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DEVELOPMENT OF THE NOISE BARRIER USING ACTIVELY CONTROLLED ACOUSTICAL SOFT EDGE - PART 2: FIELD TEST USING A LOUD SPEAKER AND A HIGH SPEED RUNNING TRUCK

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ABSTRACT
A new type of noise barrier, a prototype ASE (Actively controlled acoustical Soft Edge) noise barrier, was designed and assembled. The ASE noise barrier has the active controlled devices on its edge. The devices make the surface acoustical reflection ratio -1 (Acoustically soft condition). The 40m long ASE noise barrier was installed along the test track. ASE has shown good noise reduction performance for both a fixed noise source and a high speed running truck. In other words, ASE can follow the high speed moving noise source using active noise control technology.

1 - INTRODUCTION
Research activities to apply Active Noise Control (ANC) techniques to measures for traffic noise control have been carried out in Japan since around 1990. In conventional researches, however, the noise reduction effect of ANC technique against moving noise sources has not been confirmed yet in a wide space behind the barrier.

We are developing the ASE noise barrier in order to solve the above-mentioned issue. The fundamental principle of the ASE has been shown in the first report [1]. The second report [2] indicated the performance of the ASE cells where active control was compatible with a sound absorption effect. In this report, we will reveal the results of measuring the reduction effect of the ASE noise barrier prototype (40m long). Measurements were implemented for fixed noise sources and a running high speed truck (at speeds of 40km/h and 80km/h).

2 - OUTLINE OF THE ASE NOISE BARRIER PROTOTYPE
Figure 1 shows the fundamental principle of the ASE noise barrier. The ASE noise barrier aims at reducing diffracted sounds. It is achieved by always maintaining the sound pressure on the surface of the ASE cells installed on the upper end of the barrier at the level around zero, using ANC technique [2]. An analogue feedback control method is employed for the control.

Figure 2 illustrates the sectional, front and other views of the ASE unit (2m long) which is a minimum element of the ASE noise barrier as a product. In this experiment, 20 ASE units were installed in series on the upper end of the standard noise barrier with the specifications of Japan Highway Public Corporation (hereinafter called "the ordinary noise barrier") to construct an prototype of the 40m long ASE noise barrier (see Figure 3). Each unit contains 48 ASE cells (see Figure 1, 4 units in the lateral direction × 12 units in the longitudinal direction).

Table 1 indicates the composition of the ASE unit and its basic specifications.

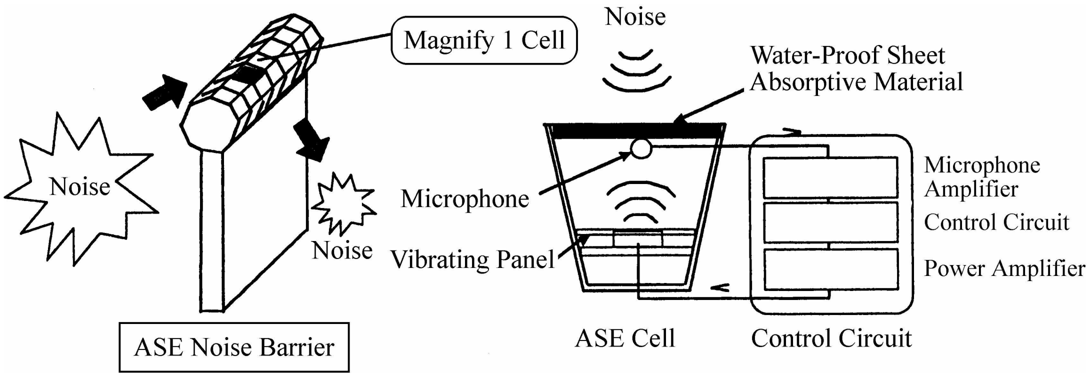

Figure 1: Principle of ASE noise barrier.

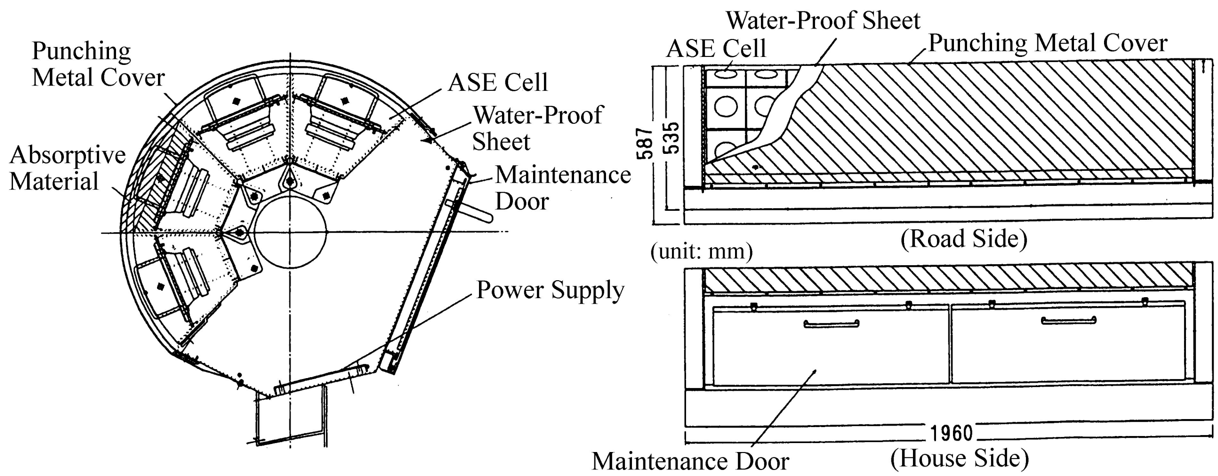

Figure 2: Cross section, front and back views of ASE unit.

1. Composition	2. Basic Specification
(1) ASE cells 48 pieces/unit Speaker, Microphone, Sound absorbing material, etc.	(1) ANC control frequencies: 200 ∼ 630Hz
(2) Control circuit 24 pieces/unit	(2) Applicable conditions Outside air temperature: −10°C or more ∼ 40°C or less Outside air humidity: 80% RH or less
(3) Frame: Frame body, Weather proof sheets, Performed plate, Maintenance lid	(3) Power consumption: 45W/unit
(4) Electric power unit	(4) Weight: 130kg/unit

Table 1: Composition of the ASE unit and its basic specification.

3 - OUTDOOR EXPERIMENTS AT TEST TRACK OF PUBLIC WORKS RESEARCH INSTITUTE

The prototype of the ASE noise barrier of 40m in length and 2.5m in height was installed on the test track of Public Works Research Institute (PWRI). Figure 3 shows a layout of the experimental devices.
Two fixed noise sources, Noise Sources 1 and 2, were arranged to make measurements at 11 points specified on P1 ∼ P11 simultaneously. Based on the results of our preliminary experiments, the voice-coil-type of speaker possible to secure almost all S/Ns at lower frequency bands was arranged downwards at each sound source to generate random noises.
Figure 5 indicates the measurement results of the noise reduction effects when a heavy truck was running. The vehicle (fully loaded, total weight: 20t) ran at speeds of 40km/h and 80km/h on the centerline of the lane, where Noise Source was placed.
At midnight of the same day, the sound pressure levels against the fixed sound source and the running

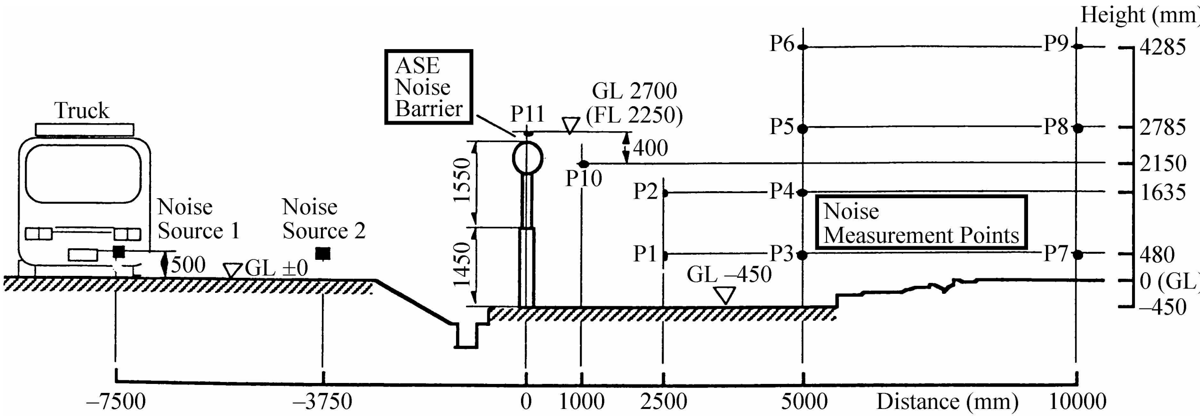

Figure 3: Test setup of ASE noise barrier.

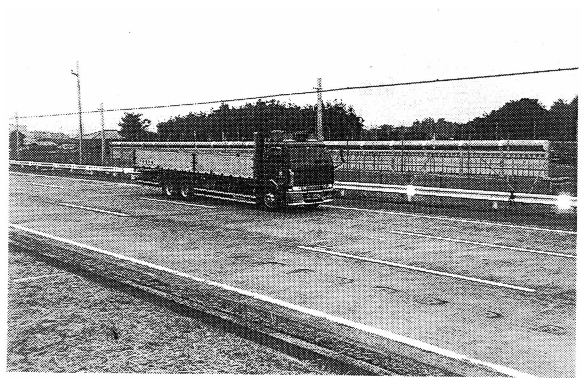

Figure 4: Noise reduction measurement using high speed running truck.

heavy truck were measured under the conditions where the control of the ASE noise barrier was ON and OFF. On the other hand, the sound pressure levels in the case of the ordinary noise barrier were checked at midnight of another day.

4 - NOISE REDUCTION EFFECT AGAINST FIXED NOISE SOURCE

Figure 5 shows the differences in sound pressure levels at 250Hz and 500Hz in the case of Noise Sources 1 and 2 when the ASE control was ON and OFF. In many measuring points, the effect of ASE control of about 2 $\sim$ 4dB was obtained. As a whole, the effect at 500Hz was slightly greater than that at 250Hz. In addition, larger reduction effects were seen when the noise barrier was closer to the sound source and the measuring point and the diffraction angle was greater.

Figure 6 shows the difference in reduction effects between the ordinary noise barrier and the ASE noise barrier (with its control ON) as overall values from 50Hz to 8kHz. It was confirmed that the noise reduction effect of the ASE noise barrier was 2 $\sim$ 6dB greater than that of the ordinary noise barrier.

Figure 7 indicates the results of the 1/3 octave analysis for sound pressure levels of the ordinary noise barrier, and the ASE noise barrier with its control ON and OFF against Noise Source 1 at the measuring point of P1. However, the power spectrum of the noise source was measured separately, and a certain correction was given to all the measured values according to frequencies for their adjustment to A characteristics representing spectrum of the car running noise. (The same procedure was applied to the values shown in Figure 6.) Figure 7 reveals that the ASE control effect (the difference between the control ON and OFF) of approximately 2 $\sim$ 4dB was obtained at 200Hz $\sim$ 630Hz, and the effect of the sound absorber underneath the ASE cell surface, around 3 $\sim$ 5dB, arose at 1250Hz $\sim$ 4000Hz.

5 - NOISE REDUCTION EFFECT AGAINST MOVING NOISE SOURCE

Figure 8 shows the results of the measurements for 250Hz at P1 when the heavy truck was running at the speeds of 40km/h and 80km/h. The measurements were made 4 times and their arithmetic means were calculated to yield the mean values. The reduction effect of the ASE noise barrier was 5dB greater than that of the ordinary noise barrier at the peak value.

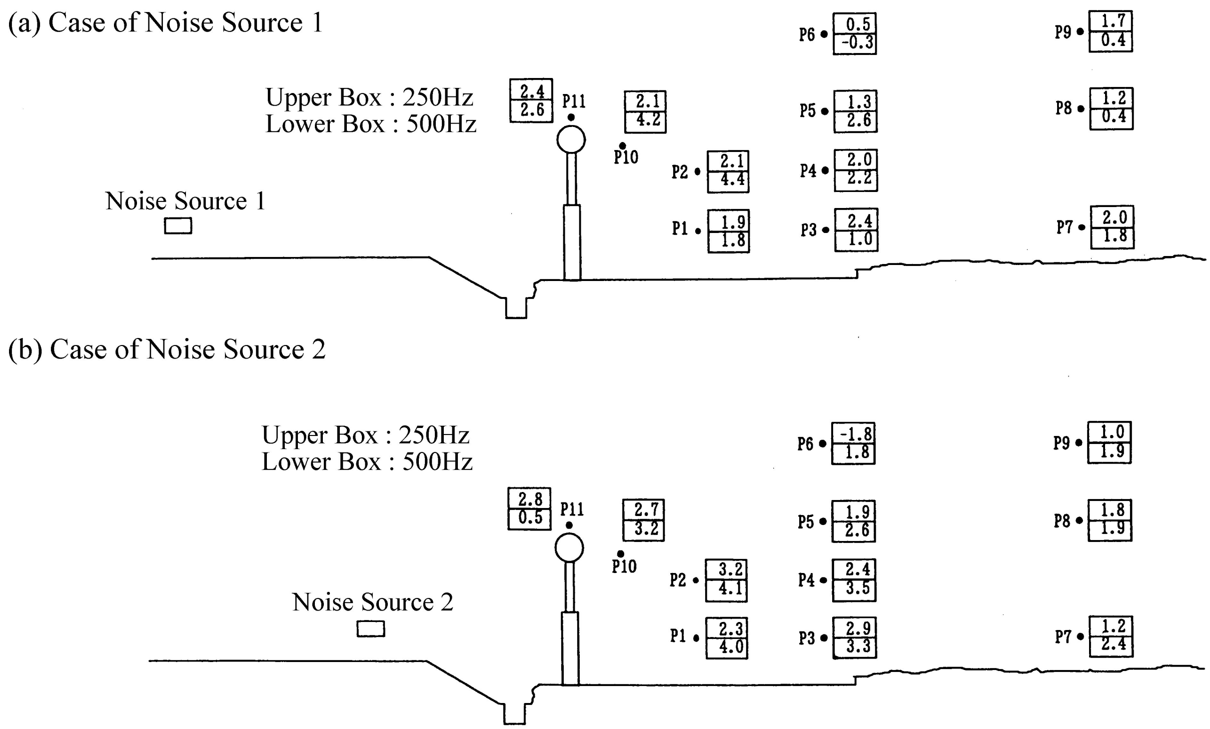

Figure 5: Difference in noise reduction effects between control-OFF and control-ON against a fixed noise source.

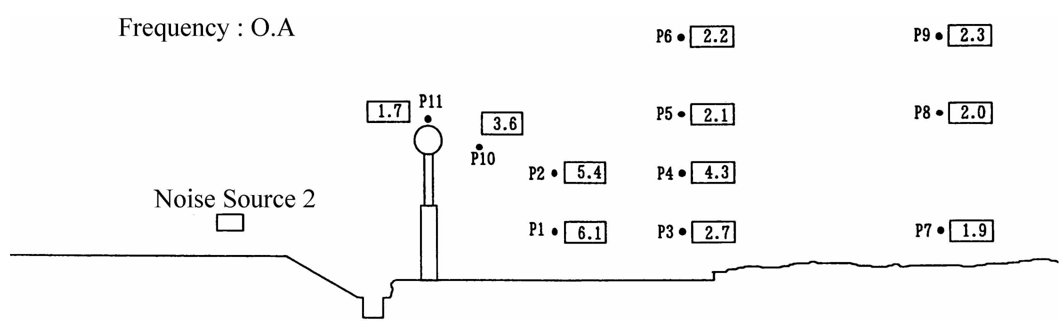

Figure 6: Difference in noise reduction effects between ASE (control-ON) and I-shape noise barrier against fixed noise source.

Figure 9 indicates the differences in reduction effects between the ASE noise barrier (with control ON) and the ordinary noise barrier against the fixed noise source (Noise Source 1) and the running heavy truck. The differences in the equivalent sound pressure levels Leq when the heavy truck was running in the track section of ±10m from the center (measuring point) of the 40m long barrier were regarded as their effects. Figure 9 shows that the ASE noise barrier has the same reduction effect against the running heavy truck regardless of its speed as that against the fixed noise source. However, its effect drop at 400Hz and 800Hz, which results in the decrease of its overall reduction effect. It is necessary to find the causes through further research.

6 - CONCLUSIONS

A prototype of the ASE noise barrier of 40m in length was installed at the test track of PWRI to measure its noise reduction effects. The results were as follows:

- The effects of the ASE control against fixed sound sources were 2∼4dB at 250Hz and 500Hz, depending on the positions of the sound receiving points.
- For the overall value of 50Hz∼8kHz, the reduction effect of the ASE noise barrier against fixed noise sources was 2∼6dB better than that of the ordinary noise barrier, depending on the positions

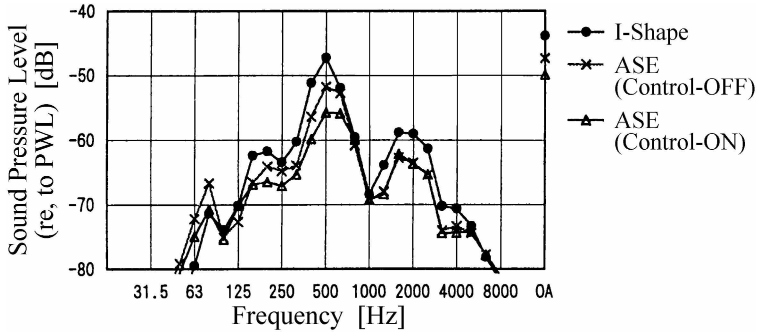

Figure 7: Noise spectrum at P1 for a fixed noise source 1.

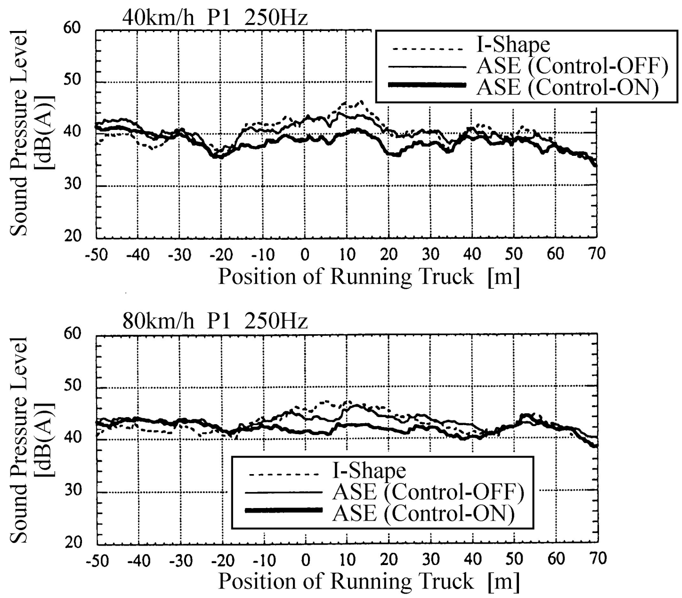

Figure 8: Noise reduction effect for a running truck.

of the sound receiving points.

- The reduction effect of the ASE noise barrier against a running heavy truck (at the speeds of 40km/h and 80km/h) was about 5dB better than that of the ordinary noise barrier in a peak value. Furthermore, it was confirmed that the barrier had the same ASE control effect as that against the fixed noise source regardless of the speed.

The major issues to solve are as follows:

- Determination of where to install the ASE noise barrier in order for it to be effective; and
- Improvement in reduction effect of the ASE noise barrier (especially, at 400Hz and 800Hz).

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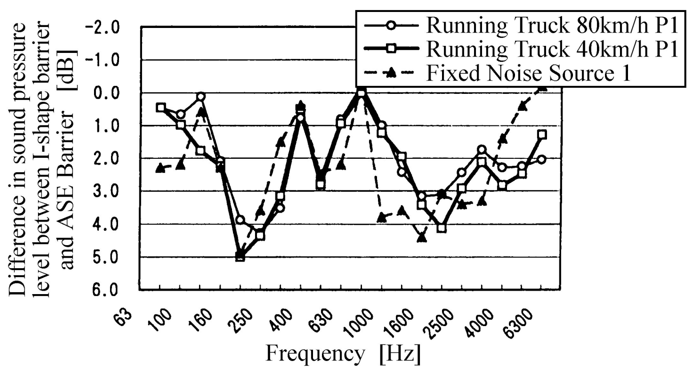

Figure 9: Comparison of noise reduction effects between a fixed source and running truck.