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A BASIC LAB STUDY FOR THE ROAD APPLICATION OF THE ACTIVE NOISE REDUCTION TECHNOLOGY

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ABSTRACT
In this study, an active noise reduction technique was presented as a means to reduce the road noise, and a basic indoor test was performed for the application of the technique to tunnels. The active noise reduction technique has been used indoors and requires a phased study procedure for its application to the outside road. This study was performed in a tunnel, which is a closed road space. There have been many test cases on the active noise reduction barrier, but most of them were only about the simulation using the existing noise source. This test was a basic stage for the actual road application and was performed in the duct structure of a tunnel model. The test resulted in a high noise reduction effect of 4-15 dB when the active noise reduction technique was applied. In addition, installing acoustic insulation materials for irregular reflection control was seemingly necessary for the application of the active noise reduction technique.

Keywords*: Active Noise Cancellation, Road Traffic Noise, Sound Insulation, ANC Barrier, Duct Structure.*

I. INTRODUCTION
More than half of the citizens in South Korea are exposed to noise, which is more severe in the bigger cities. The complaints about the noise and vibration account for 35% of the total environmental complaints, and the problem is most severe in the metropolitan area. In South Korea, the noise level is regulated at 68 dB (daytime) to control the noise after the road starts its operation (Noise and Vibration Administration Law, 2015). The countermeasures to reduce the road noise can be seen in view of the noise source, route, and listener. The representative countermeasure in terms of noise source is the low-noise pavement. It reduces the noise created by the friction between the tires and the road surface by up to 6 dB compared with the concrete pavement. . However, the low noise pavement has a disadvantage of reducing efficiency by blocking the pore.

The representative countermeasures in terms of the noise route are soundproof barriers and tunnels, but the soundproof barriers are costly to install and maintain. And they degrade the surrounding landscape. In this study, the active noise reduction technique was proposed as a new countermeasure in terms of the noise route, along with literature examination and a basic lab test. Thus, this study aimed to establish a foundation for the road application of the active noise reduction technology.

II. LITERATURE REVIEW

2.1.Overview of the Active Noise Reduction Technology
The active noise reduction technology reduces the noise by generating an anti-phase frequency to the noise source, and it has been used for the noise inside cars or acoustic devices such as headphones. Its application to the road is at an early stage: addressing the basic noise source and conducting lab tests.

The active noise reduction technology was introduced by Leug in 1936. But it did not draw much attention then due to the absence of an electronic-element technology. With the development of the relevant technology, the relevant and applied technologies have been studied since 1980. The technology can be applied to all acoustic areas theoretically. But it is used only for low-frequency noise reduction in a limited space. Therefore, efforts must be exerted to make it more widely used in diverse areas(H. K. Moon et al., 2016).

2.1. Overview of the Active Noise Reduction Technology

H. Kown et al. (2002) developed an active noise reduction barrier using six microphones and four speakers. The system used the multi-channel Fx LMS algorithm. In addition, a 60-MIPS-speed TMS320C33 DSP by TI was used for fast operation. A 190 Hz reference noise source was used in this test, and acoustic absorption materials were attached to minimize the resonance phenomenon. The amount of noise reduction was 20 dB on average.

Figure:

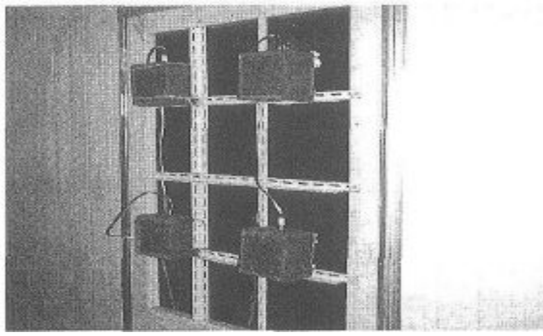

Figure 1: ANC barrier(H. Kwon et al., 2002)

W. H. Cho et al. (2009) developed an ANC soundproof barrier and the research tested it lab and field. The system used a 6713 CPU and a DAQ board. In addition, a complex-frequency noise source was used with the Fx LMS algorithm. The test results showed a 10-13 dB noise reduction.

Figure:

Figure 2: Field test (W. H. Cho et al., 2009)

H. Zou et al. (2010) installed eight controllers on top of the 1.5-m-high wooden soundproof barrier for the simulation of the ANC soundproof barrier. The system used the Fx LMS algorithm, and the noise source was a white noise below 1600Hz. The test results showed a 0.2-6.0dB(A) noise reduction effect within a 200-1250Hz range of frequency band.

Figure:

Figure 3: Field test (H. Aou et al., 2010)

In Japan, the active noise reduction technique was applied to the resonance device on top of the soundproof barrier. The system showed a 1-4 dB noise reduction at 200 Hz (P. A. Morgan et al., 2004).

Figure:

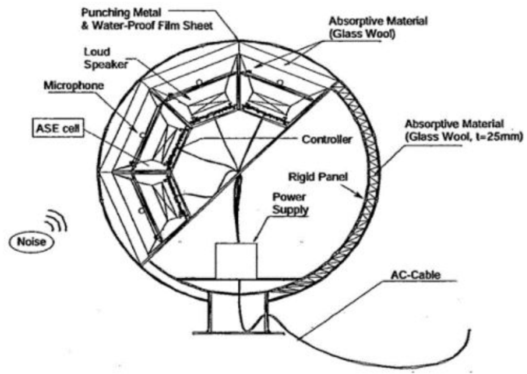

Figure 4: ASE barrier (P. A. Morgan et al., 2004)

III. LAB TEST FOR THE FIELD APPLICATION OF ANC

The active noise reduction technology has been used indoors and it requires a phased study procedure for its application to outside roads. This study was performed in order to apply to a tunnel, which is a closed road space. A duct structure like a tunnel was fabricated, and the ANC application test was performed. ANC controllers, which have already been commercialized, were used. As shown in Fig. 5, an S-Cube Development Kit by Silentium was also used. The controllers has been used for reducction the noise from the server fans, network devices, air-conditioning systems, and medical devices. They are used especially for controlling the humming of cooling fans, which causes irritating noises in electric and electronic devices(FiveGT, 2013).

Figure:

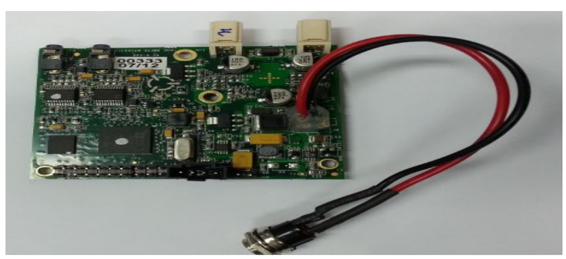
Figure 5: S-Cube Development Kit

Fig. 2 shows the test layout. A noise source was played on the front of the duct structure, and input microphones were installed. Error microphones were installed on the rear of the duct. Anti-noise was generated on top of the middle of the duct. Noise measurement microphones were installed on the front and rear to measure the amount of noise reduction. The PVC duct was 2 m long, and its diameter was 0.3 m.

Figure:

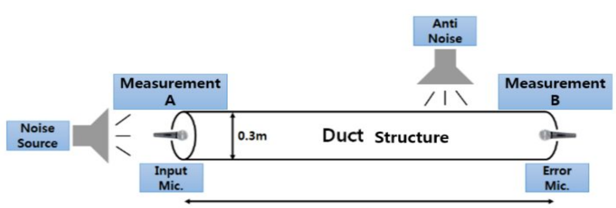

Figure 6: Test Layout

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Fig. 7 shows the devices that were used for the test. The input and error microphones were originally included in the kit. The noise measurement microphone was the Type 4949 model by B&K.

Figure:

(a) Input & measurement microphone ***(b) Speaker*** ***c) Error & measurement microphone***

Figure 7: Test Device

As for the noise source, the reference noise source was combined with the road noise source (road noise + 300 Hz sine wave + 500 Hz sine wave + white noise). This was done for the purpose of combining the road noise source with the noise source within the target noise reduction frequency range so as to clearly determine the reduction performance. Fig. 6 shows the actual test.

Figure:

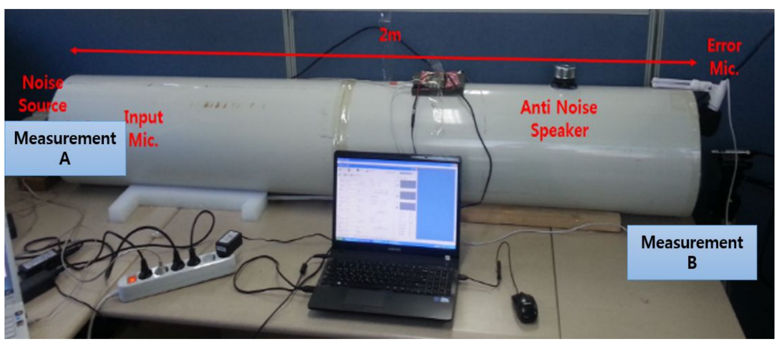

Figure 8: Installation of the Test Device

Reflection occurs when the sound runs into a rigid structure, and irregular reflection occurs in the curved structure that is found in the duct. Accordingly, it is necessary to use a soft soundproof material. In this study, the noise reduction amount was determined with and without the soundproof material as the basic stage about the tunnel application of the active noise reduction technology. As shown in Fig. 9, the sponge soundproof material was used

Figure:

Figure 9: Sound Insulation

IV. TEST RESULT

The noise reduction amount was determined with no-application, half-application, and full-application of soundproof-material conditions. Fig. 10 shows the test results, which indicate that the use of a greater amount of soundproof material increases the noise reduction effect. The full-application improved the noise reduction performance within the 3-17 dB range depending on the frequency. This indicates that the active noise reduction technology will be effective on the road when auxiliary tools such as a soundproof material are also used.

Figure:

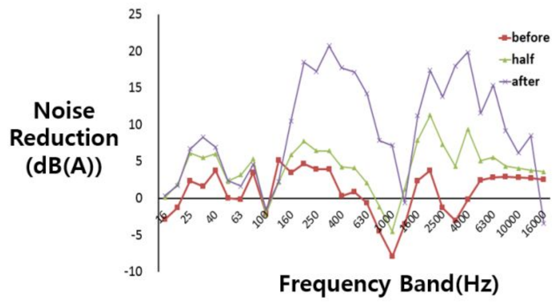

Figure 10: Noise Reduction Amount according to Soundproof Insulation

Fig. 11 shows the results of the application of the active noise reduction technology. The noise reduction amount was 4-15 dB, within the 100Hz-1.6 kHz frequency range.

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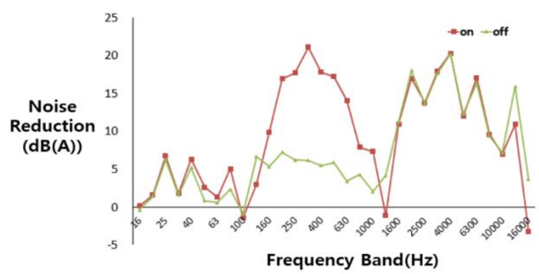

Figure 11: Noise Reduction Effect of ANC Operation

V. CONCLUSION

In this study, an active noise reduction technology was presented as a means to reduce the road traffic noise, and a basic lab test was performed for the application of the technique to tunnels. There have been many test cases on the active noise reduction barrier, but most of them were only about the simulation using the standard noise source. This research is a basic stage for the actual road application. The test resulted in a high noise reduction effect of 4-15 dB when the active noise reduction technology was applied. In addition, installing acoustic insulation materials for irregular reflection control was seemingly necessary for the application of the active noise reduction technology.

Korea Institute of Civil engineering and building Technology(KICT) will use the developed controller for the tunnel application test in the future.

VI. ACKNOWLEDGEMENTS

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