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SUSTAINABILITY ANALYSIS OF ARCHITECTURAL ACOUSTIC MATERIALS

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Abstract

Various architectural acoustic materials, including absorbers, insulators, and diffusers, may have similar acoustic performances but very different characteristics in terms of sustainability. In this study, a systematic lifecycle analysis and environmental impact assessment is being made for typical acoustic materials. Several scenarios are considered, including a room with a given reverberation time but different combinations of absorbers and an acoustic enclosure with a given sound transmission loss but different envelops. Parameters considered include a material's extraction, production, distribution, use and disposal, with a single index, Ecopoint. Significant differences have been found, both in terms of the individual environmental impact factors and in terms of overall sustainability.

INTRODUCTION

Construction industry plays an important role in the overall urban environment sustainability, relating to global warming, atmospheric and water pollution, renewable energy, and waste, for example. Consequently, it is vital to consider the sustainability of acoustic materials in environmental and architectural acoustic design [1-3].

A recent study on the sustainability of environmental noise barriers has demonstrated the importance of considering full life costs in the choice of barriers. A method for undertaking this has been developed, through assessing the impacts of different barrier material types under various lifecycle assessment (LCA) scenarios [4-6]. At the cradle-to-gate stage, it has been shown that timber is the most environmentally sustainable material, followed by recycled aluminium, recycled steel, precast concrete, living willow, woven willow, polymethyl methacrylate, un-recycled steel, and the least environmentally sustainable being un-recycled aluminium. When the gate-to-grave stage is also taken into account, considering material transportation, maintenance and recycling, the sustainability of a material can change dramatically.

A range of materials, including sound absorbers, insulators, and diffusers, may have similar acoustic performances but significantly different sustainability performances. Designing sustainable building envelops is also often related to acoustic issues. The aim of this study is to examine the differences in sustainability between various architectural acoustic materials.

METHODOLOGY

Two hypothetic rectangular rooms are considered: (1) 11m long, 7m wide and 3m high, representing a typical classroom; and (2) 27m long, 18m wide and 4.5m high, representing a typical factory. The acoustic performance is evaluated using reverberation time (RT) and sound transmission loss R of the whole envelop. The former is calculated using the Eyring formula, and the latter is calculated using

$$R = 10\log(\sum_{n=1}^{6} S_n / \sum_{n=1}^{6} \tau_n S_n) \quad (1)$$

where τ_n is the sound transmission coefficient of element n.

Two software packages are used to study the environmental impacts of architectural acoustic materials. Envest [7] gives results in terms of Ecopoint, which converts environmental profiles data into a single score reflecting the environmental impact in the UK. The data in 13 impact categories are multiplied by the agreed weight for each category and combined to produce an Ecopoint score. To aid interpretation, Ecopoints are derived so that the annual environmental impact caused by a typical UK citizen creates 100 Ecopoints. More Ecopoints indicate higher environmental impact. Software Ecotect [8] aims at conceptual environmental design and presents the environment impact, such as greenhouse gas effect and embodied energy use.

Except where indicated, in the calculation the rooms have no air conditioning, catering facilities and cellar; the windows are separate; the space for each person is 3m^2; the building operational life is 60 years; and the rooms are located in Thames Valley.

RESULT

Comparison is first made in the 7x11x3m room, between three wall materials, namely concrete, stone and brick, where the other materials are shown in Table 1. The acoustic performances of the three configurations are very similar in terms of both reverberation and sound transmission loss, as shown in Figure 1 and 2, respectively. The Ecopoints of the room with concrete, stone and brick walls are 807, 762 and 724 respectively. Considering the walls only, the Ecopoints of the three materials are 146, 102, and 63, respectively, which differ significantly. Compared to the room with brick walls, with concrete walls the greenhouse gas effect is 38% higher, and the embodied energy is 24% higher. In Table 1 the relative environmental impact of various materials is also shown. It can be seen that the overall Ecopoints will differ considerably if other materials are also altered in a similar manner as walls.

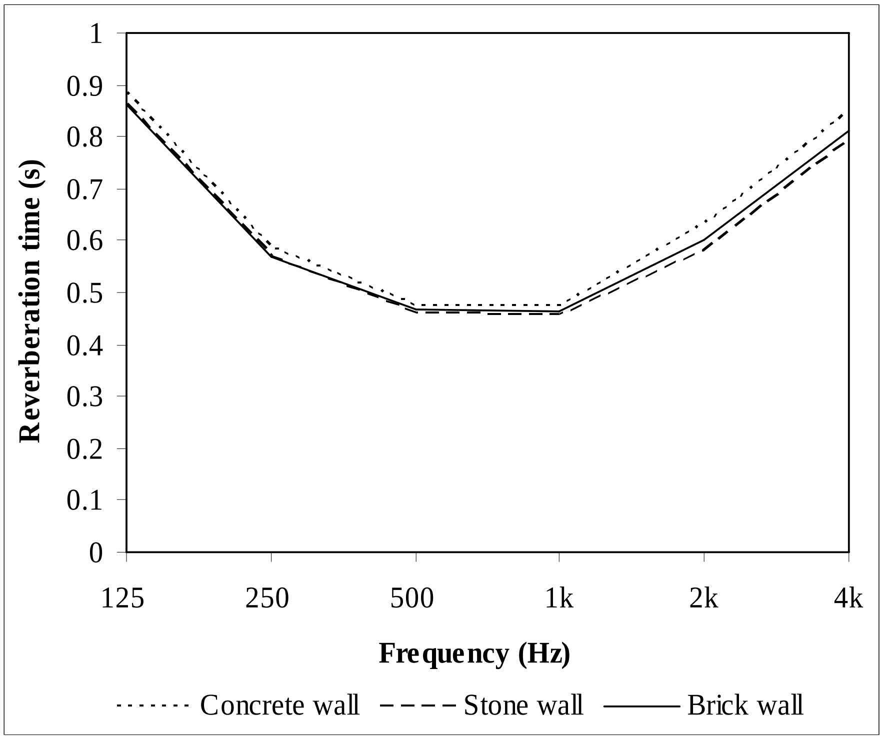

Figure 1 – Reverberation time in the 7x11x3m room with different wall materials

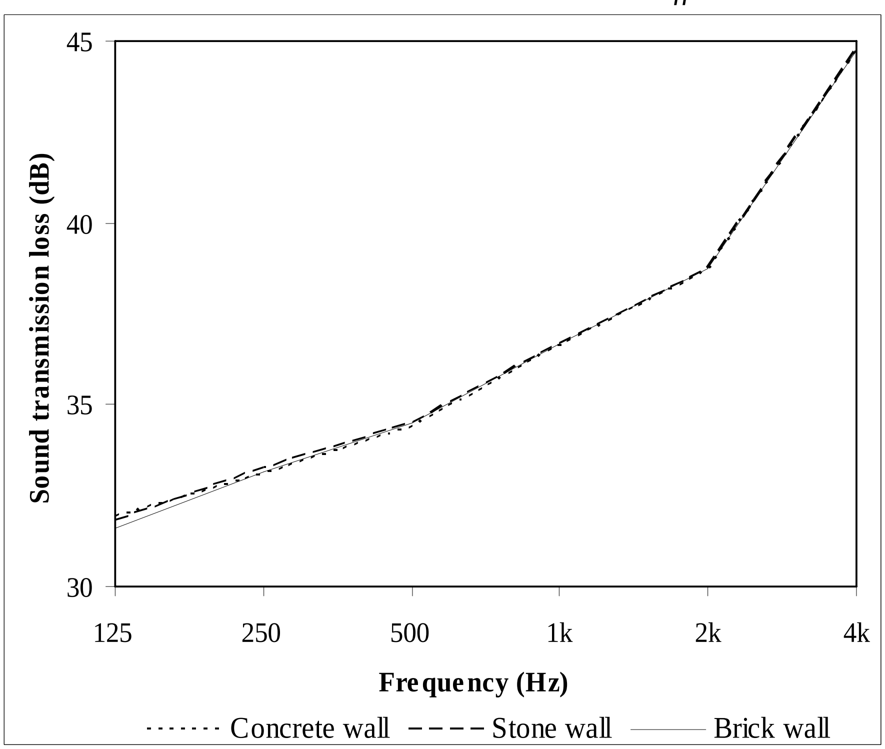

Figure 2 – Sound transmission loss in the 7x11x3m room with different wall materials

Table 1– Ecopoints of various elements

Elements	Materials	Ecopoints	
		7x11x3m room	27x18x4.5m room
Floor	Concrete 240mm thick	225	1421
Windows	Double glazing of 30% room area	11	78
Roof	Concrete 120mm thick	185	1166
Wall finishing	Gloss paint	12	752
Floor finishing	Rubber tile	72	456
Ceiling finishing	Gypsum plaster tiles, 17% perforated, 22mm mineral wool backing	14	90
Structures	Concrete frame, column base foundation	142	510
Walls	Concrete 150mm thick	146	763
Walls	*Stone 300mm thick*	*102*	-
Walls	*Brick 240mm thick*	*63*	-

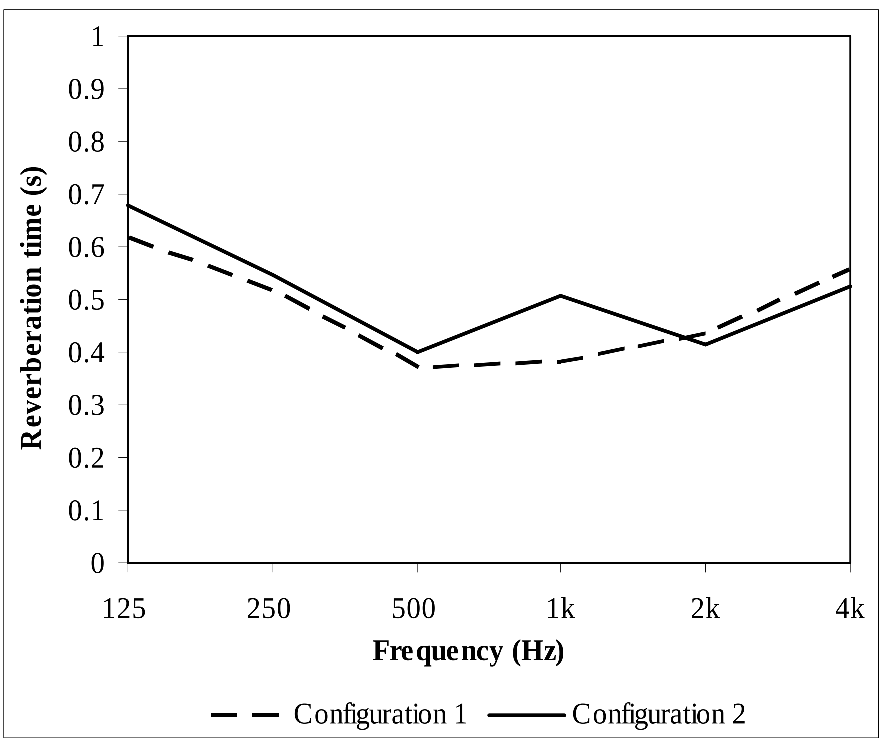

Figure 3 – Reverberation time in the 7x11x3m room with different surface finishing

Given that the environmental impact of an acoustic material depends on its area in a room, in Table 1 a comparison is also made between the two rooms, namely 7x

11x3m and 27x18x4.5m, where the difference between the two rooms is within 15% in reverberation time and 3.5dB broadband in sound transmission loss. It can be seen that in the larger room the relative contribution of the walls in the total Ecopoint is less than that in the smaller room, due to the difference in aspect ratio.

Since room acoustic design is mainly related to surface finishing, two different interior designs are compared: Configuration 1, plasterboard on walls, carpet on the floor and gypsum plaster tiles on the ceiling; and Configuration 2, fiberboard on the walls, wooden tiles on the floor and gypsum plaster tiles on the ceiling. The room dimension is again 7x11x3m. The reverberation times with the two configurations are shown in Figure 3. It can be seen that the difference between the two configurations is generally within 10%, which is insignificant. With both configurations the reverberation time is in the range of 0.4-0.7s, typical of classrooms according to the recently published UK Building Bulletin 93 [9].

In Table 2 the Ecopoints of the two configurations are compared. The overall Ecopoint is 774 with Configuration 1 and 844 with Configuration 2. In terms of the Ecopoint of the surface finishing only, the difference between the two configurations is over 100% (70 points), which is rather significant.

Table 2 – Ecopoints of various elements with two configurations

Elements	Materials		Ecopoints	
	Configuration 1	Configuration 2	Configuration 1	Configuration 2
Floor	Concrete 240mm	*Same*	225	225
Walls	Concrete 150mm	*Same*	146	146
Windows	Double glazing of 30% room area	*Same*	11	11
Roof	Concrete 120mm	*Same*	185	185
Wall finishing	Plasterboard	Fiberboard	1	7
Floor finishing	Carpet	Wooden tile	50	114
Ceiling finishing	Gypsum plaster tiles, 17% perforated, 22mm mineral wool backing	*Same*	14	14
Structures	Concrete frame, column base foundation	*Same*	142	142

Windows of buildings in noisy environments often need to be sealed, discouraging low energy strategies based on natural ventilation. Building envelops can be strategically designed, for example, using window systems which reduce noise but allow natural ventilation and daylighting [6]. It is therefore important to compare various window and ventilator systems in terms of the acoustic and sustainability benefits. A comparison is made between single and double glazing, again in the 7x11x3m room. As expected, the difference in reverberation time and sound transmission loss with the two types of window is insignificant due to their relatively small area, by approximately 3% and 1dB respectively, while the Ecopoints is 11 with double glazing and 8 with single glazing. In terms of greenhouse gas effect and embodied energy, double glazing is about 95% higher than single glazing.

CONCLUSIONS

Using some basic room configurations the importance of considering the sustainability performance of acoustic materials has been demonstrated. A range of materials, which could achieve very similar acoustic performance, in terms of room acoustics considering surface finishing as well as sound transmission considering building envelops, could have significantly different environment impact.

Currently a series of other room configurations and materials are being examined. The results will be presented in the Congress.

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