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A COMPUTER SIMULATION PROCEDURE FOR THE OPTIMIZATION OF THE JOINT EFFECT OF BARRIERS AND ABSORBING MATERIAL IN INDUSTRIAL HALLS

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INTRODUCTION

Barriers represent an effective mean of noise control in industrial halls, particularly when it is necessary to sound insulate well identified sound sources or working sites. However, design procedures do not seem to exist, relating their behaviour to the acoustical characteristics of the enclosure. This depends on the problem complexity, which requires to take into account, at the receiver point, both the energy diffracted by the barrier edges and the energy reflected at the enclosure boundaries. Therefore one must considerate both the geometrical parameters of the system source-barrier-receiver and the surface sound absorption coefficient that is optimize the joint effect barrier-absorbing material.
In literature two main approaches can be found to face this problem: one based on the statistical theory of reverberant spaces [1] and the other on the image source method [2]. The limit of the former method is the assumption of a uniform sound energy density distribution, neither modified by introducing the barrier (this assumption also implies that one of a uniform distribution of the absorbing material on the surfaces). The main limit of the image source method is represented by excessive computing difficulties in irregular enclosures and long computing time, when all surface reflections should be considered, resulting in a large number of images.
In this paper an alternative method is suggested, based on a ray-tracing simulation, which allows to foresee the joint effect of barrier and absorbing material without strict limits on enclosure

shape and proportions.

SIMULATION MODEL

The model is developed according to the procedure described in reference [3]. Shortly, a point sound source, located at a point within the enclosure, emittes a certain amount of sound energy, carried by a finite number of rays. When a ray hits a boundary surface, its energy is in part specularly reflected and in part absorbed, as a function of the sound absorption coefficient. The process is assumed to continue until the energy content of the ray falls 40 dB below the initial value. The receiver is simulated by a sphere of 0.5m radius, this dimension assuring a good resolution in sound field scanning. Any ray hitting the sphere contributes to the energy within the volume. The accuracy of the results depends on the number of rays traced from the source, which should be selected according to the dimensions of the enclosure and receiving sphere. It has been verified that, in a 3000 m^3 enclosure, the generation of 20000 rays allows to get a sufficient precision without excessive computing effort.

The barrier is assumed to be an absorbent plane surface of negligeable thickness, completely sound insulating. A ray hitting the barrier at a distance from the edge smaller than λ (λ being the sound wavelength) undertakes a diffraction. In order to take this phenomenon into account, the concepts inherent in Keller's geometrical theory of diffraction were applied [4]. In correspondence of each diffraction 40 rays are generated: they lie on the surface of a cone having as vertex the point of collision of the incident ray and as axis the diffracting edge (see fig. 1(a)). When the incident ray is perpendicular to the edge, the diffracted rays lie in a plane normal to the edge (see fig. 1(b)). Incident ray and diffraction cone are on opposite sides of the plane normal to the edge at the point of diffraction. The energy in the diffracted ray is equal to the product of the energy in the incident ray and a diffraction factor,

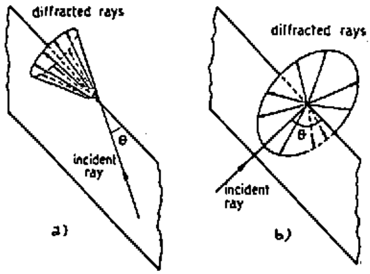

fig. 1- Incident and diffracted rays.

depending on the emission and incidence angles [3]. Each diffracted ray is traced through its reflections in the enclosure, until its energy falls below the threshold value. One assumes that the rays are diffracted by the top only of the barrier and thus the rays diffracted by the side edges are negligeable. This is the same as to divide the enclosure into two parts, acoustically coupled over the barrier. This simplifying assumption could however be removed, the receiver were not well inside the shadow zone of the barrier with respect to the side-edge-diffracted rays.

PRELIMINAR APPLICATIONS

The physical nature of the problem and the kind of adopted approach do not allow general results to be obtained. However, on the basis of the first applications, the suggested model seems to give a reliable mean of designing barriers in industrial halls, as it allows to qualitatively foresee the effects of the various parameters contributing to barrier efficiency.

Fig. 2 shows the influence of the ceiling acoustical treatment on the attenuation produced by a barrier 3m high, in an enclosure measuring (21x15x9.5) m^3; the sound source is at a distance of 3m from the barrier and at a height of 1m; the receiver is 1.5m high; the absorption coefficient of sound walls and floor is assumed to be 0.1. The simulated frequency is 1000 Hz. For untreated ceiling (α_c=0.1), the barrier is not very effective, its attenuation being lower than 5 dB at all distances. Only at high values of the ceiling absorption coefficient (α_c=0.9), the barrier gives a remarkable attenuation (11-12 dB), the ratio enclosure

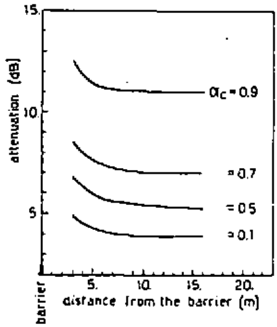

Fig. 2- Barrier attenuation for different α_c values.

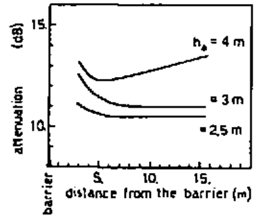

Fig. 3 - Barrier attenuation for different barrier heights; α_c = 0.9.

height/barrier height being also considered. When increasing the barrier height the attenuation obviously increases (see fig. 3), also owing to the shielding effect on ceiling reflections, which gets larger when increasing the distance from barrier to receiver. Fig. 4 shows the influence of side reflections on barrier efficiency: the solid line corresponds to a side-wall absorption coefficient α_W=0.1, the dashed line to α_W=1 (in both cases the ceiling absorption coefficient is 0.5). It can be seen that to neglect side reflections makes the barrier attenuation overestimated, particularly at small distances. In the implemented model, the dependence on frequency is given by the surface absorption coefficient and bandwidth of diffraction of the barrier. Fig. 5 reports the attenuation as a function of frequency of a barrier 3m high, for a distance from source to receiver of 10m, in the case of treated ceiling, its absorption coefficient being 0.45 at 250 Hz, 0.75 at 500 Hz, 0.9 at 1000 Hz, 0.92 at 2000 Hz, 0.95 at 4000 Hz (dashed line). The solid line corresponds to barrier attenuation for untreated ceiling (α_c=0.1 at all frequencies).

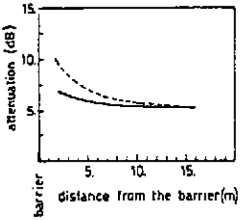

fig. 4- Influence of side reflections.

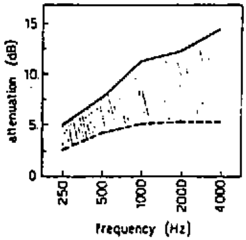

fig. 5- Barrier attenuation as a function of frequency.

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