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A new design procedure of a half-plane noise barrier with a non-straight top edge

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This paper introduces noise reduction of the "noise barrier with a non-straight top edge" that has a periodic structural feature on its top edge along the length. The top edge geometry of this noise barrier is created by optimization of the diffracted sound field based on the theoretical calculation. To further enhance the noise barrier performance, the rear of the top edge is covered with porous sound-absorbing material. The excellence of this complex system is improvement of its noise reduction by over about 3 to 5 dB at the point behind the barrier in frequency ranges from 125 Hz to over 4 kHz compared with an ordinary noise barrier of the same height. It will not create a zone in which sound is augmented, either. Originally designed primarily for temporary hoarding at a construction site, this noise barrier is expected to effectively serve against a wide range of noise sources. This paper reports a case example of use of this noise barrier and outlines the characteristics of its noise reduction performance and mechanism.

1 Outline of M Shaped Noise Barrier

The authors proposed a method for improvement of noise barrier performance by providing the top edge of the barrier with a periodic structure irregularly patterned in the longitudinal direction (noise barrier with non-straight top edge) [1]. Figure 1 shows an example of such a barrier that has improved performance, based on the principle that, by adjusting the relevant geometric parameters, will reduce the coherence of diffracted waves in the shadow zone. Attaching this element to the top edge of an existing noise barrier is a practical way for improved noise reduction in terms of load, wind pressure resistance and installability. The method is also advantageous in that it allows numerical evaluation of the diffracted sound field. Take the type shown in Fig. 1 (referred to as M shaped) for instance. This model has a lower cut-off frequency f_L nearly equal to c / h as in Fig. 2, where c is sound velocity and h is the height of the M type edge, so that the effective frequency range is limited within the mid- to high-frequency range. The purpose of this paper is to discuss the further improvement task to solve for practical application.

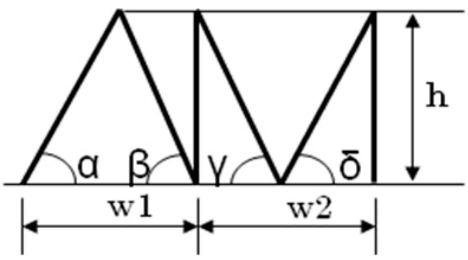

Fig. 1 Geometric parameters of M shaped noise barrier.

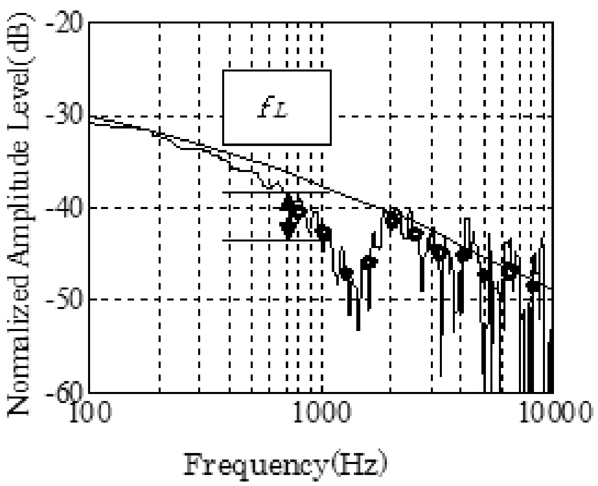

Fig. 2 Measurement example of the cut-off frequency f_L

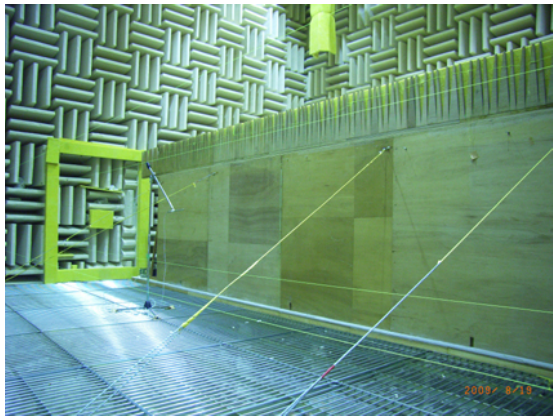

Fig. 3 Anechoic measurement.

2 Experiment in Anechoic Chamber

Figures 4 shows the experimental result of the insertion loss of two types of noise barriers, one with an M shaped barrier (Fig. 5) and the other with a flat top edge (half-plane) conducted in an anechoic chamber (inside dimension 8.4^L x 7.8^W m x 9.8^H m). The test specimens were made from a 1 mm thick plumbum sheet sandwiched by two 24 mm thick plywood panels. These two barriers are both 2 m high, while the top of the flat edge was tapered. The sound source was located 1.9 m down from the top of the edge and 1 m linearly away, and emitted 1/3 octave band noise. The receiving point was varied from 0 to 2 m down from the top of the edge and 1 to 2 m linearly away. Because the magnitude of insertion loss is pretty high at higher frequency, up to around 35 dB, careful attention was paid not to cause any contributions other than the diffracted sound, the subject of the experiment.

The theoretical values in the figure were both obtained from DLSM (Directive Line Sound Model) equation [2] assuming zero for the barrier thickness.

$$P_d = -\frac{AF_f}{4\pi}\int_{edge}\frac{e^{ik\sqrt{\rho^2+l^2}}}{\sqrt{\rho^2+l^2}}D(\phi_{rec};\phi_0)dl \qquad (1)$$

$$D(\phi_{rec};\phi_0) = \sec(\frac{\phi_{rec}-\phi_0}{2}) + \sec(\frac{\phi_{rec}+\phi_0}{2}) \qquad (2)$$

Here, the parameters in the equation are given in Fig. 6. As a reference, the exact solution of diffraction for the half plane [3] and Eq. (1) were compared for the case of Fig.4.1, and it was confirmed that the both methods numerically agree with each other with an error of less than 0.1 dB in the shadow zone including the scope of the experiment conditions.

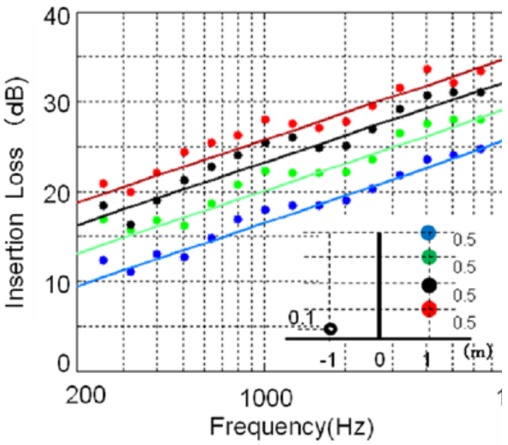

Fig. 4.1 Comparison of the insertion loss of the flat top edge between measurement (circle) and calculation (solid line).

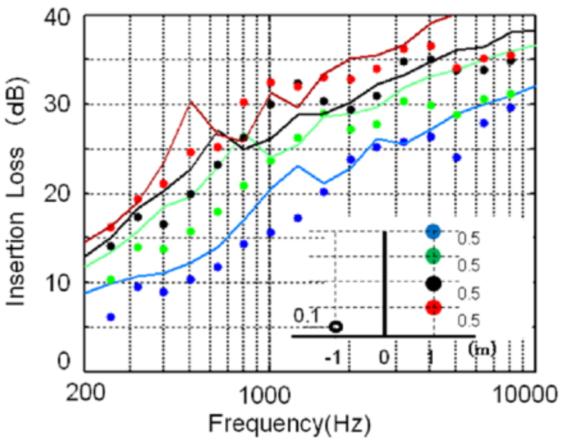

Fig. 4.2 Comparison of the insertion loss of M shaped edge between the measurement (circle) and calculation (solid line).

Figure 4.1 for the flat top edge indicates that the experimental data and calculation almost coincide with each other, which indicates the sufficient precision is maintained for the experiment. On the other hand, the correlation between them is slightly poorer for the M shaped edge. The causes for this may be (1) validity of Equation (1), (2) the finite thickness of the test specimen, (3) interference of surrounding reflections, and (4) variation in the sound pressure along the edge direction. But it is revealed from the comparisons in Figs. 4.1 and 4.2 that the insertion loss of the M shaped edge is greater than the flat edge in the mid- to high-frequency ranges.

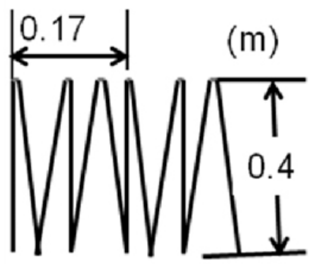

Fig. 5 M shaped wedge test specimen for anechoic measurement.

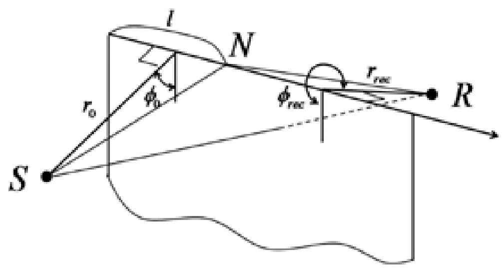

Fig. 6 Geometrical parameters of Eq. (1) and (2).

3 Outdoor Measurement

Figure 7 shows the difference in sound reduction (the sound pressure level relative to 1 m from the sound source measured in free field) between flat edge and the M shaped barriers measured outdoors. In the latter case, two measurement with and without glass wool board behind (thickness = 25 mm, density = 40 kg/m^3) are compared, that modification was obtained from another examination. For this measurement, a 30 m long sound barrier was set up to avoid the diffractions around both ends, and the top of the edge was set 2.4 m high from the ground surface in common. The measurement field was flat grassland of 80 m x 50 m in area, but small reflections came from the surrounding buildings and slopes.

Fig. 6 Field measurement. Receiving positions are covered by flat grass. Left and right half of the barrier are consist of M-shaped and flat top edge, respectively.

The sound source was set 2.35 m down from the top of the edge and 2.5 m linearly away from the barrier. The sound receiving area was set up to 5 m linearly from the barrier and up to 1.5 m vertically from the ground level. For the M shaped barrier, the average SPL value over a single cycle of the M shape patterns (*w*1+*w*2) was taken. It is seen that about 5dB improvement in insertion loss almost over all the frequency ranges can be obtained by providing absorption material behind the simple M-shaped edge compared to the flat edge barrier with the same height. The similar improvement to Fig. 7 was observed in the entire sound receiving area (Fig. 8). For reference, the partial dips in the measured insertion loss are caused mainly by the reflections from the ground surface.

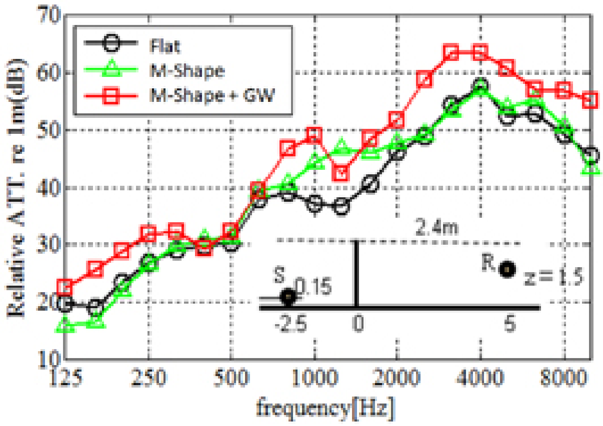

Fig. 7 Measurement example of the relative attenuation (re. 1 m in free field) of flat edge barrier and M shaped barrier with / without glass wool board behind. The shape parameter of the latter is h = 340 mm, $w1$ = $w2$ = 360 mm, and $\alpha = \beta = \gamma = \delta = 62°$.

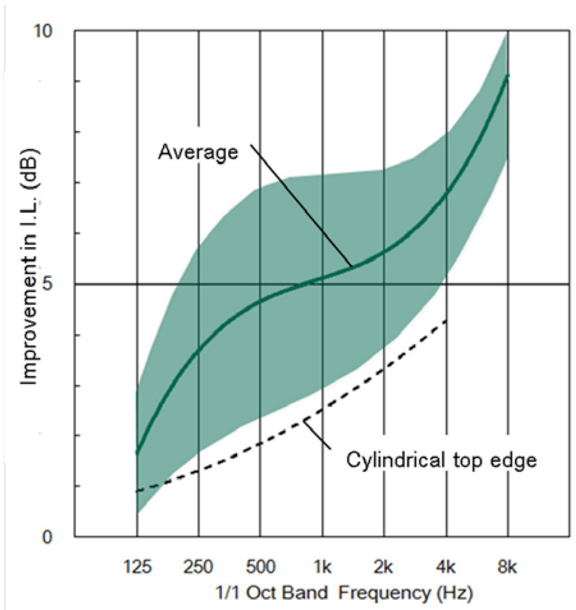

Fig. 8 Measured variation range of the improvement in the insertion loss of M shaped barrier with grass wool behind compared to flat top barrier with same height. The dotted line means expected value of the cylindrical top edge barrier.

(a) Receiver's side

(b) Sound source side

Fig. 9 Practical application of M shaped edge barrier at a construction site.

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