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DEVELOPMENT OF A NOVEL FORM OF SOUND ABSORBENT FACING FOR TRAFFIC NOISE BARRIERS

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INTRODUCTION

It has become commonplace to build noise barriers at critical points along highways to screen adjacent areas from the worst effect of the noise pollution. Conventional barriers generally reflect a large proportion of the sound which falls upon them, which creates a problem when there is also a requirement to minimise the reflection of sound toward noise sensitive areas adjacent to the highway, or to reduce reverberant build-up of noise between parallel barriers sited on either side of the highway. There is a need for traffic noise barriers which either absorb noise, or redirect it into insensitive regions of space. The main design criteria for an absorbent noise barrier are as follows: (i) the frequency range of high sound absorption should be at least from 250-5000 Hz; (ii) the barrier should be heavy enough to still be effective as a screen; (iii) the barrier should be rugged so as not to be degraded by long term exposure to the elements, vermin and vandals; (iv) minimum costs should be incurred in materials, construction, installation and maintenance.

Current designs either incorporate packs of bulk absorbent, such as mineral wool, contained and protected by a perforated or slatted cover, or incorporate sound absorbent structures as integral part of the barrier structure, such as wood-wool cement or fired clay. A potential problem is that caused by the ingress and retention of moisture, and the accumulation of dust or ice deposits on the exposed surface of the absorbent, both processes resulting in a diminution of absorption performance. In addition, some of the latest designs of absorbent noise barriers are constructed from materials costing up to three times that of conventional timber barriers. Existing reflective barriers cannot be readily converted into absorbent barriers without significant cost and increase of thickness. This paper presents the results of a research programme having the aim of developing a form of sound absorbent element which is less susceptible to the deleterious effects of moisture and dust precipitation, and which can either be quickly and simply attached to existing barriers, or incorporated into new barriers.

PRINCIPLE OF THE DESIGN

It was decided to employ a single or double cavity resonant cavity element to enhance low frequency (<800 Hz) absorption, and to exploit geometric form both to minimise the reflection of higher frequency sound back across the highway and to protect the absorbent element from precipitation. Quite shallow double cavity tuned absorbers, employing thin resistive sheets attached to perforated support sheets, can be designed to be effective over considerable frequency ranges, but they cannot deal with the whole of the desired range because the reactive inertial impedance of the perforate becomes too large at high frequencies (Figs. 1 and 2).

Consequently, it was decided to employ a layer of bulk absorbent to provide both the optimum low frequency resonator resistance and the high frequency bulk absorption. Sound will diffract strongly into a correctly tuned resonant absorber and will also diffract around an obstacle of which the cross-sectional dimensions are small compared with the acoustic wavelength: consequently, the entrance to the resonator cavity does not have to face the source of the sound. Sound of wavelength much smaller than an obstacle will tend to be strongly scattered and reflected by it. It was therefore decided to redirect the high frequency sound into the absorbent element, or upwards into the sky, by utilising an appropriate orientation of faceted surfaces. The resulting elements are shown in Fig.3. The dimensions of the triangular cavity are theoretically predicted to provide resonant absorption at appropriate frequencies, and the sloping upper surface provides protection and redirects the high frequency sound into the element above. Designs were tested with both 45 and 60 degree angles of elevation on the sloping faces: in the latter case, a small proportion of horizontally incident sound is scattered upwards to miss the absorbent element above, but sound travelling in this direction is generally likely to cause little problem.

The elements can be stacked one above another in an array, and can either be incorporated into a barrier as part of the structure, or attached in appropriate lengths as a retro-fit to an existing barrier. A typical vertical dimension of an element is 300mm and the front-to-back dimension may be as small as 180 mm. The acoustic performance of this arrangement is almost independent of the angle of sound incidence in the horizontal plane. High frequency sound reflected off the surface of a highway will be particularly well absorbed. Rain will drip off the 'nibs' of the array, and free-falling, or horizontally wind-blown dust will not be readily retained on the surfaces of the elements.

ACOUSTIC TESTS ON A HALF-SCALE PROTOTYPE

Low frequency impedance tube tests of the resonant element
A special-purpose impedance tube of rectangular cross-section was constructed to measure and optimize the impedance (and hence absorption coefficient) of the resonant cavity of one element (Fig. 4). A two-microphone FFT technique which requires only a short tube even at low frequencies was employed (Fahy [1]). A number of impedance measurements were made to investigate the effect of varying the thickness of a mineral wool bulk absorbent layer, and of the effect of introducing a second layer within the cavity to extend the low frequency range of high absorption. Some examples are shown in Fig. 5.

Impulse response measurements in an anechoic chamber
A half-scale model array of four elements was attached to a plain 25 mm thick sheet of plywood measuring approximately 700mm in height by 1000mm in width. The flow resistance of the absorbent layer was selected to provide optimal tuned cavity absorption according to theoretical analysis. The operational absorptive (or non-reflective) performance of such a geometrically-tailored design cannot be evaluated by a standard reverberation room test under diffuse field incidence. In a three-dimensional diffuse field, sound waves are incident from all directions with uniform probability, thereby arriving at the face of the barrier from angles which are impossible in practice (e.g. from the sky and from points deep below the road surface. In order to overcome this difficulty, the model was mounted vertically within a large anechoic chamber on a simulated ground plane and subjected to continuous broad-band noise from a loudspeaker placed at a distance of 3m from its face, and slightly above the ground plane to simulate a typical traffic noise source location (Fig.6). Measurements were repeated many times to ensure that the averaging time was sufficient to reduce the random error of the estimate to a negligible value.

With the model reversed to expose the plain plywood surface, it was very easy to detect by ear the location of the strongest reflected sound. The impulse response was measured by an omni-directional microphone placed at that location in a vertical plane somewhat to the rear of the loudspeaker. Then the model was rotated through 180 degrees, to expose the absorbent face, and the location of the strongest reflected sound was again detected by ear. Although much weaker, it lay clearly in the same region as before. The impulse response was again measured. Finally, the impulse response of the empty chamber was recorded at the same position. Tests were made at angles of horizontal incidence of zero and forty five degrees. An example of the impulse response of the novel design is compared with that of a conventional commercial barrier comprising a bulk absorbent layer protected by thick wooden slats is shown in Figs. 7 and 8 (in these diagrams the initial large pulse is that of the direct field from the loudspeaker which has not been removed).

In order to compare the sound reflected by the plain panel and the absorber array, the empty-room impulse response was subtracted from the corresponding impulses, to remove the direct field of the loudspeaker and any room effects. The resulting impulse responses were then Fourier transformed and the ratio of the squared magnitudes of the frequency components was formed to produce the effective intensity reflection coefficient, from which the effective absorption (non-reflection) coefficient could be derived. All the measurements were made using a standard FFT analyzer.

RESULTS AND DISCUSSION

In Figs. 9 and 10 the performance of the novel design is compared with that of the commercial product mentioned above (note that the frequency scale of the half scale prototype has been halved in order to give the acoustic performance of a full scale novel barrier). The result is representative of the improvement to be obtained by attaching such an array to an existing reflecting barrier, and of the benefit to be obtained by incorporating such elements into a barrier. This form of barrier facing not only provides absorption comparable with, or significantly exceeding, that of existing designs known to the authors, but also provides greatly improved protection of the absorbent elements from the adverse effects of precipitation of moisture and dust. It also offers practical advantages in terms of simplicity, versatility and low cost of application to existing 'hard' barriers, combined with an aesthetically pleasing appearance.

REFERENCE

1. FAHY, F.J. Rapid Method for the Measurement of Sample Acoustic Impedance in a Standing-Wave Tube *J. Sound Vib.* **97**, no. 2 ,168-17O (1984)

ACKNOWLEDGEMENT

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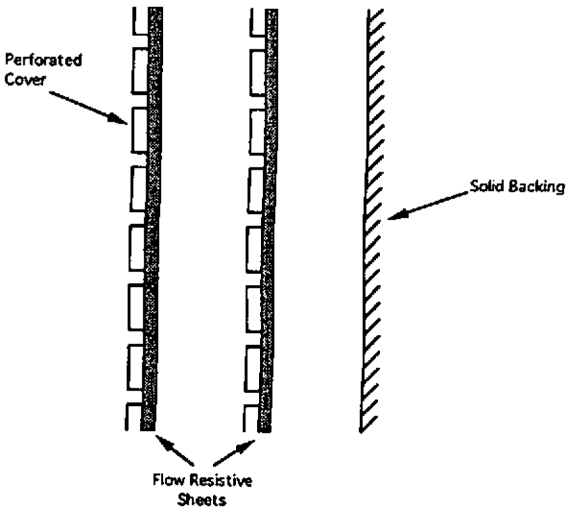

Fig.1 Double cavity tuned absorber

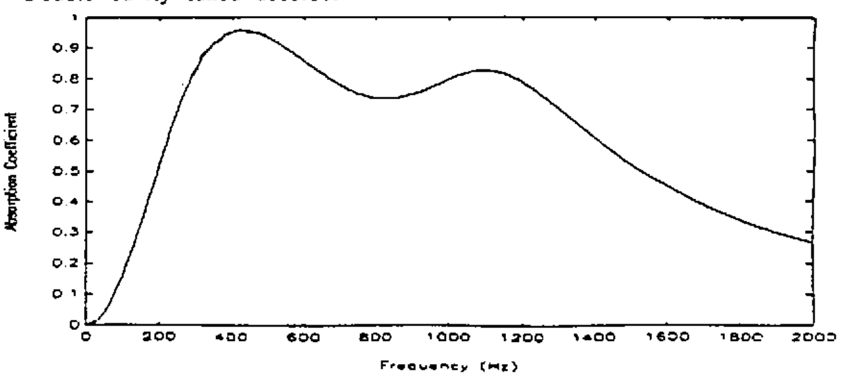

Fig. 2 Normal incidence absorption coefficient for double cavity tuned absorber

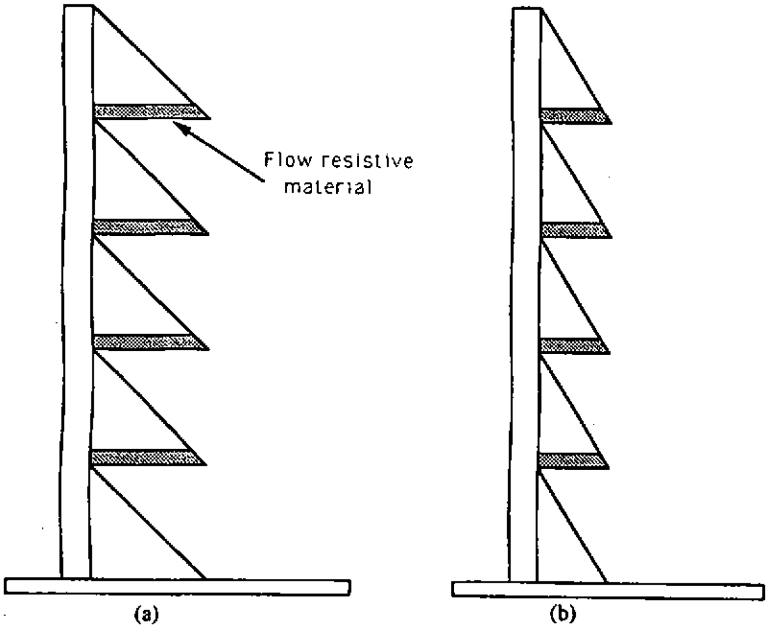

Fig. 3 Cross-sectional view of the two novel noise barrier prototypes

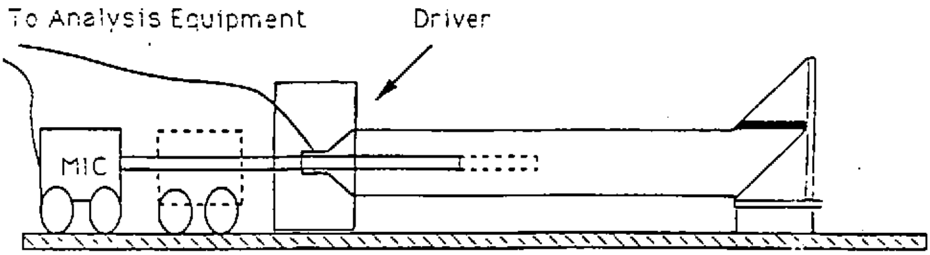

Fig. 4 Apparatus used for low frequency impedance tube tests on the resonant cavity

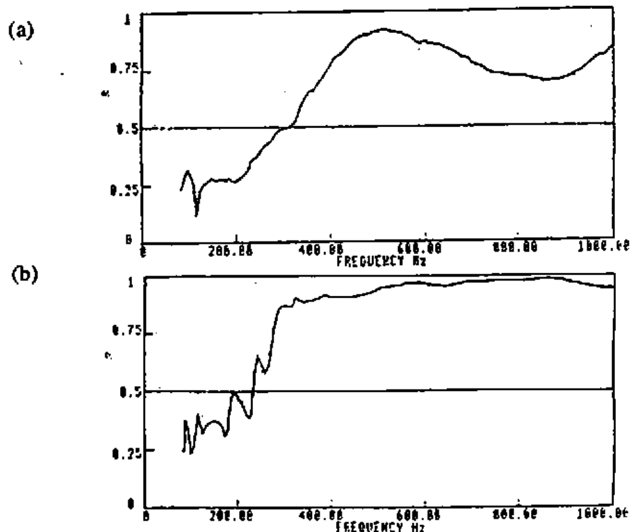

Fig. 5 Experimental normal incidence absorption coefficient for 45° resonant cavity with (a) 5mm of mineral wool or (b) 20mm of mineral wool placed in cavity entrance

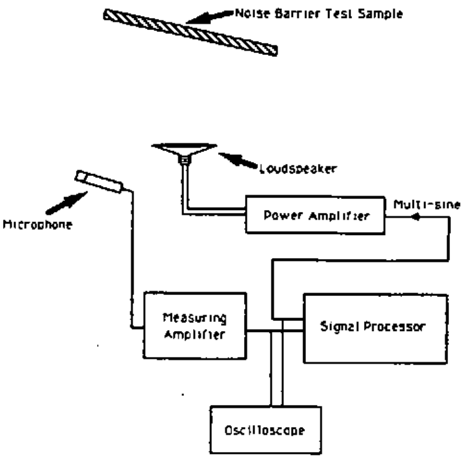

Fig. 6 Apparatus used for impulse response measurements of test noise barriers

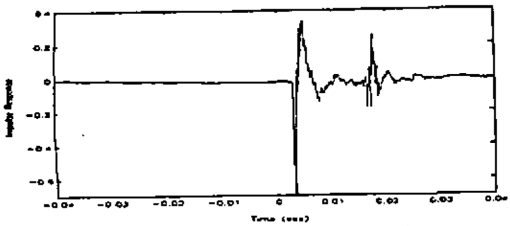

Fig. 7 Impulse response of bulk absorbent barrier

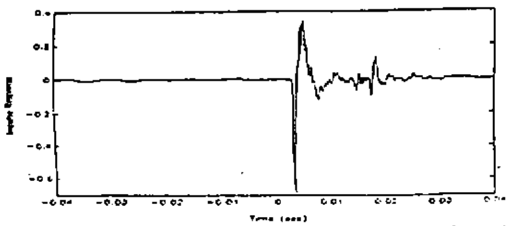

Fig. 8 Impulse response of 60° resonant cavity novel noise barrier

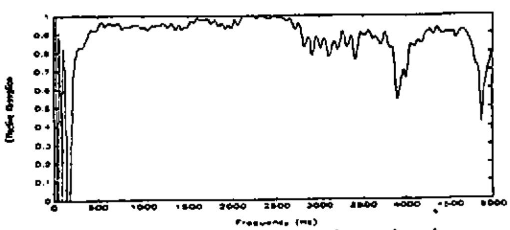

Fig. 9 Effective absorption of bulk absorbent barrier

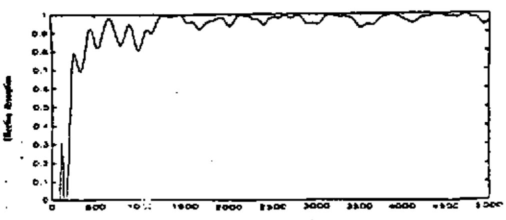

Fig. 10..Effective absorption of 60° resonant cavity novel noise barrier