Mukhady Sh. ISRAILOV
D.Sc., Professor
Scientific consultant
Sensor Fusion and Monitoring Technologies, LLC
1990 North California Blvd, Suite 20, #1149,
Walnut Creek, California 94596, USA
Tel. (925) 330-5493
E-mail: m.israilov@sfm-technologies.com
Webpage: htps://www.sfm-technologies.com/

WHITE PAPER 1. OPTIMAL DESIGN OF SOUND BARRIERS AND THE PROBLEMS OF NOISE INSULATION AND PROTECTION OF OBJECTS FROM THE EFFECTS OF EXPLOSIVE WAVES

Section 1. Barriers containing elements (sides) absorbing or scattering sound

The possibility of using an absorbing (or scattering sound) element in the construction of barriers protecting from road noise (motorways or railways), was first, apparently, expressed by K. Fujiwara [1]. He suggested that since direct rays from the sound source do not fall into the shadow area protected by the barrier, but only sound waves scattered from the upper edge of the barrier fall, then an additional effect of sound attenuation by the barrier can be achieved by placing an absorbent material on the edge of the barrier (Fig. 1). In practice, various variants of such barriers have been proposed and implemented. For example, barriers with a cylindrical nozzle or a mushroom-shaped nozzle-a flowerpot, so that the upper edge of the barrier is a flower bed (Fig. 1).

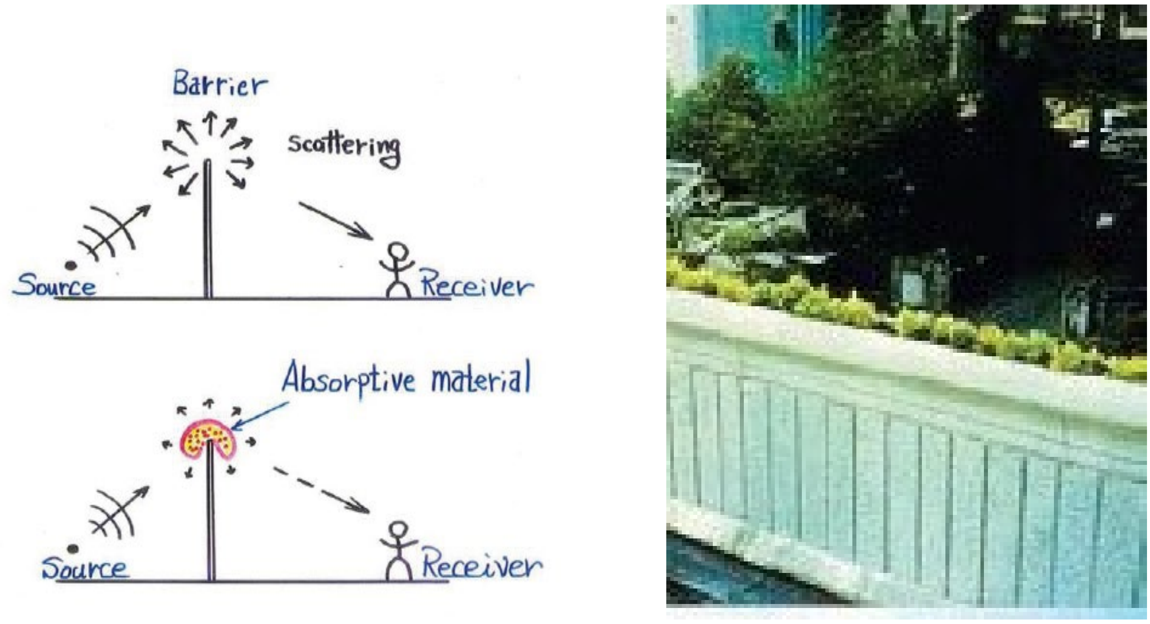

Fig. 1. K. Fujiwara 's idea

Subsequently, rather massive and high (4-5 m) barriers were proposed and implemented to protect residential buildings in the city from the noise of high-speed railways, the upper part of which (usually more than 1/2 of their height) was made of sound-absorbing material or had a sound-scattering structure (Fig. 2).

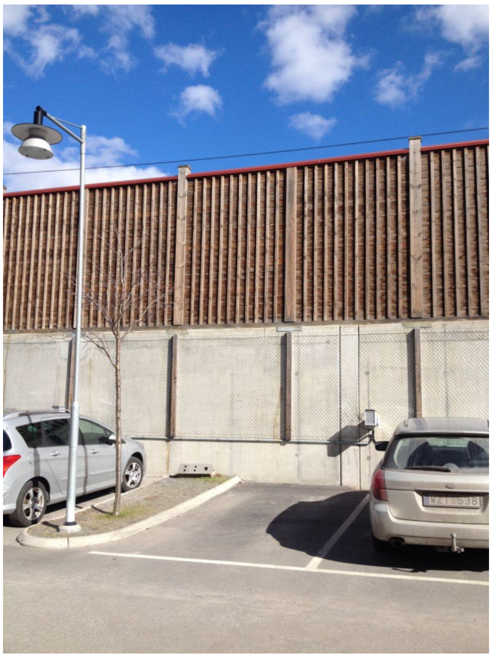

Fig. 2. A barrier protecting buildings from the noise of the high-speed railway. Sweden

Section 2. Theoretical foundations of sound-absorbing barriers and the idea of composite (combined) barriers

There are Rawlins' solutions to the problems of wave diffraction on a half-plane with a part of finite length at the vertex [2, 3] partially or completely absorbing sound, which give theoretical grounds for the barriers specified in Section 1. However, it is difficult to say whether the designers of these barriers were based on Rawlins' results.

The idea of optimal design of sound barriers is to propose two-layer barriers, in which only one of the sides is scattering or absorbing sound, partially or completely (in the barrier shown in Figure 2, both sides of the upper part are scattering sound, which is not an optimal option). The theoretical basis for such barriers is based on solutions to the problems of wave diffraction on a half-plane under mixed or different boundary conditions (different conditions on different sides of the half-plane). These solutions were obtained in [4-11], and they are presented in simple forms (not containing Fresnel integrals as Rawlins' solutions), convenient for using them in the design of sound barriers. The main conclusions from these solutions, which can serve as the basis for the creation of a new generation of sound barriers, are reduced to the following provisions.

a) It is sufficient that only one side of the barrier (facing the sound source or facing the object protected from noise or explosion) is sound absorbing.

b) Which side of the barrier for greater attenuation of sound or blast wave should be made of absorbent material follows from the theoretical solutions obtained and depends on the relative location of the sound source (explosion site), the barrier, and the object protected from noise or explosive impact.

Section 3. Promising areas of research

1) New solutions to the problems of diffraction of sound waves on obstacles (barriers) under different types (Dirichlet-Neumann) and impedance boundary conditions on the sides of the barrier. Analysis of the effects of sound attenuation and attenuation of blast waves in the shadow region. Optimal design of barriers to protect against noise and the explosion impact on objects.

2) The study of the effect of sound barriers experimentally on models. Partial similarity criterion.

Measurement of sound damping by barriers in the laboratory meets a number of difficulties. These difficulties are due to the fact that, firstly, the barrier is effective (it shields well from noise) if its height is greater than the wavelength, and secondly, in theory, to assess the degree of attenuation of sound by the barrier, we use the solution of the diffraction problem on a half-plane, which is possible, again, with a barrier height greater than the wavelength. Thus, for an experimental study of motorway barriers, when the peak noise intensity is reached about 500 Hz, it is necessary to have a barrier with a height of more than 60 cm. On the other hand, objects protected from noise (for example, residential buildings) are located at distances of 10-50 meters or more from the motorway. Measurements at such distances are also not feasible in the laboratory. This problem also arises in the case of sound barriers that protect from the noise of a high-speed railway (sound frequency 1600 Hz).

For these reasons, the question arises about the possibility of studying the effect of sound barriers on models of reduced dimensions with measurements at shorter distances from the barrier, i.e. the question of the existence of similarity when the results obtained on the model can be transferred to nature. Some thoughts on this matter are available in [12], but they are insufficient to establish a similarity criterion.

In fact, from Fresnel's solution of the half-plane diffraction problem for rigid barriers and from the new solutions of diffraction problems for absorbing barriers obtained in this Project, it follows that there is no complete similarity, but **partial similarity** can be established in the far zone by the **Fresnel number Fn**. Namely, the possibility of transferring the results for the model to nature at observation points located at distances from the edge of the barrier significantly exceeding the wavelength is proved.

3) Creation of a platform for experimental research in the laboratory on the effect of sound damping by barriers on models based on the established similarity criterion. Carrying out experiments, analyzing the results, and comparing them with theoretical studies. Elaboration of recommendations for the optimal design of sound barriers for various practical purposes.

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