DEVELOPMENT OF INNOVATIVE PRODUCTS FOR NEWBUILT HOMES TO MEET THE TIGHTENING BUILDING REGULATIONS

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1 INTRODUCTION

All new houses built in UK have to comply with the Building Regulations for residential dwellings set in their country. These regulations are reviewed on a regular basis, with use of research studies and open consultations. The main aim of reviewing the regulations is to set new targets for the performance of the buildings – in aspects of structure, fire, sound, structure, water, waste and others.

1.1. Building regulations for sound

England and Wales
Until December 2011 England and Wales had been using the same Building Regulations set in Approved Documents [1], which were in power from 2003. On 31st December 2011 the power over Building Regulations' changes for Wales was transferred to Welsh ministers [2]. The Approved Documents as set on the date of transfer are currently applicable in Wales.

The most recent amendments of English Approved Document E (sound), introduced in April 2013 and then will come in July 2013, will be applied for building works carried out in England, with option to be applied to building work carried out on excepted energy buildings in Wales as defined in Transfer of Functions document [2].

Scotland
Building Regulations in Scotland are controlled by Scottish Government Building Standards Division and are separate from those applied in England and Wales. The Regulations are separated into Sections 1 to 7, which cover structure, fire, waste, water, sound, energy and sustainability [3]. The Regulations were updated in 2010 with main changes being implemented for fire, sound, energy and sustainability.

The sound insulation criteria for Scotland, England and Wales are shown in Table 1.

Other criteria for new built houses
Together with the core regulations set in the Building Regulations there are several other standards applicable to the new built housing built by the contractors who wish to incorporate sustainable design and construction and target the improved level of health and wellbeing. The recommended standards are described in Code for Sustainable Homes (for England and Wales) [4] and Sustainability Section 7 (with recommended levels to achieve) [3].

The Robust Details Scheme is an alternative scheme to pre-completion sound testing operating in England, Wales and Scotland [5]. The scheme could be applied to all new build joined houses, bungalows and flats. The constructions promoted to Robust Details scheme should demonstrate through the site testing the compliance with the relevant minimum Building Regulation performance standards by achieving the level higher than the regulations on a certain value. The residential dwellings registered with the scheme and built using the constructions from the Robust Details list are thoroughly checked during the construction process by the inspectors. For these registered dwellings there is no requirement of the re-completion sound testing.

The requirements for all aforementioned schemes are also listed in Table 1.

Table 1. Summary of sound insulation criteria set in UK regulations

Construction in new built houses	Scotland, Section 5	England, ADE	Wales, sound regulations	Section 7: Sustainability (Scotland)	CfSH credits (England)	Robust Details (England)	Robust Details (Scotland)
Walls, airborne	56, $D_{nT,w}$, dB	45, $D_{nT,w}+C_{tr}$ dB	45, $D_{nT,w}+C_{tr}$ dB	Bronze: $D_{nT,w}$ +0 dB Silver: $D_{nT,w}$ +2 dB Gold: $D_{nT,w}$ +4 dB	1 credit: $D_{nT,w}+C_{tr}$ +3 dB 3 credits: $D_{nT,w}+C_{tr}$ +5 dB 4 credits: $D_{nT,w}+C_{tr}$ +8 dB	$D_{nT,w}+C_{tr}$ +5 dB	$D_{nT,w}$ +5 dB
Floors, airborne	56, $D_{nT,w}$, dB	45, $D_{nT,w}+C_{tr}$ dB	45, $D_{nT,w}+C_{tr}$ dB				
Floors, impact	56, $L'_{nT,w}$, dB	62, $L'_{nT,w}$, dB	62, $L'_{nT,w}$, dB	Bronze: $L'_{nT,w}$ -0 dB Silver: $L'_{nT,w}$ -2 dB Gold: $L'_{nT,w}$ -4 dB	1 credit: $L'_{nT,w}$ +3 dB 3 credits: $L'_{nT,w}$ +5 dB 4 credits: $L'_{nT,w}$ +8 dB	$L'_{nT,w}$ +5 dB	$L'_{nT,w}$ +5 dB

1.2. Building regulations for energy

Dwellings should be constructed and equipped with energy-related devices so that performance is consistent with Dwelling Emission Rate (DER). In calculating DER for a dwelling, the U-values for partitions should be predicted or measured in-situ. To calculate the whole house performance the individual U-values could be predicted using the certified software. The minimum U-values for wall and floor partitions as required in different UK standards are shown in Table 2.

Table 2. Recommended U-values for separating walls and floors set in UK

	Scotland, Section 6	England, ADL	Wales, Energy regulations
Walls:			
Solid wall	0.0 W/m^{2}K	0.0 W/m^{2}K	0.0 W/m^{2}K
Unfilled cavity with no effective edge sealing	0.2 W/m^{2}K	0.5 W/m^{2}K	0.5 W/m^{2}K
Unfilled cavity with effective edge sealing		0.2 W/m^{2}K	0.2 W/m^{2}K
Fully filled cavity with effective edge sealing		0.0 W/m^{2}K	0.0 W/m^{2}K
Floors:			
Timber floor	0.15 W/m^{2}K	0.25 W/m^{2}K	0.25 W/m^{2}K
Concrete floor	0.15 W/m^{2}K	0.25 W/m^{2}K	0.25 W/m^{2}K

In England some minor changes to Approved Document L were introduced from April 2013 and further changes are due in July 2013.

The consultation on changes of energy section 6 in Scotland was completed recently, and the new regulations for energy are expected later in 2013. The main reasons for changes are to continue the process of carbon emission reduction as suggested in Sullivan report written in 2007 towards very low carbon houses target.

Energy regulations for Wales is currently under revision led by Welsh Government. The consultation on the changes was run between 31 July 2012 and 23 October 2012. The main aims of the changes are to influence emission reductions in new buildings and existing buildings in Wales, to improve the energy performance of buildings. This will help Wales move towards zero carbon and near zero carbon energy buildings by 2020.

1.3. New guidance for timber frame during construction

The UK Timber Frame Association (UKTFA) has launched new guidance designed to help clients, designers and construction companies [6]. Coordinators consider the risk of fire to neighboring buildings should a fire occur in a timber frame building under construction and improve the building fabric's defense against accidental fire and also arson attack. The guidelines also consider susceptibility to ignition of fire, a much overlooked subject.

The guidance focuses principally on separating distances between a receiver (existing building) and emitter (new timber frame building) and has established how wide these distances need to be to mitigate the fire risk through newly defined Categories A,B and C:

Category A - Standard open panel timber frame;
Category B - Reduced fire spread frames;
Category C - Fire spread resistant frames.

All constructions used for new built houses should fall into one of the above categories to be approved for use on site.

2 COMPATIBILITY WITH REGULATIONS FOR LOW CARBON HOUSING PRODUCTS

2.1 Low Carbon Building Technologies Gateway

Currently the Institute for Sustainable Construction at Edinburgh Napier is leading the Low Carbon Building Technologies Gateway (LCBT Gateway [7]), which had started in July 2010 and is going until end of October 2013. LCBT Gateway project is set to support 300 Scottish based small and medium sized companies working in design and development of innovative low carbon products for new built housing. Previously government funded research had specifically only focused on energy performance, but to deliver the energy saving and carbon reduction solutions will require the product or system to be also compatible with other standards and regulations. Some of the outputs of the project were previously presented by the authors at the Institute of Acoustics conference in 2011 [8], during the first year of the project.

The project is currently within 32 months of its duration. In this period 235 enterprises are supported through the project, that includes construction product manufacturers, house builders, housing associations, designers and architects. The project had assessed and supported around 130 new construction building technologies, systems and products; created 25 supply-chain partnerships and forwarded over 60 products to full scale installations. The key goal of the project is to investigate for each of these products the technical compatibility between four main areas of building regulations

and standards: energy efficiency, structure, sound insulation and sustainability. The brief list of the achieved outputs is shown in Table 3.

Table 3. LCBT Gateway project outputs

Outputs	Expected	Achieved
Organisations reached through conferences & workshops	1000	2445
Products or systems reviewed through the project	300	265
Number of products tested	125	94
Number of products forwarded to full scale installation	80	65

2.2. Effect of regulatory changes on the choice of constructions

Scottish Building Regulations for sound insulation had been considerably reworked in 2010. The minimum airborne performance requirements were increased for 4 dB (walls) and 3 dB (floors), and the maximum impact performance requirement was reduced for 5 dB (floors). This alteration of acoustic performance standards means that in order to consistently pass the performance criteria set the specifications of standard floor and wall constructions will have to change.

The wall constructions which previously passed the Regulations now have to be reinforced to achieve the new performance levels. Some of the samples of the wall and floor constructions demonstrating the changes which should be required to get the performance improved are shown in Table 4.

Table 4. Typical constructions passing new regulations

Type of construction	Original dimension (pass pre-2010 regulations)	Recommended dimension (pass 2010 regulations)	Difference, %
Wall constructions			
Solid block wall	282 mm	366 mm	30%
Cavity block wall*	317 mm	347 mm	9%
Timber frame unsheathed wall*	260 mm	300 mm	15%
Timber frame sheathed wall*	300 mm	310 mm	3%
Floor constructions			
In-situ concrete floor with floating floor treatment	395 mm	425.5 mm	8%
Pre-cast concrete floor	277.5 mm	410.5 mm	48%
Timber floor (I-joists)	372 mm	407 mm	9%
Timber floor (solid joists)	357 mm	387 mm	8%

* walls are traditionally built with clear cavities.

The main changes for the constructions are: increase of the thickness of the constructions (i.e. widening the air gaps between the leafs, use of thicker slabs or thicker wall panels), change of the materials (thicker or denser insulation, different type of plasterboard, addition of resilient bars) and addition of extra layers of insulation and finishing (extra plasterboard on walls, screed and/or floating floor elements on floors etc). All these alterations will affect the footprint of the house as built or lead to the reduction of the habitable area of the dwelling, and also will increase the overall building cost for the house builders.

In addition to the above, the changes in energy regulations for all countries state that to meet the lowest U-values under the new energy requirements, the cavities in the double leaf walls are required to be fully filled, preferably with effective edge seal implemented. The solution for effective edge seal problem had been addressed by researchers before, and described, for example, in article [9].

The above issues could be solved by developing new constructions for party walls and floors, which will are compatible with all new regulations.

3 CASE STUDIES

A number of innovative wall and floor constructions were assessed and tested over the duration of LCBT Gateway project.

3.1. Single leaf timber party wall

Single leaf party wall construction was developed by Scottish SME Intelligent Wood Systems is shown in Figure 1, and also described below:

- 38x245mm profiled top and bottom rails
- 38x75mm timber studs
- *FrameTherm* 35 insulation behind studs
- *FrameTherm* 40 insulation between studs
- 9mm IWS-FAST board
- 15mm *SoundBloc* plasterboard to both sides

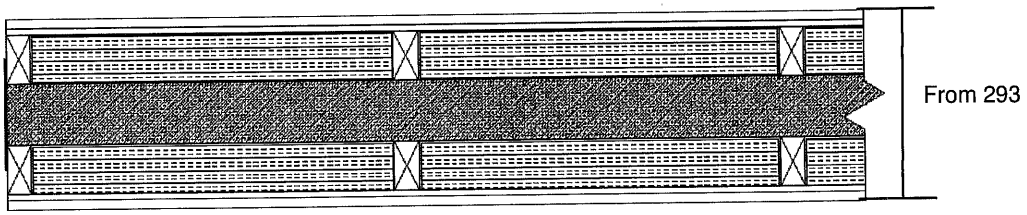

Figure 1. Single leaf party wall

The performance of this wall as tested at the laboratory in close to real site conditions is given in Table 5 assessed against the regulations for Scotland, England and Wales. The results suggest that the current wall construction satisfies the acoustic regulations for party wall construction for all these countries.

Table 5. Results of sound insulation testing of single skin party wall		
Construction type	Scotland:	England, Wales:
IWS Single Leaf Separating Wall	Airborne: 56 $D_{nT,w}$ (dB)	Airborne: 50 $D_{nTw} + C_{tr}$, (dB)
Result:	Pass	Pass

The U-value for single skin party wall in SAF software is set as 0 W/m^{2}K. This means that the above construction passes the energy regulations as set for all countries.

The wall construction includes the FAST board. It is the fire resistant MgO board, which allows the overall system to satisfy fire regulations during the construction (as category C construction) and during the lifetime of the building.

3.2. Separating floor construction for masonry building

Traditionally masonry buildings are built in England and Wales, where about 75% of the houses are masonry. The main advantage of this type of construction is its increased thermal mass, which leads to improved energy performance of the overall construction. In Scotland the small percentage of houses is built masonry, with main issues raised by the contractors such as building time, mortar collected in the cavity which reduces the acoustic performance, and, most recently, the necessity to use the thicker concrete slab floor to achieve acoustic regulations set in Scotland, which are more restrict than the once in England and Wales.

The innovative cassette timber floor construction was tested at the laboratory conditions for masonry walled house type (aircrete walls). The floor design is shown in Figure 2. The floor is to be delivered on site pre-assembled at the factory, with top and bottom layers screwed together. Once arrived on site, the floor is installed on the top of the masonry wall and then unscrewed to drop the ceiling part of the cassette construction in its place.

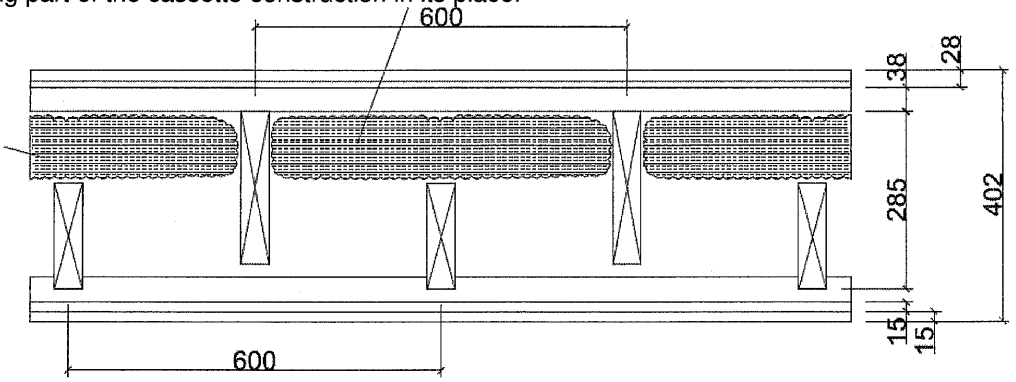

Figure 2. Timber floor for masonry building

Acoustic testing conducted at the laboratory demonstrated that the floor construction would meet all the regulation criteria for Scotland, England and Wales. The results are shown in Table 6. The results suggest that this floor construction meets all the regulations as required for Scotland, England and Wales.

Table 6. Results of sound insulation testing of timber floor		
Construction type	Scotland:	England, Wales:
Timber floor in masonry building	Airborne: 62 $D_{nT,w}$ (dB) Impact: 55 $L'_{nT,w}$ (dB)	Airborne: $D_{nTw} + C_{tr}$, 55 (dB) Impact: 55 $L'_{nT,w}$ (dB)
Result:	Pass	Pass

The U-value for timber floor in SAF software is set the same for timber and masonry floors. This means that the above construction passes the energy regulations.

The joists in the proposed system are treated for fire resistance prior assembly, and the overall system satisfies fire regulations during the construction (as category C construction) and during the lifetime of the building.

3.3. Waste material use for cavity insulation in party wall

One of the main issues at any building site is related to the waste recovery of off-cut materials which should be collected. The waste removal is priced per volume, so the larger the off-cut pieces are binned the removal of waste becomes more expensive. To reduce the amount of waste going off the site and to create the possibility to re-use the off-cuts of site materials the study was undertaken to process the polyurtheane foam into the fine crumb material (shown in Figure 3) and then measure the acoustic performance of these crumbs when poured into the cavity wall.

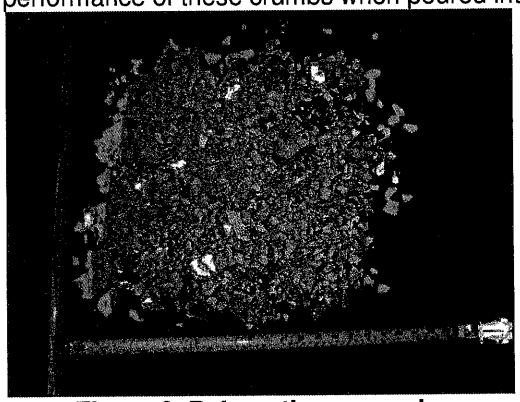

Figure 3. Polyurethane crumbs

The laboratory testing of timber frame walls and masonry cavity wall with cavities filled with polyurethane crumbs was conducted. The results of tests, shown in Table 7, suggest that the all regulations can be met with this material placed in the cavity.

Table 7. Results of sound insulation testing of fully filled cavity walls

Construction type	Scotland/result	England, Wales/result
Timber frame sheathed wall	Airborne: 71 $D_{nT,w}$ (dB)/ Pass	Airborne: 58 $D_{nTw} + C_{tr}$, (dB)/ Pass
Timber frame unsheathed wall	Airborne: 63 $D_{nT,w}$ (dB)/ Pass	Airborne: 54 $D_{nTw} + C_{tr}$, (dB)/ Pass
Masonry lightweight aggregate wall	Airborne: 62 $D_{nT,w}$ (dB)/ Pass	Airborne: 55 $D_{nTw} + C_{tr}$, (dB)/ Pass

To achieve the most recent energy regulations, the party walls should be built with fully filled cavities and/or with effective edge seal. The proposed crumb material will allow the walls to pass the energy regulations for walls and still satisfy the acoustic regulations for Scotland, England and Wales.

The material is currently tested against fire regulations.

4 ACKNOLEDGEMENTS

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