Acoustic Properties of Loose and Consolidated Granulates

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1. INTRODUCTION

Loose granular materials can be regarded as an alternative to more common foams and fibrous acoustic absorbers. In their consolidated state, these materials often combine high structural strength with good acoustic performance and excellent vibration insulation properties Recently, it has been demonstrated that a particular class of acoustic absorbers can be developed from granulated elastomeric industrial waste (Swift, 2000; Miraftab *et al*, 2004). This type of process addresses directly the growing public concern for the environment and increased landfill taxation which is forcing manufacturers to look into alternative uses for their waste output. In this paper the acoustic performance of some porous materials made from loose and consolidated granulates have been investigated experimentally. It has been shown that a thin layer of recycled material can yield relatively high values of absorption coefficient. This is mainly attributed to the unique pore size distribution and fibre-grain composite structure resulting from the granulation and consolidation processes. A formulation has been proposed which yields samples with optimum acoustic absorption properties.

2. METHODOLOGY

For this study, loose mixes of granular and fibrous carpet tile waste were obtained from a typical recycling operation carried out on PVC-backed reject carpet tiles with nylon pile. The operation consisted of granulating the carpet tiles through a triple-blade, vertical rotation, granulator that had been fitted with a 2mm-aperture screen in order to control the particle size distribution ($< D > \cong 0.85$mm). The granulator output was then passed directly into a cyclone system that separated the material into fibrous (nylon pile) and granular (PVC tile backing) components. Consolidated samples were produced by adding 30% (by mass) PU binder to the loose aggregate of the selected particle size and leaving the sample in a mould to cure under a pressure of 850 Pa.

Figure 1 presents the measured normal incidence absorption coefficient for two 20mm hard-backed layers of loose mixes of purely granular component which differ by the particle dimension, *D*. Figure 1 also presents the measured absorption coefficient for a 20mm hard-backed layer of fibreglass to provide a direct reference to the expected acoustic performance. The results demonstrate that for the selected layer thickness the acoustic performance of the recycled carpet granulates is comparable or superior to that observed in the case of fibreglass in the low and medium frequency range. This performance can be associated with relatively high values of the porosity and flow resistivity which this particular type of materials normally exhibits. A summary of the non-acoustic parameters for these materials is provided in Table 1.

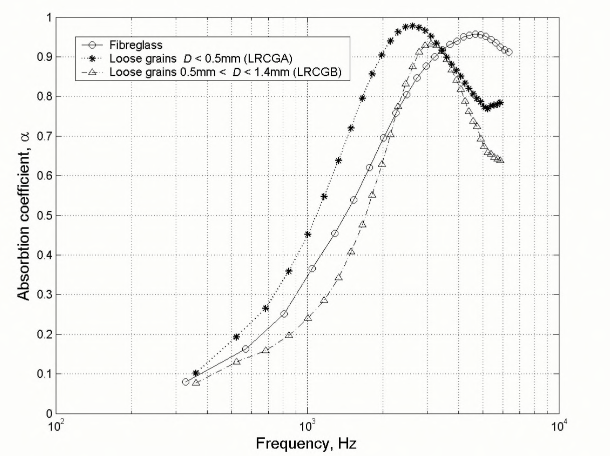

Figure 1. A comparison of the normal incidence absorption coefficient for a 20mm hard-backed layer of loose recycled granulates and commercial fibreglass.

Unfortunately, applications for loose materials are limited because it is more practical to use acoustic absorbers in the consolidated form. A major problem with the consolidation process in the case of granulates is the inevitable loss of porosity and the increase in the values of the real part of the characteristic impedance resulting in the reduced absorption performance. Figure 2 presents the measured real and imaginary parts of the normalized characteristic impedance and complex wavenumber for the loose and consolidated mixes which were prepared from the same type of aggregate (0.5-1.4mm base). The experimental data confirms that the consolidation process results in up to 50% increase in the real part of the characteristic impedance in the frequency range of 400-4000 Hz. Although the tortuosity (α_∞) is relatively unchanged by the compaction process, the porosity value is strongly affected (see Table 1). In the case of material CRCGG, the porosity is reduced from 71% to 40% due to the binder and compaction pressure effects. The consequences are that despite some increase in the attenuation (see $\mathrm{Im}(k_b)$ in Figure 2) the absorption coefficient of the consolidated sample reduces by up to 20% in the higher frequency range.

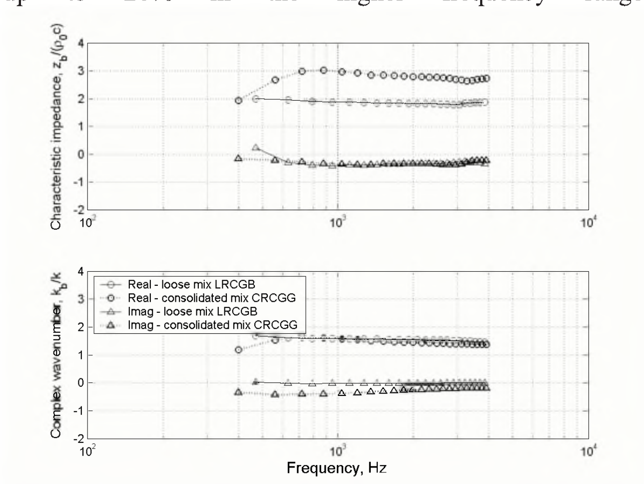

Figure 2. The effect of consolidation on the characteristic impedance and complex wavenumber of the 0.5 – 1.4mm material.

A noticeable improvement in the absorption performance can be attained if a 50% fibrous component is added to the purely granular mix (sample CRCGF). Adding the fibrous matter helps to recover the porosity to around 55% and reduce the mean pore size (r) from 230μm to 180μm. As a result, the value of the flow resistivity (R) increases from 18 kPa s m^{-2} in the case of the purely granular mix to 46 kPa s m^{-2} in the case of the grain-fibre composite mix. This combination of medium porosity and flow resistivity values yields a porous structure which is a more efficient acoustic absorber if manufactured in the form of 20-50mm layers. Similar values of porosity and flow resistivity are characteristic of Coustone or QuietStone which are granular acoustic absorbers manufactured by Sound Absorption UK Ltd. This phenomenon is related to the reduced sound speed and the increased attenuation in the consolidated grain/fibre mix (see Figure 3).

Table 1. Summary of material parameters (F – fibre, G – grains).

Material	R, kPa s m^{-2}	Ω	α_∞	D, mm	r, μm
LRCGA	41.8-48.7	0.75	1.39	< 0.5$^{(G)}$	N/A
LRCGB	10.2-14.1	0.71	1.26	0.5 - 1.4$^{(G)}$	N/A
CRCGG	18.0	0.40	1.31	0.5 - 1.4$^{(G)}$	230
CRCGF	45.9	0.55	1.22	0.5 - 1.4$^{(G+F)}$	180

Adding the fibrous component results in an increased imaginary part of the characteristic impedance which appears to have a noticeable positive effect on the measured values of the normal incidence absorption coefficient presented in Figure 4. This figure demonstrates an up to 25% improvement in the absorption coefficient in the low and high frequency regimes. This effect is closely predicted by the model proposed in (Horoshenkov and Swift, 2001).

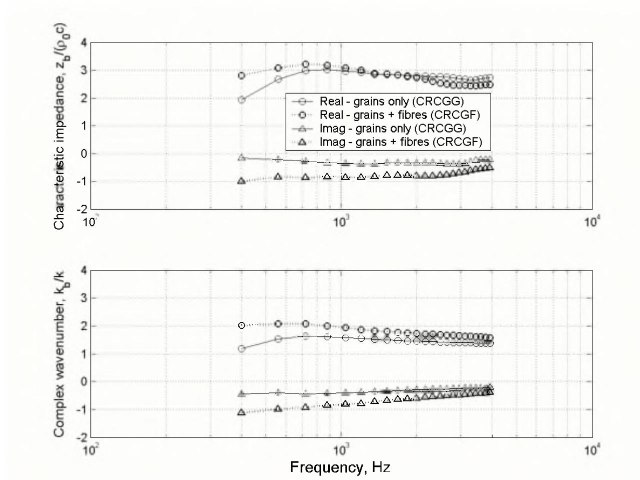

Figure 3. The measured characteristic impedance and wavenumber for two consolidated granular mixes.

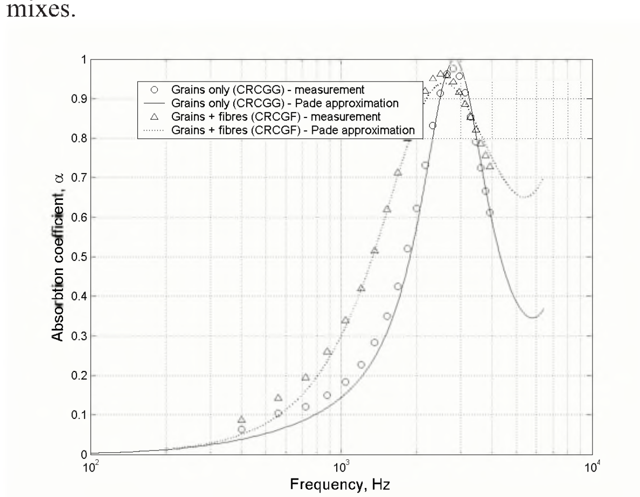

Figure 4. The normal incidence absorption coefficient of 20mm layers of consolidated granular mixes.

3. REFERENCES

Miraftab, M, et al. (2004). *Recycling Carpet Waste into Acoustic Underlay for Commercial Production*, Final Report for WRAP, UK http://www.wrap.org.uk/reports.asp

Swift, M.J. (2000). *The Physical Properties of Porous Recycled Materials.* PhD thesis, University of Bradford, UK

Horoshenkov K.V. and Swift, M. J. (2001). "Acoustic properties of granular materials with pore size distribution close to log-normal," J. Acoust. Soc. Am. Vol. 100(5), 2371-2378.