek Haus' from Kingspan (which was introduced this year from Germany) and 'Griffnerhaus' from Griffner Coillte (which was introduced from Austria in 2002).

3. Rendered external insulation systems where the science is in creating a multi-layered flexible strong skin on insulation which is bonded to the structure. Examples of this are Sto and Weber ATC.

4. Blocks with integral insulation: these include honey-combed terracotta blocks and blocks of rigid insulation foamed between two lightweight concrete leafs.

All four groups have been highly tested, all of them are built by technicians trained for that specific technology. The first two groups maximise the effect of shop floor quality control on the final building, and consequently reduce the impact of siteworks on quality and performance. The second two build/install on site. It's no coincidence that all of the creators of these systems emphasize their high thermal performance and low fuel bills. Outside of these innovative areas Ireland's fairly conservative construction industry must now come to terms with the ever-increasing importance of insulation, airtightness, controlled ventilation and increasing environmental concern in light of global warming and the Kyoto Protocol.

2.4 The Boom, Kyoto and lobbying

In 1997 under the EU burden-sharing arrangement it was agreed that Ireland, which was clearly coming out of a long recession, would be allowed increase its greenhouse gas emissions by 13% over a 1990 baseline (when measured in 2012). Anxious not to stifle growth the government delayed the introduction of higher U-values 15 and green taxes. Most business elements in the economy therefore took a 'business as usual' approach and emissions spiralled. The 2012 emissions figure was reached in 2000 and looks set to increase to at least 37% over the baseline by 2012. 10 Up to 2002 Ireland's increase in CO2 emissions were the highest of any EU state: in contrast Britain's fell by 8.9% in the same period. [14]

The Boom was accompanied by net immigration (for the first time), a population increase and huge growth in the Construction Industry. Despite having a population of four million 50,000 houses will be built in Ireland in 2004. To put this extraordinary figure in perspective 'only' 160,000 houses will be built in the UK despite having a population fifteen times larger! As residential buildings account for 30% of the total national CO2 emissions and space heating accounts for 60% of that [9] it is clear that there is a vital link between CO2 emissions and the actual thermal performance of dwellings.

Gerry McCaughey CEO of Century Homes, the largest timber frame company in Ireland and the UK, is firmly of the opinion that the Government was extensively lobbied by the concrete industry. To prove this he gained access to ministerial documents through the Freedom of Information Act. One confidential Department of the Environment note from 1998 acknowledged that the Building Regulations would have to be revised much sooner than 2002/2003 because of the Kyoto Protocol, but continues:

'However we don't want to signal this to the outside world just yet because the next leap in building standard insulation will probably make it difficult for 'hollow block' construction, used widely in Dublin, to survive'. [15]

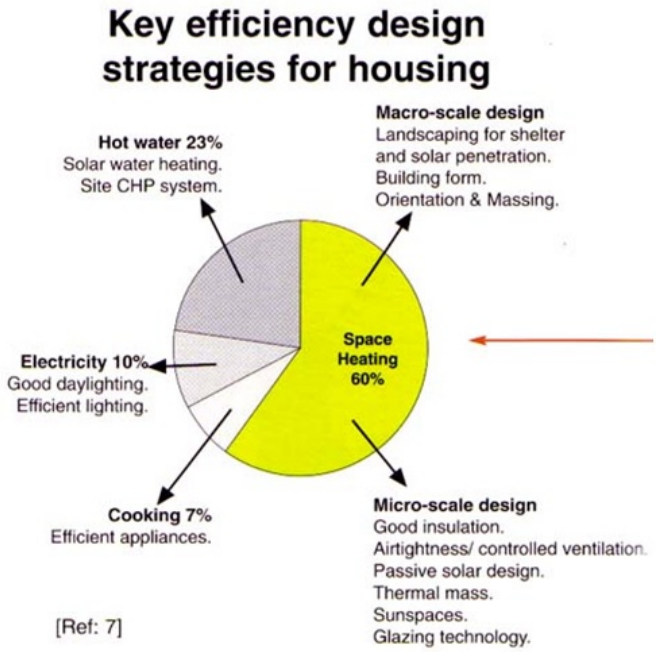
In the end the Department did delay the new TGD L till 2002. Even then they relaxed the implementation date till the end of the year. This resulted in developers 'stock-piling' Planning Permissions for housing of the more lenient standard to construct later in 2003, even 2004. One result of this is that two houses built in the same year could legitimately meet energy standards that differ by 30%. Sadly I believe that McCaughey is justified in saying that the Government protected

'the concrete industry and vested interests in the building sector at the expense of the consumer' [15]

and I can add, the Environment. The other result is that since 1998, when the government privately recognised the need for higher thermal standards, 250,000 new homes have been built of the older less efficient standard having a direct negative impact on CO_2 emissions.

[FIGURE 4

Insulation for Sustainability - A Guide [9]



Perhaps because of this the Minister for the Environment announced in 2001 that the Department's plan to increase thermal standards in the residential sector in two-stages was going to be compressed into one: this resulted in Technical Guidance Document L: Conservation of Fuel and Energy: Dwellings of the 2002 Building Regulations. TGD L (2002) represented a substantial increase in thermal requirements for wall, floor and roof assemblies over the 1997 edition. For instance U-values for wall constructions in new-builds jumped from 0.45W/m2K to 0.27W/m2K. Nonetheless at draft stage wall values of 0.25W/m2K had been proposed. One of the researchers involved in the creation of TGD L 2002 informed me that the reason for this relaxation was specifically to allow cavity wall and hollow block wall construction to remain compliant, if only nominally. So are they?

Part 3 ANALYSIS

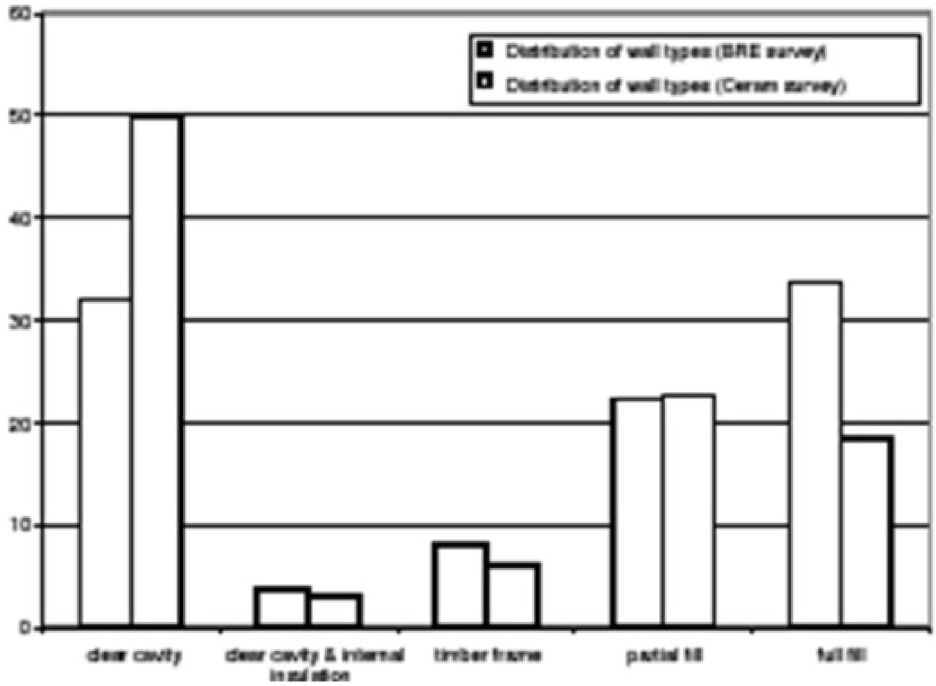
3.1 Measured Performance

Field Investigations of the Thermal Performance of Construction Elements as Built, 12 is a report and discussion document by the BRE on two separate field studies made between 1998 and 2000 by the BRE and Alba Building Services. They measured thermal performance in a total of 29 buildings of varying construction, mostly houses, and compared them with their calculated U-values. It gave a report on each house, the investigative work done, the measurement methods used, a discussion on the mismatch between measured and calculated U-values and some alternatives.

The table below from *Field Investigations* gives some idea of the extent to which cavity wall construction has dominated other forms of construction in the housing market. Given the fact that these houses were surveyed in 1998, by which time most were no more than two years old, I find it surprising that so many of the houses have 'clear' (i.e. uninsulated) cavities. A later table shows them as having a calculated U-value of 0.68W/m2K, which could only be possible if the inner leaf was built with lightweight thermal block.

FIGURE 5

Percentage distributions of domestic wall types in the UK [12]



This would be a very unusual approach in Ireland where lightweight blocks are less frequently used than in the UK. 3 Another difference between the industries is that many Irish developers have a preference for dry-lined solid (or cavity) block walls. While dry-lined cavity block walls can meet the 1997 and 2002 U-values they are the bête noire of Irish architects because the narrow profiles of concrete that surround its cavities are more vulnerable to structural failure and will resist damp penetration less if the external render is damaged. Figure 6 graphically shows the overall findings. Each horizontal and vertical band on the graph represents 0.10W/m2K. It can quickly be seen that eight out of the fifteen houses with partial fill cavity wall are under-performing. One house which was designed to have a U-value of 0.45W/m2K has a measured U-value of more than double: 097W/m2K. Proportionately the thermal performance of buildings with fully filled cavity walls is as poor, though over a far narrower range of U-values. In contrast the timber frame housing, designed in general to meet a standard of 0.35W/m2K, performed well. In fact eight out of nine exceeded the design requirement, one by as much as 0.10W/m2K. The BRE believe this is because of the tendency of timber frame builders to compress quilt insulation between studs of a narrower dimension thereby inadvertently increasing the thermal value of the insulant.

The sample of buildings studied were intended to be a representative selection. Given that most of these buildings were completed in a two year period before the study, any claim that they represent a previous building culture and not the present one is untenable. It may reasonably be assumed that further studies in the UK and presumably Ireland would give similar results but this needs to proven. One alternative, which is to abandon constructions that under-perform, is unlikely to be stomached by the Government given the information in section 2.4 above. I refer to what *Field Investigations* highlighted about the U-value calculating system below (section 3.6), but first I want to look at why partial cavity walling under-performs and whether it is possible to make it perform better or not.

3.2 Site culture & procedures

3.2.1 Blockies

When designers first started specifying insulation for cavity walls it fell to blockies to install it. Despite being a 'dry' procedure it made sense in the sequence of work for blockies, 'wet' tradesman, to install it as it was surrounded by their work. However whether or not blockies ever received training to do so, the firsthand experience of a great deal of architects and clerks of works, including me, is that this work is rarely done as well as required. The craft of laying a straight, neat length of blockwork is immediately evident to all on site. The relationship between that and the wall's strength and weatherproof characteristics is also immediately intelligible, not so with insulation. When installed it's invisible, furthermore it's performance may also be intangible as buildings are only made air-tight and therefore capable of remaining warm *after* blockies leave site. Lastly blockies are typically paid for the amount of *blocks* they lay, which inevitably focuses the mind.

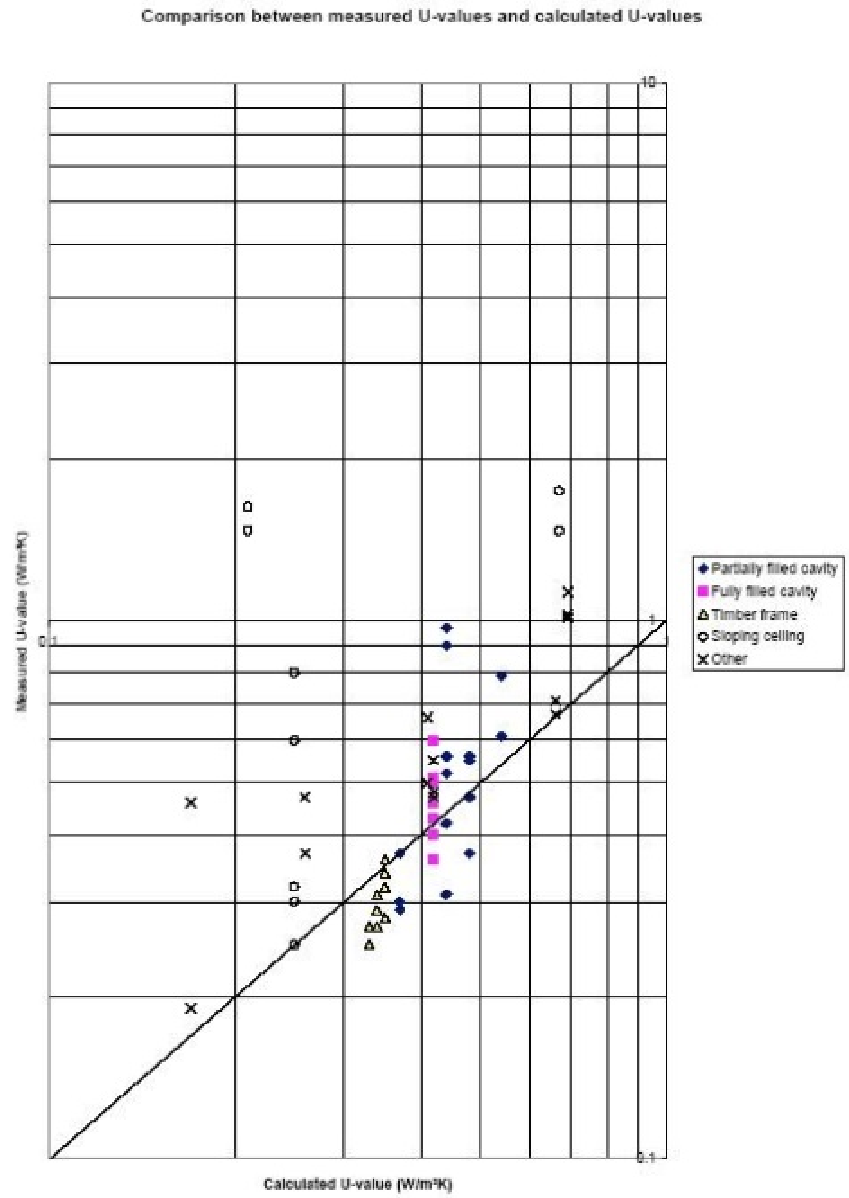
Solution?: Re-training, particularly focused on insulation and its significance in terms of CO2 emissions, and a different pay structure could help change this culture.

impact of these variables is a major reason why many new building systems tend to be factory-assembled, and why they appear to consistently out-perform insulated blockwork structures.

Solution?: a focused contract manager with a team of well-trained foremen and well-thought out site procedures cold do much to help this.

FIGURE 6

Field Investigations of the Thermal Performance of Construction Elements as Built [12]



: *A graph of measured U-value against calculated U-value shown for various construction types. Those points which lie above the diagonal line correspond to the measured U-value exceeding the calculated U-value whereas the points which lie below the line are cases where the measured U-value is less than predicted*

3.2.2 Site

Rain, poor storage, a muddy, dirty or dusty site, poor overseeing and time pressures, even the hiring regime and team morale can all effect the quality of work on site. Reducing the However in my experience this is far more likely to be in place in building firms that focus on commercial projects than those that focus on the residential market.

2.3 Clearing the cavity

An important function of a clerk of works or foreman on site is to ensure that the men continuously clean the cavity, removing any 'snots' of mortar that could result in the cavity being bridged. This was relatively easy to do when both sides of the cavity were bare. It became more difficult to supervise and retrospectively fix when cavities were insulated. Snots of mortar could now push an insulation batt out of place from behind. The batt could bridge the cavity or provide a surface for more snots of mortar or debris to stick to. If left too late it is impossible to clean behind the insulation without removing a portion of wall. The cover photograph of this essay is instructive in this regard.

Solution?: Re-training of blockies and consistent vigilance by supervisors.

3.3 Thermal looping

While preventing the cavity being bridged (by insulation batts, debris or snots of mortar) is clearly significant from a moisture penetration point of view, there is added significance to insulation batts being pushed out of place by even a few millimetres. Jan Lecompte's 1990 paper 'The Influence of natural convection on the thermal quality of insulated cavity construction' [11] makes clear the substantial effect that air passage through these gaps has on the thermal performance of insulated cavity walls. This is known as 'thermal looping'.

His study looked at the effect of air gaps between insulation batts, behind insulation batts and through mineral wool type insulants. The test wall consisted of an inner leaf of 90mm of cellular concrete, plastered on both sides (presumably for smoothness as much as U-value) and an outer leaf of 12mm plywood set into a calibrated 'Hot Box-Cold Box'. In his graphs 'C' is the cold or outer void, 'H' is the hot or inner void.

In the first tests the overall cavity was 90mm wide. 50mm of extruded polystyrene was inserted leaving a 10mm void between it and the inner leaf. The theoretical U-value of this test wall was 0.34W/m2K. Fig 2. illustrates two tests examining the effect of gaps on convection and thermal performance. Both graphs show four vertical lines representing the temperature on either side of the inner (HB) and outer (CB) leafs of the test wall for its two metre height. In both cases there is a 10mm void behind the insulation and 40mm in front. The graph on the left represents the first test where the insulation was tightly sealed on all sides. The right graph represents the second test where a 10mm gap was allowed above and below the insulation.

By comparing the two graphs It can be clearly seen that two things occurred in the second test: (1) a convection current occurred which reduced the temperature of the inner leaf and increased the temperature of the outer leaf and (2) warm air circulating around the insulation generally rose which meant that the upper part of the outer leaf grew warmest and the upper part of the inner leaf lost least heat. At the same time cold air gathered at the bottom leading to a very serious reduction in temperature of the cavity face of the inner leaf but little change to the outer leaf.

What is startling is that Lecompte measured a 193% increase in heat transfer, due to the 10mm void and 10mm gaps, which resulted in an actual U-value of 0.65W/m2K in this experiment! This clearly shows that it would have been better to have had a *lower* U-value for this wall, say of 0.45W/m2K, and take care to either eliminate a rear void entirely or seal around the insulation than to specify a higher U-value alone. What is also striking is that the existing calculation methods listed in TGD L could not predict this. In fact as the Elemental

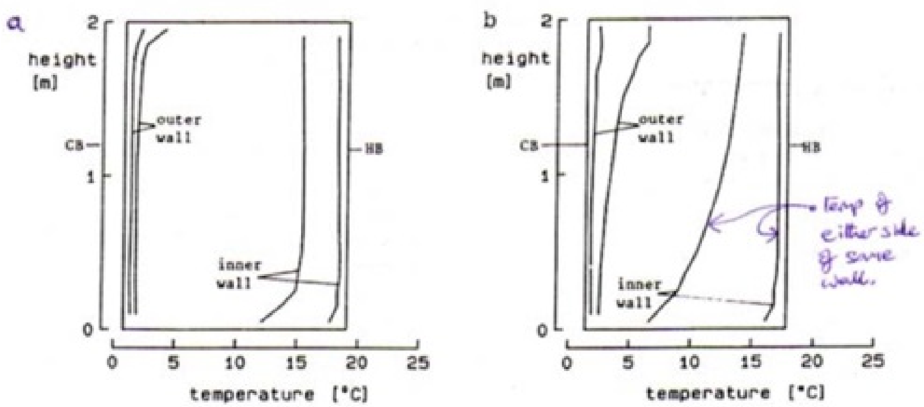


FIGURE 7

Measured Temperature profiles, gaps at top and bottom: (a) gaps = 0mm. (b) gaps = 10mm

Heat Loss method in TGD L gives an air cavities a Resistance value of 0.180m2K/W regardless of its width (or any gaps) an enthusiastic estimator might count *both* voids and expect an even better U-value than 0.34W/m2K!

air leaks and residual cavities can cause a substantial increase in heat transfer.' [11]

What struck me in researching this essay is that thermal looping and its impact is not refered to in any of the following key publications:

FIGURE 8

Influence of gaps and cavities on the heat transfer

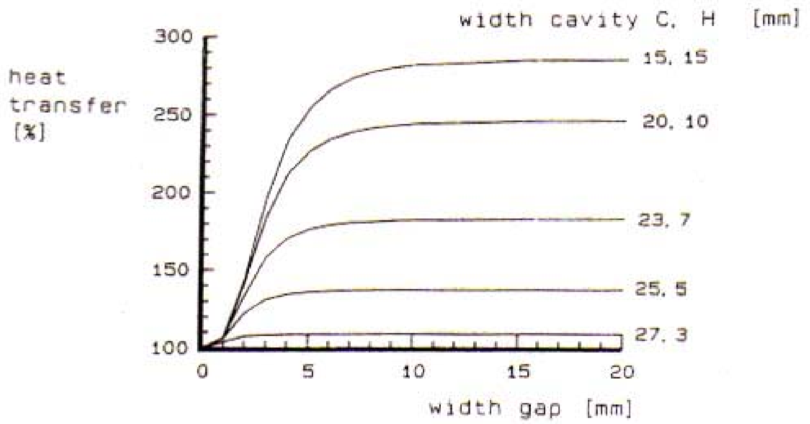


Fig. 4. Influence of gaps and cavities on the heat transfer

In his second set of experiments Lecompte reduced the overall cavity to 80mm and moved the position of the 50mm of insulation within it. What he found was that the width of the gap *behind* the insulation had a greater effect than the width *between* the insulation batts. Gaps greater than approximately 5mm had little extra effect on the rate of thermal heat transfer regardless of the inner void width. In this experiment even a 5mm inner void could lead to a 35% increase in heat transfer, while a 15mm void led to an amazing 280% increase. A conclusion he reached from a further experiment which looked at permeability through mineral wool batts was that gaps behind the insulation were more significant than gaps through it: i.e. its permeability.

I believe thermal looping must be one of the main causes of the thermal under-performance the BRE and Alba Building Services discovered in partial fill cavity walls. Full fill cavity walls on the other hand can suffer from greater moisture penetration problems than partial fill, particularly in areas exposed to high winds, but won't suffer from thermal looping if insulation beads are used.

Solution? Lecompte stated

'From this research it can be concluded that stringent requirements must be formulated concerning the application of insulation in cavity construction, since the presence of small

Building Regulations 2002, Technical Guidance Document L: Conservation of Fuel and Energy: Dwellings, *Mitchell's Building Series: Structure and Fabric Part 1, HomeBond' House Building Manual* or *No.4 Robust Details - Masonry: Cavity Wall Insulation: Partial-Fill*.

Nor are there guidelines in these publications that would prevent the problem. The emphasis in fixing insulation always appears to relate to keeping cavities clear and preventing mositure penetration. This is particularly surprising in the last booklet listed which is after all quite closely focused. It appears that thermal looping is not only a highly significant issue but a virtually unknown too. This is depite the fact that Lecompte's article is fourteen years old and was published in a well-regarded scientific journal: *Building Research and Practice.*

In my view the requirements that the cavity face of the inner leaf be perfectly clean and true, *and* that the insulation be so tightly fixed to it that any resulting air gap is a millimetre or less in order to prevent a sizeable reduction in thermal performance is impossible on site. Lecompte was able to entirely eliminate a rear void by using laboratory conditions, a limited length of wall and by plastering the cavity face of the inner leaf. Perhaps this is the only way a rear void can be avoided. The other solution is to seal the entire layer of insulation including perimeter so that even if there is a rear void it's isolated. While other issues mentioned here might be resolved by re-training or altering specifications this issue in my view demands a move away from partial fill cavity walling. insulation the technology has already reached a limit and won't be able to accommodate a farther increase in standards.

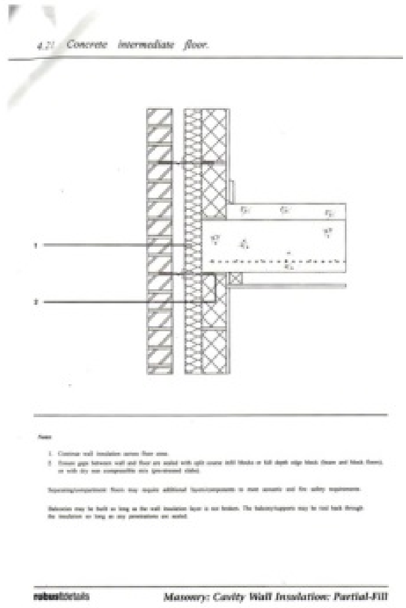


FIGURE 9

excerpts from HomeBond's House Building Manual and from No.4 Robust Details - Masonry: Cavity Wall Insulation: Partial-Fill.

3.4 Self-assessment

Because many of the new systems, and I include timber frame in this, are 'chasing a market' *and* because many have been conceived specifically to deliver better thermal performance it is more common to see those involved, be they architects, builders or the system designers commissioning thermal imaging and 'blower door' tests (where air-tightness is proven by sucking air through) the completed structure. This has two benefits: they can then carry out remedial works on those buildings to upgrade their performance, and secondly they can learn lessons about how to design and construct buildings that perform as they were intended to.

Solution?: The concrete industry and those building and designing blockwork structures need to learn lessons from the opposition.

3.5 Materials and dimensions

The latest TGD L shows a 120mm cavity filled by 80 mm of extruded polyurethane and 40mm void. If a mineral wool insulant was used a 112mm batt would be necessary to achieve the same U-value: this would result in a 152mm cavity. Both Foster [3] and Ancon Building Products [5] give 150mm as the maximum size for a cavity when normal wall ties are used. This means that for those who wish to specify mineral wool in preference to a cellular plastic

As U-values get higher it becomes more important that every element performs at the estimated value. As the Resistance value (m2K/W) of insulation has become proportionately more significant in the overall calculation, the importance of that performance being achieved has grown. Unfortunately this is also the area where it's hardest to get objective information. If this was easier one would be better able to arrive at a tight specification for a higher performing partial fill cavity wall for instance. The effect of ageing in cellular plastic insulants and of wetting of mineral wool insulation on thermal performance are two of the disputed areas. The UK Mineral Wool Association claim the first has a significant effect but dispute any reduction in performance of the second, 6 while XCO2 state that the aged value is the figure used (contrary to what suppliers have told me) and go on to emphasise negative nature of the second. The UK Mineral Wool Association has an obvious stake in promoting its product, but so do independent consulting engineers XCO2. Their booklet *Insulation for Sustainability- A Guide* was sponsored by BING, the Federation of European Rigid Polyurethane Foam Associations.

Solution?: Recognise that in at least one area partial fill cavity walling has reached its limit. The only solution for the second issue is to get truly independent analysis done of all insulants. But this might be difficult as the stakes are high.

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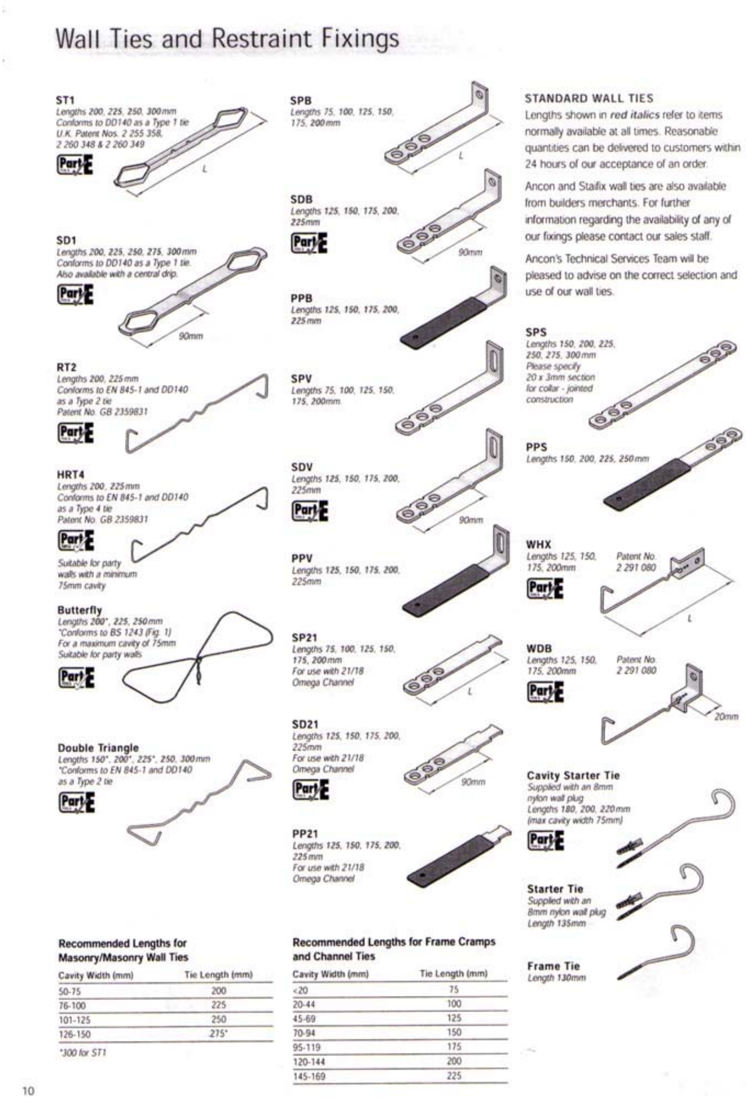
FIGURE 10

A page from a brochure on wall ties from Ancon



Wall Ties and Restraint Fixings

ST1
Lengths 200, 225, 250, 300mm
Conforms to DD140 as a Type 1 tie
U.K. Patent Nos. 2 255 358, 2 260 348 & 2 260 349

SD1
Lengths 200, 225, 250, 275, 300mm
Conforms to DD140 as a Type 1 tie.
Also available with a central drip.

RT2
Lengths 200, 225mm
Conforms to EN 845-1 and DD140 as a Type 2 tie
Patent No. GB 2359831

HRT4
Lengths 200, 225mm
Conforms to EN 845-1 and DD140 as a Type 4 tie
Patent No. GB 2359831
Suitable for party walls with a minimum 75mm cavity

Butterfly
Lengths 200, 225, 250mm*
**Conforms to BS 1243 (Fig. 1)*
For a maximum cavity of 75mm
Suitable for party walls

Double Triangle
Lengths 150, 200*, 225*, 250, 300mm*
**Conforms to EN 845-1 and DD140 as a Type 2 tie*

SPB
Lengths 75, 100, 125, 150, 175, 200mm

SDB
Lengths 125, 150, 175, 200, 225mm

PPB
Lengths 125, 150, 175, 200, 225mm

SPV
Lengths 75, 100, 125, 150, 175, 200mm.

SDV
Lengths 125, 150, 175, 200, 225mm

PPV
Lengths 125, 150, 175, 200, 225mm

SP21
Lengths 75, 100, 125, 150, 175, 200mm
For use with 21/18 Omega Channel

SD21
Lengths 125, 150, 175, 200, 225mm
For use with 21/18 Omega Channel

PP21
Lengths 125, 150, 175, 200, 225mm
For use with 21/18 Omega Channel

STANDARD WALL TIES
Lengths shown in *red italics* refer to items normally available at all times. Reasonable quantities can be delivered to customers within 24 hours of our acceptance of an order.

Ancon and Staifix wall ties are also available from builders merchants. For further information regarding the availability of any of our fixings please contact our sales staff.

Ancon's Technical Services Team will be pleased to advise on the correct selection and use of our wall ties.

SPS
Lengths 150, 200, 225, 250, 275, 300mm
Please specify 20 x 3mm section for collar - jointed construction

PPS
Lengths 150, 200, 225, 250mm

WHX
Lengths 125, 150, 175, 200mm
Patent No. 2 291 080

WDB
Lengths 125, 150, 175, 200mm
Patent No. 2 291 080

Cavity Starter Tie
Supplied with an 8mm nylon wall plug
Lengths 180, 200, 220mm (max cavity width 75mm)

Starter Tie
Supplied with an 8mm nylon wall plug
Length 135mm

Frame Tie
Length 130mm

Recommended Lengths for Masonry/Masonry Wall Ties

Cavity Width (mm)	Tie Length (mm)
50-75	200
76-100	225
101-125	250
126-150	275*

**300 for ST1*

Recommended Lengths for Frame Cramps and Channel Ties

Cavity Width (mm)	Tie Length (mm)
<20	75
20-44	100
45-69	125
70-94	150
95-119	175
120-144	200
145-169	225

10

The effect of ageing in cellular plastic insulants and of wetting of mineral wool insulation on thermal performance are two of the disputed areas. The UK Mineral Wool Association claim the first has a significant effect but dispute any reduction in performance of the second, 6 while XCO2 state that the aged value is the figure used (contrary to what suppliers have told me) and go on to emphasise negative nature of the second. The UK Mineral Wool Association has an obvious stake in promoting its product, but so do independent consulting engineers XCO2. Their booklet *Insulation for Sustainability- A Guide* was sponsored by BING, the Federation of European Rigid Polyurethane Foam Associations.

3.6 Change the Standards & Δ U-values

Besides highlighting thermally under-performance by building type *Field Investigations of the Thermal Performance of Construction Elements as Built* also highlighted an under-performing prediction or calculating system. EN ISO 6946 sets out the measuring system upon which TGD L (and the UK equivalent) are based. CEN/TC 89, the committee responsible for this standard

'is aware that there are shortcomings in the Standard and has requested research to develop it. Hitherto the necessary work has not been done and as a result questions remain

about the accuracy of the Standard in practice'. [12]

Nonetheless two years after this report was published the Department of the Environment continued to base its measurement system on EN ISO 6946 to achieve even higher thermal standards than those studied in the Report. It would be fascinating, and timely, therefore to measure 2 year old buildings in 2004/5 that were built using the 2002 TGD L standard.

Solution?: Are their alternative measurement systems and do they overcome this dichotomy between calculated and measured values?

Yes there are. Current practice in Sweden for instance requires 'adjustments' to be made to the calculated U-value to reflect the kind of problems that have been described in this essay. These adjustments are broke into two ΔUg and ΔUk. The first deals with uncertainties in the properties and dimensions of materials themselves due to conditions of production. The second deals with uncertainties which arise from the object or material's use due to the design and construction of the particular building or building type. Both also allow for workmanship.

'In practice, the two correction terms, ΔUg and ΔUk, typically add up to between 0.02 and 0.06 W/m2K. This would, for typical walls in Sweden, correspond roughly to a 5% - 20% adjustment in the U-value, and it is notable that the latter figure of 20% is similar to the average level of difference observed in the present work for wall U-values. Sweden also has provision for a "type approval" system which makes it possible for good, controlled constructions to be assigned smaller Delta-U adjustments where these smaller adjustments can be shown to be appropriate.' [12]

This system could be layered on top of the existing measurement systems in use in the UK and Ireland (based on EN ISO 6946) which would lessen the sense of embarassment for a minister (it's an improvement not a reversal of policy) and the inconvenience for the industry which has got used to the existing method of meaurement. It is essentially a serious of checks and balances based, unlike EN ISO 6946, on the fact that each material, each building technology and construction company are likely to fall short of the ideal to a certain degree. This is only reasonable and must be accounted for.

PART 4 Conclusions

4.1 Partial Fill cavity walling

'Radical abatement measures must be implemented immediately to offset further growth in these emissions over the next ten years and to prepare for much more onerous obligations in the longer term'.

EPA Newsletter Vol 7 No 2 October 2000 13

In my view the quote above from the Irish Environmental Protection Agency (EPA) would be a useful guiding principle for the Irish Government and construction industry professionals in making decisions about which building technologies and thermal performance measurement systems to use. It's clear the government will need to look to guiding principles and the big picture to deal with the heavy lobbying it will face if it does move from its present position of appeasement.

If one looked at partial fill cavity walling using EPA's statement as a principle and the information I have examined above as the context, the only sensible decision would be to say that partial cavity walling *has* reached its limit and is no longer useful in achieving this society's goals of improved living standards while *also* abating environmental degradation. There are now ample more predictable, and adaptable technologies available to replace it.

4.2 Who will wear the crown?

Rendered external wall insulation technology (EWI) seems to be particularly suited to becoming the best practice *site-built* building technology. Given the growth and exciting variety of *factory-based* building systems it would however be inappropriate for any technology to dominate as much as cavity walling (partial and full-filled) has again. Nonetheless it is ironic that EWI is basically an updated version of the rendered 215mm solid block, but without the original drawbacks of low thermal values, inflexible render and moisture penetration that led to the growth of cavity walling. It also avoids some of the increasingly obvious drawbacks of cavity walling itself, which I looked at above (sections 3.2 to 3.2).

With EWI all the insulation applied may be inspected in one go before being closed-up: remedial work is also easily done at this stage.

It would also appear from my discussions with manufacturers, such as STO that rendered external wall insulation technology can accommodate future higher levels of thermal insulation with ease, which I have argued partial fill cavity walls cannot. Finally it is significant that there is a sensible division of trades: blockies build and the installers insulate and weatherproof. Only installers that are trained by each manufacturer and who work for a company on an approved list may apply the rendered insulation system. This training focuses closely on the link between thermal performance and careful installation of the insulation.

The downside for the contractor is that EWI is more expensive, despite reductions in the volume of blockwork and in secondary steel (e.g.: lintels and wall ties for the external leaf). The Client and the specifier (either a Builder or an architect) therefore need to be very clear on why they are choosing EWI over partial fill cavity walling. Making this decision is not helped by the fact that key publications of the building industry (listed above) mention little about the dichotomy between measured and predicted U-values and its causes, and have nothing to say at all about thermal looping.

4.3 Direct effects of under performance

The continued dichotomy between measured and predicted U-values in housing will have several important effects. There is the negative impact on:

1) The consumer buying a house that needs more heating than it should do. In this area at least the Government is making progress and things are likely to change. Energy rating legislation will come into force in 2006 that will force all those selling or renting property to have a certificate rating its thermal performance. It is hoped that this will create a link between the percieved worth of a building and its thermal performance. If it does the market place may itself begin to demand better performing construction types.

2) Citizens's pockets: The EU is already threatening the Irish Government with a penalty of billions of Euros for its failure to mitigate greenhouse gas emissions. As I have already shown poor thermal performance in housing contributes substantially to this. This penalty will have to be paid by the taxpayer.

3) Compliance certificates: At the completion of construction projects a professional (generally an architect) acting on behalf of the Client, signs a 'Certificate of Compliance with the Building Regulations'. This basically states that the standards as set-out by the regulations for structure, disabled access, thermal performance etc have been met. Architects who have specified partial fill cavity walls based on the information available to them are signing these forms quite confidently after a visual inspection of the works.

I theorise that if the information presented here became more widely known and further tests carried out on thermal values in Irish construction confirmed the results of Lecompte 11 and Doran's 12 work in particular, insurance firms would either refuse to insure architects who signed Certificate of Compliance for buildings with cavity walls or would increase the premiums for their professional libabity insurance.

4.4 The funnel narrows

'The Natural Step' (a worldwide environmental consultancy that started its work in Sweden) has a powerful metaphor for the period we are moving into of increasingly limited resources, higher populations and tighter legislation: its consultants refer to a narrowing funnel that a body (be it a population, practice, an industry, or a technology) is on a flight path through. As a resource is depleted, or legislation is created or a cost increases unexpectedly that body hits the wall of the funnel. If it cannot re-position itself beforehand it will not get through the narrowest point. It can only do this by changing its practices, resources or attitudes.

I think this is a very relevant metaphor for partial fill cavity wall technology and the Irish building industry in general. The three examples listed in 4.3 above are examples of flght paths that will hit the wall. If the government or industry does not take steps to re-position that technology and the measurement systems used, we will hit the wall and be forcibly and painfully re-positioned.

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