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Sound absorption characteristics of air laid non-woven feather mats

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ABSTRACT

Chicken feathers are an industrial waste that can be used to form sustainable materials suitable for use in sound insulation applications. Clean and disinfected waste chicken feathers were processed into fibres and these were air laid using commercial pilot plant facilities to form non-woven feather fibre composite mats. Varying the composition and processing conditions produced mats with different density, thickness and weight per unit area. The sound absorption coefficients of the non-woven feather fibre composites were determined using the impedance tube method. The tests used normal incidence and were completed over the frequency range from 63 and 1,600 Hz. The performance of feather fibre mats were then compared to commercially available sound absorption products.

Keywords: Feathers, Absorption, Sustainable
I-INCE Classification of Subject Number: 35

1. INTRODUCTION

Feathers have unique properties derived from their composition, which is based on the protein keratin, and their inherent structure [1]. This structure consists of a hollow shaft (quill) and rachis, with vanes consisting of barbs and barbules, as shown in Figure 1. The complex composite structure of feathers results in high tensile strength and toughness, extremely lightweight and thermal insulating properties. Feathers also

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have interesting acoustic properties as the shaft and barbs are hollow and this inhibits sound transmission by absorbing and dissipating sound waves [2].

The vast majority of poultry feathers produced from chicken, turkey, duck and goose have low value and they are often a problematic industrial waste [3]. Annual feather production from the poultry industry in the EU is reported to be ~3.1 million tonnes per annum. Applications for this material are currently limited, particularly compared to other natural fibres such as wool, hemp and sisal. Specific types of feathers are used for filling duvets, garments and upholstery. The major use for waste poultry feathers generated in the UK is as feather-meal [4]. This low-value, low-grade protein rich animal feed that is currently exported from the UK to markets in Eastern Europe and Russia.

Lightweight sound absorbing materials are critically important in buildings and in aerospace and automotive applications [5]. Feathers derived sound insulating materials may have potential to provide improved performance over the conventional non-sustainable materials that are currently being used.

In this research the sound absorption properties of air laid, non-woven materials produced from waste feather fibres have been investigated. The acoustic performance of feathers has been previously investigated but the samples produced were of a simpler construction [6]. The performance of the feather fibre mats formed were compared to other sustainable materials and more traditional absorbing products. Samples with a range of densities and thickness have been produced and the influence of processing parameters on sound absorption coefficients is reported.

2. MATERIAL AND METHODS

Chicken feathers were obtained from a major poultry processing facility in the UK (Cargill Ltd, Hereford, UK). This plant processes ~1.6 million chickens a week and this produces approximately 160 tonnes of wet soiled by-product feathers.

A schematic diagram of the air lay process used to form samples from the feather fibres is shown in Figure 1.

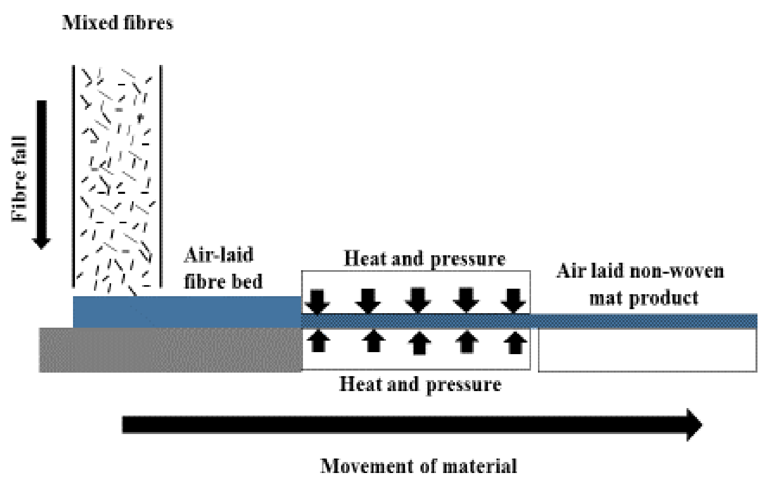

Figure 1. Shows the air laid process used to form non-woven feather mats

Processing involved blending feather fibres, in some cases mixed with additional cotton fibres, with different samples containing a 10 to 30% addition of short bi-component fibre (LMF-Bico, Fipatec) made from polyethylene (PE) with a polyester (PET) core. The bi-component fibres were 6mm and 12mm long and were 2.2 decitex (mass in grams per 10,000 meters of fibre length). These have a key role in forming a coherent non-woven mat product because the outer surface of the fibre softens during the heating stage of the air laid process and this bonds the fibres into a coherent isotropic mat. A typical air laid non-woven feather fibre composite material is shown in Figure 2.

Figure 2. An example of an air-laid non woven feather mat

Table 1 Composition, thicknesses, densities and mass of the air laid non-woven feather fibre composites produced during pilot scale industrial trials using air-laid processing.

Material	Composition			Density Kg.m^{-3}	Thickness Mm	Mass g.m^{-2}
	Feather Fibre Content (%)	Bi-component Fibre Content (%)	Cotton Fibre Content (%)			
ANW3	90	10	0	30	30	900
ANW4	85	15	0	50	75	3750
ANW5	70	30	0	100	25	2500
LR3	60	10	30	32	50	1600
LR5	45	25	30	32	75	2400
LR7	45	25	30	32	15	480
Gramitherm	100% cellulose (grass) fibres			56	50	2800
Mineral Wool	100% Glass fibre			41	50	2040

Sound absorption coefficients were determined using an impedance tube (BSWA Tech Ltd) with a tube width of 100 mm, following the method described in BS EN ISO 10534-2: 1998 [7]. The sound absorption coefficient was determined for normal incidence over the frequency range from 80 Hz and 1,600 Hz using typically three test samples to obtain each data set, with each sample tested three times. The temperature during the test was 21.7°C and the relative humidity was 47%. Random incidence absorption coefficients could be extrapolated from the data in accordance to ISO 354:2003 [8] which would give higher values across the frequency range. However, this would require much larger sample sizes, $10m^2$, and as such was impractical at this stage.

3. RESULTS

The result section focuses on the normal angle of incidence sound absorption coefficient. The feather samples will be compared to Gramitherm (sustainable grass based product) and mineral wool (glass fibre).

The sound absorption results have been summarised in Table 2. The measurements have been extrapolated from the impedance tube tests to give the weighted sound absorption coefficient, α_w , as defined in BS EN ISO 11654:1997 [9], although the standard does specify random incidence absorption coefficients rather than normal angle absorption coefficients and hence give a lower absorption classification [10]. As such, the values calculated and presented in Table 2 assume the following; for a porous material absorption measured at 1.6 kHz will have a similar performance at the 2 kHz frequency, see figure 1. This allows the measured absorption coefficients to be assessed in accordance to BS EN ISO 11654:1997 give a sound absorber classification, see Table 2, class A being the best performing material. In addition, the Noise Reduction Coefficient, averaged 250 to 2000 Hz octave band rounded to 0.05, is given, as well as the newer Sound Absorption Average is which the 200 to 2500 Hz 1/3 octave band rounded to 0.01. The NRC was calculated to remain consistent for reasons of comparison with previous work.

Table 2 Extrapolated weighted absorption coefficients and absorber classification

Material	Weighted Absorption Coefficient	Noise Reduction Coefficient	Sound Absorption Average	Absorption Classification
ANW3	0.40	0.55	0.55	D
ANW4	0.60	0.60	0.58	C
ANW5	0.40	0.45	0.44	D
LR3	0.60	0.70	0.68	C
LR5	0.80	0.80	0.78	B
LR7	0.25	0.30	0.30	E
Gramitherm	0.50	0.65	0.63	D
Mineral Wool	0.50	0.65	0.66	D

Figure 3 shows the sound absorption coefficients determined over a range 80 to 1600 Hz for the samples prepared and tested in this study. The sound-absorption properties of the specimens tested tend to be high at frequencies above 800 Hz, where the absorption coefficients typically exceed 0.70. However, the sound adsorption coefficients at frequencies below 200 Hz are low. Sound absorption is highly dependent on the sample thickness as can be seen by comparing the data for samples LR5 (75mm) and LR7 (15mm). These have the same composition and density but different thickness. The 75mm thick sample of LR5 has high sound absorption coefficient down to 315 Hz, while the 15mm thick sample (LR7) has the lowest sound absorption coefficient of the material samples tested. The sound absorber classification, see Table 2, further confirms that the best performance material corresponds to the thickness of the sample and the density of the sample, 75 mm thick and a mass of greater than 2400 g/m^2.

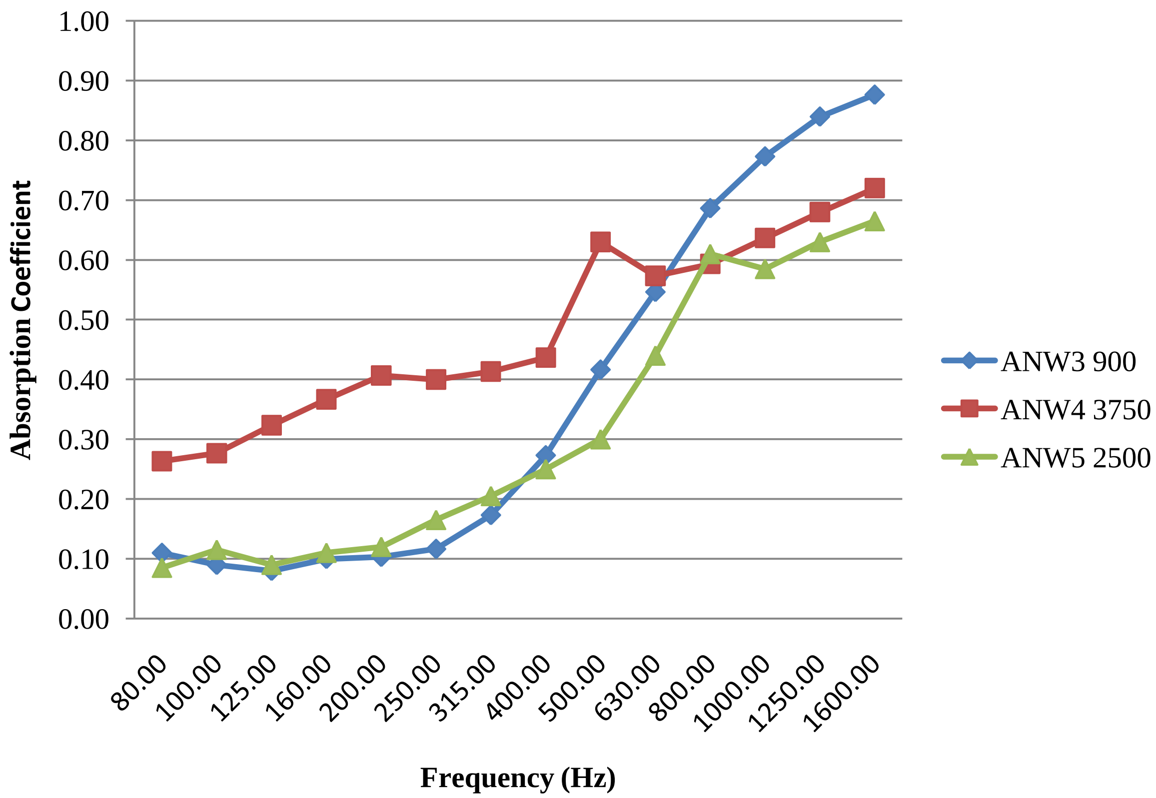

Figure 2. Absorption coefficient data for samples which had different feather fibre content, bi-component fibre content, and thickness

In figures 2 and 3 the sound absorption performance of the feather based samples, ANW and LR, are compared. Figure 2 shows that density is a significant factor in sound absorption with ANW4 having much improved low frequency performance. This was confirmed by the LR measurements with LR5 performing well above 250 Hz. Conversely, the thinner lighter material performed poorly, providing a similar performance but at a one octave high frequency for each halving of the mass and/or thickness.

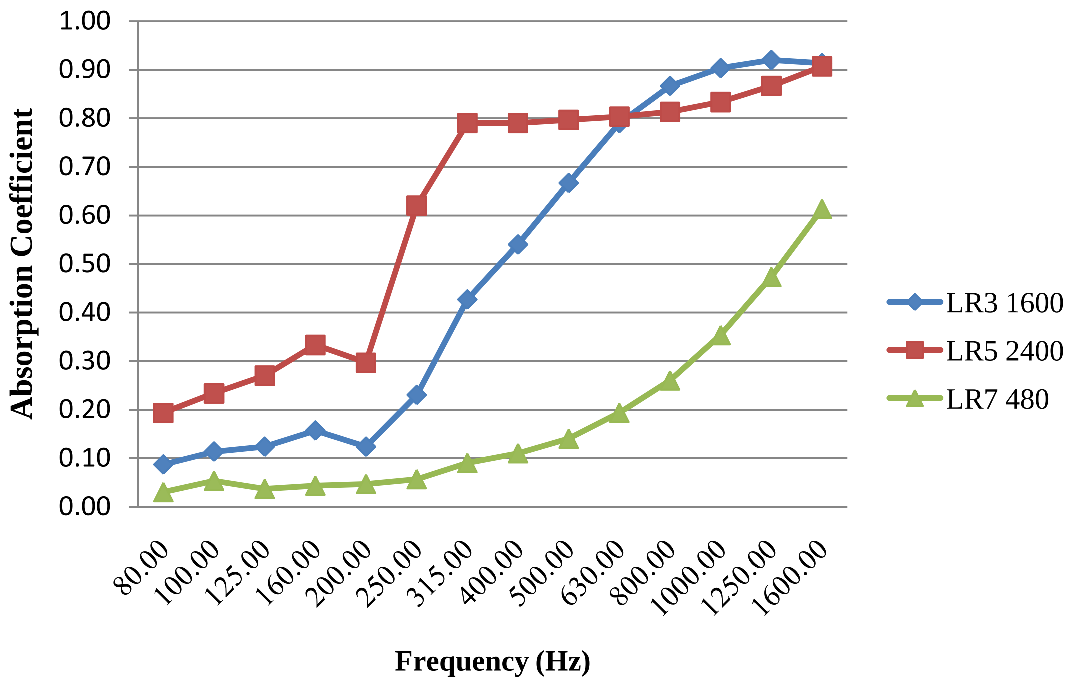

Figure 3 Shows the absorption coefficients for samples with 30% cotton fibre, constant density and varying thickness.

Figure 4 shows only the results for material of the same thickness comparing LR3, Granitherm and Mineral Wool. It can be cleanly seen that all three samples show very similar performance across the frequency range of interest. However, at the critical frequencies 250 Hz and above the LR3 demonstrated superior performance and this in particular is the reason for the better absorption classification

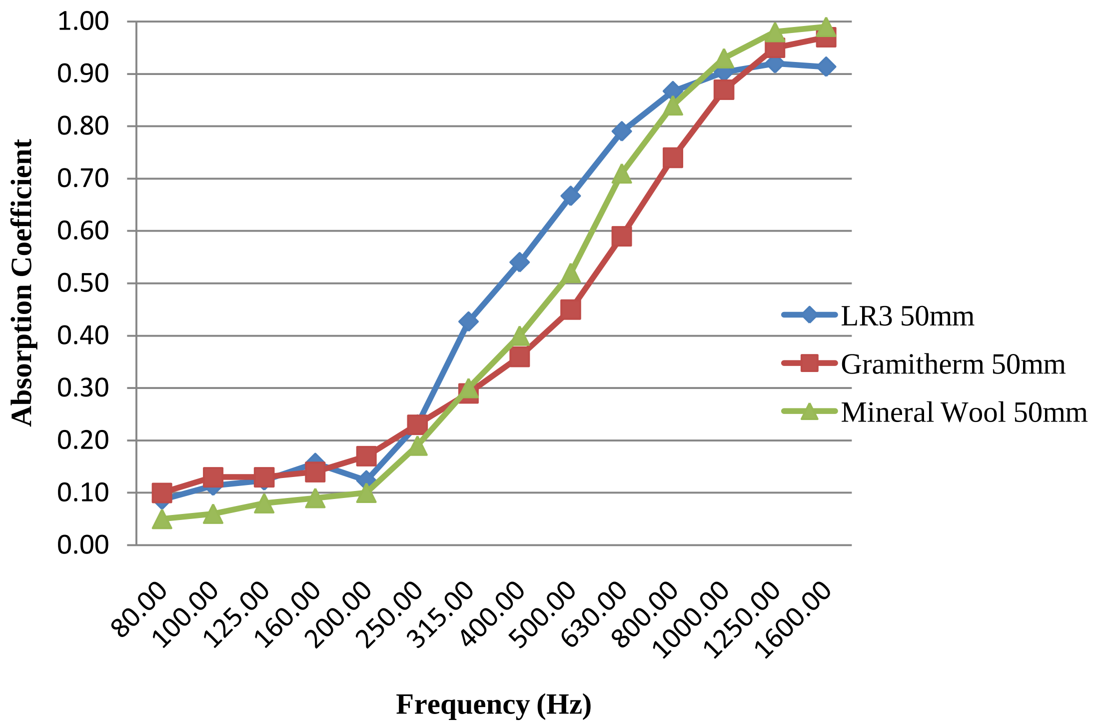

Figure 4. Absorption coefficients for material samples with the same thickness (50mm)

4. DISCUSSION

It can be clearly seen from Figure 4, that the Gramitherm material, 50 mm thick grass based, and the 50mm thick Mineral Wool is out performed by the LR3 50 mm sample. This is further supported by the class D classifications of Gramitherm and Mineral Wool compared to classification C for the LR3 sample, see table 2. Also the extrapolated weighted sound absorption coefficient was calculated as 0.5 for the Gramitherm and the Mineral Wool compared to 0.6 for the LR3 sample. The feather based sample was also less dense and hence requires less material, 1600 g/m^2 compared to 2800 g/m^2 for Gramitherm and 2040 g/m^2 for the Mineral Wool.

5. CONCLUSIONS

Air laid non-woven feather fibre composites have excellent sound absorption properties, particularly at sound frequencies greater than 500 Hz. The sound absorption properties are highly dependent on sample thickness, whereas specific variations in the fibre composition and the relative amount of bi-component fibre and the inclusion of cotton fibres in the mix have less impact on performance. The results show that feather fibre composites have great potential in sound absorption applications and their performance compares favourably with other sustainable biomaterials, as well the industry standard mineral wool.

6. ACKNOWLEDGEMENTS

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