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Living with helicopter noise - an evaluation of the performance of acoustic double glazing and sound attenuated ventilation units when fitted to a traditional UK dwelling

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ABSTRACT

Sound insulation grant schemes have been available in the UK for a number of years, to eligible sections of the public living near airports, military airfields and certain road improvements. The need to minimise the use of fuel and power to heat homes has driven technology and resulted in the extensive use of insulated glazing units (IGUs) often referred to as thermal double-glazing. Standard thermal double glazed units are not particularly effective at sound reduction but special units have now been developed using panes of different thicknesses, some laminated, which when mounted in high quality frames provide higher levels of sound insulation. With permission of the householders and land agents a properties located near a military helicopter training airfield were modified and fitted with acoustic double glazing units, and in a second phase, with acoustic ventilation units to meet current regulations. A series of measurement exercises using helicopters provided by MOD were then conducted to assess, objectively, the effect of the modifications on the sound insulation and resultant internal noise levels. This paper describes the modifications carried out and presents the practical improvements obtained.

1. INTRODUCTION

Sound insulation grant schemes have been available in the UK for a number of years to eligible sections of the public living near airports, airfields and certain road improvements. The grant is a contribution towards the cost of carrying out, usually quite specific, insulation works to reduce external noise heard in the homes. To be eligible for grants near airports and airfields, householders usually have to live within a noise contour defined by some form of averaging process involving levels of flyover noise and numbers of flyover events. This invariably means that only householders living near busy airports or airfields where larger multi-engined jets or in the case of military airfields, fast jets, are the main user.

Homes near airfields where helicopter operations are dominant very rarely qualify. However many helicopters have a distinctive noise footprint rich in low frequency harmonics which is instantly recognisable to people living near airports, airfields and helicopter bases. Overall noise levels from individual helicopters are often not as high as those from fixed wing aircraft using the same facility but helicopter noise is often claimed to be more intrusive and can lead to complaints from householders.

The schedule of works for grant schemes has, in the past, been based on technology and needs some thirty to forty years ago[1,2] and only recently have newer advances in building technology been included[3,4]. Recent changes in the U.K. Building Regulations place considerable weight on the conservation of heat and power in dwellings and in future sound insulation schemes will have to comply with these Regulations. This paper describes the outcome of a series of field trials set up to evaluate the use of acoustic double glazing together with insulated ventilation units in a traditional brick built dwelling to reduce the noise from passing helicopters whilst providing adequate fresh air for combustion and background ventilation.

2. SELECTING SOUND INSULATION IMPROVEMENTS

A Background

When considering the acoustic insulation of dwellings it is normally assumed that the windows form the weakest element of the building. For this to be true the wall in which they are mounted must have a much higher sound reduction index than the windows themselves. However the overall insulation of the wall and windows may be reduced by sound gaining entry through other routes such as through roof structures, doors and chimneys and ventilators.

In the case of the UK building stock, traditional dwellings are usually substantial structures with brick built walls carrying a slate or concrete tiled roof on a timber sub-frame. Internal ceilings are constructed with timber joists, underlain with skimmed plasterboard or on earlier examples, lathe and plaster. External doors have timber frames with simple infill panels or outer plywood panels with either a hollow or solid timber core. Windows are mainly timber framed with opening lights and glazed with 3 or 4mm single glass sheets although some metal frames were used. From the 1970s onwards, newer materials and construction techniques have been introduced with an ever-demanding goal of providing increased thermal insulation, sometimes, but very rarely, with a view to improving sound insulation as well.

Where sound insulation was a prime consideration, for instance near airports, military airfields and certain road improvements, emphasis was placed upon improving the insulation of the weaker component, mainly the windows. The improvements chosen were dependent on the technology of the day and the first sound insulation grant schemes were based around retaining the existing primary windows and adding a lightweight framed secondary pane in the window reveal. To obtain optimum sound insulation it was necessary to keep the opening lights closed and ventilation was provided by a fan driven attenuated ventilation unit. Additional works include weather stripping (draught sealing) the primary windows and also doors that lead directly from outside into a habitable room.

Site tests and comments obtained from householders have indicated that the expected sound insulation was often not achieved[5]. Existing frames, especially timber ones, were often warped and difficult to seal with weather stripping and many types of secondary frames (where framing has been minimised to improve appearance) allow the windows to bow and the seals to break open. Some internal cavities of secondary glazed windows were ventilated to the outside to limit the formation of condensation on the inner surface of the outer panes of glass, thus further reducing the acoustic and thermal properties of the window. Adverse comments from users of secondary glazing systems that support the above statements have been made in the past and include criticism of the loss of the use of the windowsill and the need to clean four sides of glass. The continued use of secondary glazing has, no doubt, been a contributor to the fact that insulation grant schemes were, not always, fully subscribed.

Setting aside any need for additional sound insulation, the basic ventilation requirements of earlier U.K. Building Regulations have been met by utilising natural airflow. Stale or moist air warmed by the occupants and by heating and lighting is convected out of the building through airbricks, louvres or openable windows, and replaced by cooler air from outside through airbricks or low-level openable windows. In small domestic rooms the same window, either vertical or horizontal opening, could usually serve the dual task. The effect is known as the “stack effect” and can also be induced by wind pressure across the dwelling. In traditional dwellings the stack effect was quite effective because gaps under doors, warped window frames and direct airflow through simple airbrick ventilators or indirect airflow through gaps in floorboards, invariably augmented the process even when windows were closed. Enough air permeated through the dwelling to feed open fires and stoves and resulting draughts were tolerated. However the introduction of central heating diminished the need for combustion air, except in rooms where boilers were housed and improved air permeability has been encouraged as a means of saving heat and reducing energy consumption. Thermal double glazing has reduced energy consumption further but its installation, in better sealed frames, affected the natural airflow mechanisms that remove excess moisture and potentially foul air resulting in condensation forming on cold surfaces[6]. Removing the source of water vapour, and increasing the temperature in the room or at the cold surface so that it is above the dew point can alleviate but not eliminate such problems. However, it is also necessary to ventilate the room properly so that the air containing the moisture is removed and replaced by drier and fresher air for the comfort of the occupants. The current UK Building Regulations[7] have addressed these matters and minimum standards of air permeability in dwellings have been set requiring the installation ventilation systems to provide the necessary airflow through the various rooms.

Therefore the task of improving the sound insulation of dwellings has become more complicated. In addition to providing adequate sound insulating windows it is necessary to fit an adequate means of ventilation that incorporates sufficient sound insulation so that the performance of not only the windows but also the whole façade is not degraded.

B Glazing System

To obtain a satisfactory acoustic performance using either acoustic insulated glazing units (IGU) or secondary glazing it is necessary to ensure that the window frames and the opening lights are well sealed and therefore it can be expected that the air permeability of such windows will be low. A preliminary study considered a range of glazing systems including the results of laboratory measurements of sound reduction index and estimates of expected field performance for both helicopters and fast jets. The study also looked at the advantages and disadvantages of conventional dual glazing (single panes separated by a wide airspace) and of double glazing (IGUs) over single glazing systems and the differences between thermal and acoustic IGUs.

Standard thermal IGUs do not offer much improvement in performance over well-sealed single glazing of the same weight, although it is acceptable practically (and financially due to long term energy savings). More recently, a range of acoustic IGUs has been developed incorporating laminated glass, panes of different thickness and, because of the additional weight, the need for new heavier frames with inherently high quality sealing mechanisms for opening lights. Laminated glass has the advantage that it reduces the effect of resonances and this is potentially useful against exposure to sources with strong low frequency harmonic content, such as helicopter noise. IGUs also bring the same advantages as traditional single glazing regarding access for cleaning inner surfaces, for quick and ready access to opening lights, for access to and use of any window sill area, and for general internal room aesthetics.

Noise insulation grants schemes introduced in recent years at civilian airports have favoured [3,4] the use of acoustic double glazing and in particular the use of 6.4mm (PVB[1] laminate) - 12mm air gap – 10mm glass sealed units (coded 6.4L–12–10 or 6L-12-10) or 6-12-10.4L units (it does not matter which element has the laminate within), which has been shown to provide good insulation across a wide range of frequencies. Alternative units based on softer PMMA[2] laminates with the same glass thickness can provide higher levels of insulation but at a higher cost. It was therefore decided to investigate the use of acoustic IGUs at the property by replacing the windows with heavy duty uPVC frames with opening lights in a pattern similar to those they were replacing and fitted with acoustic double glazing units incorporating 6.4L–12–10 or 6L-12-10 and to test the performance in-situ when exposed to helicopter noise.

C Ventilation Components

The current U.K. Building Regulations, Approved Document F[7] requires that habitable rooms, kitchens, bathrooms and utility and sanitary accommodation in domestic buildings are provided with both whole building (background) ventilation and purge (rapid) ventilation. In addition in rooms where most water vapour and pollutants are released such as kitchens, bathrooms, utility and sanitary accommodation (known as “wet” rooms), extract ventilation, which may be either continuous or intermittent, is required to minimise their spread to the rest of the building.

Whole building ventilation maintains fresh air throughout the building and dilutes and disperses residual water vapour and pollutants. The provision of whole building ventilation implies a continuous flow of air providing nominally continuous air exchange that can be guaranteed, under normal circumstances. Therefore it is no longer acceptable to rely upon gaps under doors and ill-fitting window frames. Background ventilation can be provided by airbricks with “hit and miss” grills, trickle ventilators or suitably designed opening windows normally located 1.7m above floor level.

Background ventilators, trickle ventilators and fans are normally fitted either directly into outside walls or within a window aperture, either through the frame, above the window or in the case of fans, set in the glass itself. There is often very little, if any, sound attenuation provided by such installations and therefore the sound insulation provided by the window, wall or even the façade in which they are fitted could be severely compromised.

The acoustic performance of small building components such as trickle ventilators can be determined in an acoustic transmission laboratory using a special technique detailed in BSEN ISO 140 part 10[8]. The results are presented as a sound reduction value known as the weighted element normalised level difference (Dn,e,w) and may be used in comparative calculations of overall wall performance with weighted normalised sound reduction indices (Dn,w) obtained on larger wall components such as windows. The Dn,e,w of trickle and other ventilators should be at least 40 dB and preferably above 45dB if they are not to reduce significantly the overall sound insulation of the wall in which they are placed. This assumes that the external wall is of a dense construction such as 225mm

[1] PVB – Polyvinyl butyral laminate
[2] PMMA – Polymethyl methacrylate laminate

plastered brickwork and that the windows (of conventional size) have been replaced by high performance acoustic IGUs.

A number of manufacturers offer sound reduction kits that can be used in conjunction with wall mounted background trickle ventilators or fans to considerably improve the sound reduction properties. These kits usually take the form of a wider diameter duct with an internal acoustically absorbent lining that replaces the standard duct section passing through the wall. The amount of sound attenuation achieved is therefore dependent upon the length of the duct (depth of the wall). Many such systems can provide Dn,e,w values over 45dB provided the duct length is over 225mm (a typical brick wall width). Where necessary the performance can be improved with the addition of an external acoustically lined cowl. Manufacturers have also developed trickle ventilators that can be incorporated into whole window frame designs directly or as an add-on unit. These have acoustic insulation built in and can provide Dn,e,w above 40dB.

There are also available several proprietary wall mounted fan units. These were developed for use in situations where traffic noise had to be attenuated, especially following the introduction of the U.K. Land Compensation Act[9]. These units utilise a sound absorbent duct lining but rather than having this in the extract duct through the wall, it is contained within the fan casing. Ventilation fans and fan units should produce self-generated noise of less than 30dBA at 1m from the unit and preferably less than 25dBA in critical situations. Indeed in such situations it could be argued that an individual acoustic assessment should be made, balancing airflow requirements against useful masking noise and unwanted intrusive noise.

In habitable rooms the sound insulation of the windows can be improved and the requirements of the current U.K. Building Regulations met by the use of acoustic IGUs fitted in sealed frames with opening lights for purge ventilation and with soundproofed, through the wall and cowled, trickle ventilators to provide controllable background ventilation. In “wet” rooms the requirements for additional extract ventilation can be met by the use of fan assisted ventilators ducted through the wall with suitable sound proofed linings/cowls.

At the test property it was decided to fit replacement combustion air and trickle ventilation in place of any existing ventilation units and to bring all non-ventilated rooms up to the required standard. For combustion, in the lounge and dining room, 20000mm^2 was provided by two Passivent Acoustic Fresh 18 wall vents and for background ventilation in all other rooms, 8000mm^2 was provided by two Passivent Fresh 80dB acoustic wall vents, all complete with Fresh dB external cowl. The expelair unit fitted in the kitchen was replaced with an attenuated powered version and a second was fitted in the bathroom.

2 EXPERIMENTAL DETAILS

A Description of the test property

The property is an “L” shaped two storey brick dwelling rendered in concrete with “mock” half-timber finish. There is a brick walled ground floor extension (conservatory) with lightweight corrugated plastic roof infilling the “L” and providing the rear access. The main roof is of conventional tile and extends down over the bedrooms so that the top ½ metre of the bedroom sidewalls are formed by the ceiling/roof structure. The ceiling void has 75mm of glass fibre laid over the purlins. The main bedroom window is set in the gable end of the roof covering the short L and there is a hip roof over the second bedroom with a window set in its gable. There are no windows to the rear of the property apart from those in the conservatory but there is an Expelair extractor vented through the rear wall from the kitchen. There are air vents that lead directly into the bedrooms below eaves level.

The front entrance is in the centre of the façade facing the airfield. The door is a single half glazed timber door which leads directly into a vestibule with the lounge and dining room doors to left and right and the stairs immediately ahead. At the rear, the kitchen has a window overlooking the side of the house and two small windows looking directly into the conservatory. The lounge and dining room both have fireplaces. All doors are single timber plank farmhouse style. Before the modification works were carried out, windows in the cottage on the front façade and the side lounge window were all fitted with single glazed panels of either 3mm or 4mm glass with standard weather-stripping. The kitchen side window and the rear bedroom window were fitted with double glazed units set in wooden frames with direct flow trickle ventilators set in the bottom of each frame. The double glazed panes were 4mm-6mm-4mm narrow airspace thermal units. Throughout the project the house remained occupied and the rooms furnished. Little change took place between measurement sessions in internal furniture and its layout.

B Measurement procedure

To minimise room mode effects, in each room, a minimum of three low level helicopter flybys were recorded at each of four microphone positions chosen on a predetermined matrix. Simultaneously recordings of the outside level were made at a microphone located at a fixed distance between 1m and 2m in front of the relevant room window. Each pair of recordings comprised short $Leq_{(1\ sec)}$ samples recorded continuously during the flyby. The difference between inside and outside short Leq levels was then computed and averaged over the length of the flyby defined by the 10dB down points from the maximum $Leq_{(1\ sec)}$ sample recorded externally for each particular flyby.

The final level difference, outside to inside, was taken as the average of each flyby for all microphone positions. This procedure minimised the effect of background noise on the internal noise levels and hence the calculated sound insulation. The reverberation time was measured in each room using a simple impulse technique and the results used to normalise the data. The data were logged in one-third octave bands from 25Hz to 5kHz. Above 5kHz measurements inside the property were subject to increasing levels of background noise and were excluded.

C Calculation of Sound Insulation

The "global" method of determining the insulation of a façade outlined in[10] formed the basis of the calculation. The global method defines a quantity known as the standardised sound exposure level difference ($D_{E,2m,nT}$). Since both external and internal sound levels were measured simultaneously over the same time period the same quantity can be expressed directly in terms of Leq. To uniquely identify the source as a helicopter flyby the suffix H is used hence:

$$D_{H,2m,n,T} = L_{E1,2m} - L_{E2} + 10\ \mathrm{Log}(T/To)\ \mathrm{dB} \qquad (1)$$

where $L_{E1,2m}$ is the Leq measured between 1 and 2 metres from and outside the relevant window
L_{E2} is the spaced averaged Leq measured over the four microphones in the room
T is the relevant room reverberation time (secs)
To is the reference reverberation room 0.5secs.

The results are representative of an average level taken with the source over a range of angles of incidence as the helicopter moves some distance relative to the normal of the particular window during the flyby. The weighted standardised level difference $D_{H,2m,n,Tw}$ ($D_{H,w}$) values been evaluated using the procedure for evaluating single figure insulation values[11].

3 RESULTS

The analysis was completed in 1/3 octave bands but to simply the discussion the results are presented here as sound level difference in octave bands (figures 1 to 6) and overall as the weighted standardised level difference $D_{H,2m,nTw}$ (dB) in table 1. This table provides a good overview of the results. At the completion of phase 1 there was an average improvement in $D_{H,2m,nTw}$ of nearly 10dB; a significant and worthwhile improvement in insulation although increases in insulation in individual rooms varied from 6dB to 14dB. At the completion of phase 2 following the installation of the silenced ventilators, that improvement had reduced by only 1.6dB on average with an improvement of up to 12dB above that obtained with the original single glazing. If the back bedroom (see Discussion below) is excluded, then the reduction is only 0.5dB.

Table 1: Weighted Standardised level differences $D_{H,2m,nTw}$ (dB)

Location	Measured Sound Insulation, $D_{H,2m,nTw}$ (dB)			Change (re-original)		Notes
	Original	Phase 1	Phase 2	P1	P2	
Back Bedroom	33	41	33	8	0	i
Front Bedroom (left)	31	41	43	10	12	ii
Front Bedroom (right)	31	39	42	8	11	iii
Dining Room	30	42	38	12	8	iv
Kitchen	30	36	37	6	7	v
Living Room	30	44	40	14	10	vi

i to vi Originals single glazed except i and v (4-6-4 thermal glazing with in frame un-attenuated trickle vents)
ii & iii Un-silenced ventilators in Phase 1
iv No ventilation in phase 1, attenuated ventilator fitted for Phase 2
v Windows to conservatory (single glazed) not changed until Phase 2, Expelair in wall, new attenuated unit fitted in phase 2
vi Two windows (inc bay) in this room

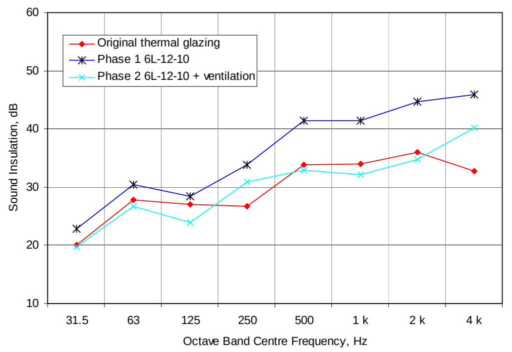

Figure 1: Sound Insulation Back Bedroom

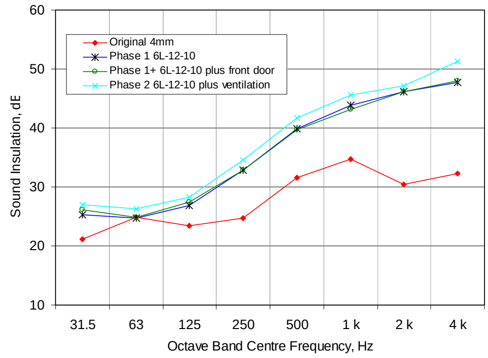

Figure 2: Sound Insulation Front LHS Bedroom

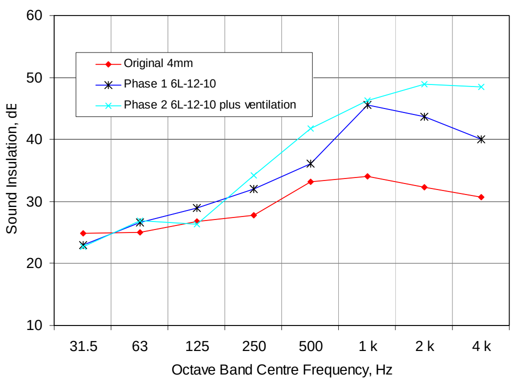

Figure 3: Sound Insulation Front RHS Bedroom

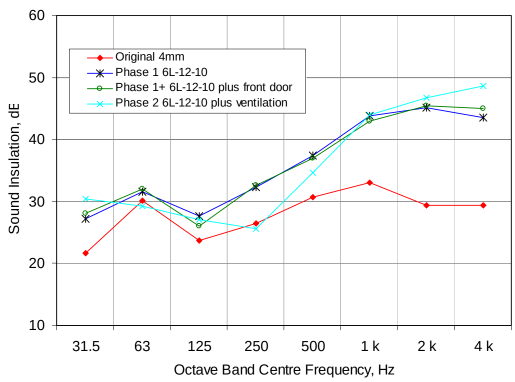

Figure 4: Sound Insulation Dining Room

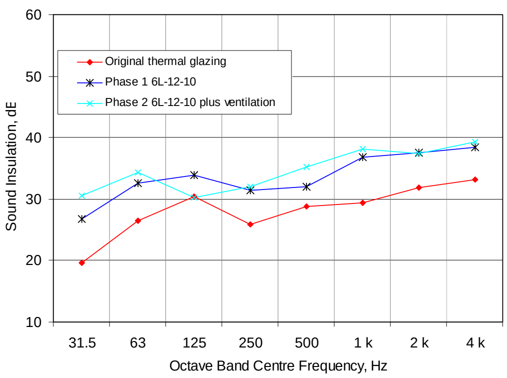

Figure 5: Sound Insulation Kitchen

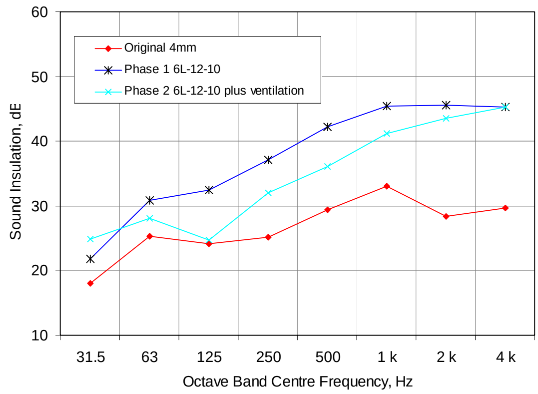

Figure 6: Sound Insulation Living Room

4 DISCUSSION

The most likely cause of the reduction in insulation in the back bedroom, down from a worthwhile improvement of 8dB to what it was with the original thermal glazing installed, is bad fitting of the ventilators. In this room there were two ventilators fitted through the wall with one sitting immediately above the other and it is possible that the brick cavity between the two was not sealed properly. Unfortunately it has not been possible to confirm this at the time of writing.

Looking at the results in the other rooms in a little more detail it can be seen that the insulation in the two front bedrooms improved by 1-2dB following the installation of attenuated ventilators. Both rooms had un-attenuated through the wall ventilators fitted as original. On the other hand, the living room and dining room had no ventilators fitted initially (although both had open fire places and the living room one was in use) and both suffered a reduction of 4dB following the installation of the silenced units. The final insulation values of 40 and 38dB were nevertheless acceptable especially since the living room had two sets of windows as well as the open fireplace. The sound insulation improvement in the kitchen was limited by the un-attenuated extract fan and possible noise entering through the conservatory. There was only a marginal improvement when an attenuated unit was fitted and the conservatory windows double glazed.

Summarising the octave band results in a concise manner is a little difficult since each room clearly illustrates its own insulation characteristics. However, all results indicate that improvements below 125Hz are typically 3 to 5dB. Above 125Hz there is generally an improvement in insulation with increasing frequency to, in most cases above 15dB. The living room and dining room lose out at mid frequencies following the installation of the albeit silenced ventilators, but the two front bedrooms gain at both mid and high frequencies with the installation of the attenuated rather in place of un-attenuated units. In the kitchen, the attenuated fan together with the double glazed windows to the conservatory has resulted in a small improvement above 250Hz, whilst the form of the post phase two insulation curve for the back bedroom supports the possibility that bad fitting has lead to some leakage.

5 CONCLUSIONS

The installation of acoustic double glazing (Rw 41dB) has resulted in an average increase in sound insulation for helicopter noise from typically 30 to 40dB ($D_{H,2m,nTw}$). The installation of attenuated ventilators, meeting the requirements for ventilation of the current UK Building Regulations, has resulted in a small reduction in that improvement in sound insulation of around 1/2dB. Overall sound insulation improvements in individual rooms depend upon whether any ventilation was provided in the first place.

Carrying out a coherent set of insulation measurements over an extended time period in an occupied house using a real noise source such as a helicopter can never be easy and the results must be viewed critically. The insulation values obtained apply specifically to the test property. However, a great deal of effort went into ensuring that the noise source was reasonably consistent, that the house itself, the furniture, the fittings and soft furnishings and the setting of the closed doors remained consistent throughout the each trial. The results were all treated in the same way and it can be argued that, with six individual rooms, yielding similar results and with most of the differences explained, the overall result is a fair indication of what could be expected at other brick built properties treated in the same way with materials offering the similar claimed performance.

The trial has demonstrated that a significant improvement in sound insulation can be obtained to the advantage of the householder, to whom there is also the bonus of improved thermal insulation with proper control of ventilation, but care must be exercised when selecting and installing individual components.

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