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DEVELOPMENT OF A MEASURING INSTRUMENT FOR ROAD SURFACE ABSORPTION COEFFICIENTS

K. Mikami, H. Suzuki, M. Ohkoshi

Ono Sokki Co., Ltd., 1-16-1 Hakusan, Midoriku, 226-8507, Yokohamashi, Japan

Tel.: +81-45-935-3818 / Fax: +81-45-935-3806 / Email: mikami@onosokki.co.jp

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ABSTRACT
An in-situ measurement instrument for the absorption coefficient of road surface was developed. This paper presents the principle of the measurement, the system layout and some measurement results. The instrument is composed of an I/O controller, a personal computer (PC) and an acoustic apparatus. The PC drives the I/O controller, which triggers a discharger and a large impulsive current flows through a voice-coil of a dynamic loudspeaker. The direct sound pulse and the reflected pulse from the road surface is picked up by a microphone. The analogue signal is AD converted in the controller and the digital signal is supplied to the PC through a universal bus. The entire signal processing is carried out in the PC. The results of the measurement are stored in the hard disc memory and also displayed on the screen.

1 - INTRODUCTION
The porous road pavement has been recently used for the purpose of preventing slip accidents and reducing traffic noise. The effect of this type of pavement may decrease if the pore holes of the pavement is clogged with dust. A periodic inspection of the road surface is therefore necessary and for this purpose a quick and reliable inspection method is strongly required.
There are three commonly used methods for the measurement of absorption coefficients, the impedance tube method, the reverberation chamber method, and the impulse method. The first two methods are not suitable for the outdoor measurement. because the apparatus gets complicated and the measurement gets very time consuming. We employed the third method because the system is easily assembled on the spot. This system measures the incident sound and the reflected sound from the road surface and the sound absorption coefficient is computed using the energy ratio of the reflected sound to the incident sound.

2 - MEASUREMENT SYSTEM
Fig. 1 shows the configuration of the system. The instrument is composed of a personal computer, an I/O controller, and an acoustic apparatus. The I/O controller generates a short impulse of 10 micro second duration according to the command from the PC. An intensive impulse sound is radiated by the loudspeaker to the road surface. The incident and the reflected sound are picked up by a microphone. The peak sound pressure of the impulse reaches more than 130 dB at the microphone position. A sufficient signal to noise ratio is achieved in the normal measurement environment. The analogue signal is AD converted in the I/O controller at the sampling rate of 50 kHz and 12 bits accuracy. The digital signal is supplied to the PC through a universal bus.

3 - PRINCIPLE
Fig. 2 shows one example of the entire waveform, the separated incident wave and the reflected wave. The incident sound and the reflected sound is separated in the time axis. The time windows of the same shape are used for the frequency analysis as shown in Fig. 2. One third (1/3) octave band frequency analysis is carried out by 1,024 points FFT and the energy ratio of the reflected and the incident wave in each frequency band is computed.

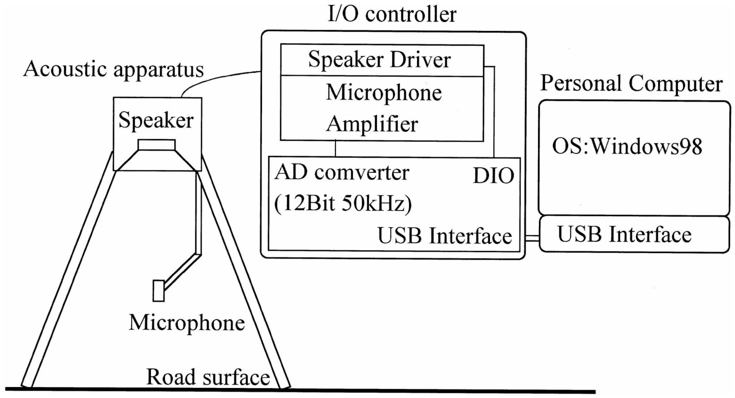

Figure 1: Configuration of the system.

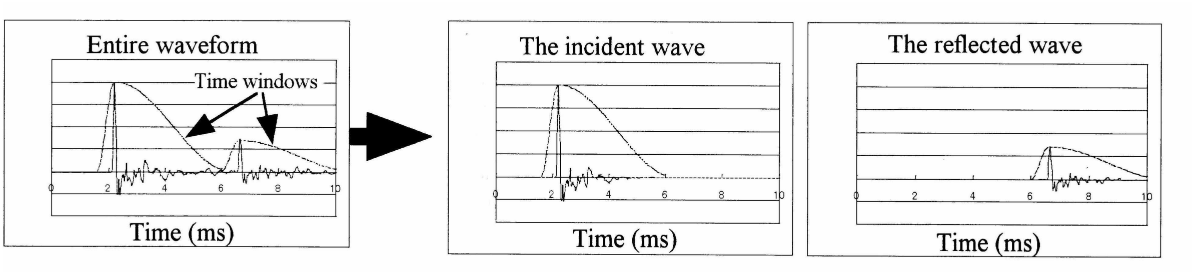

Figure 2: Wave forms.

The process of the data analysis is as follows:
(1) The one third (1/3) octave band spectra of the incident wave $X(f)$ and that of the reflected wave $Y(f)$ are computed from the separated wave forms, where f is the center frequency of 1/3 octave bands.
(2) The reference ratio $R_0(f)$ is computed using a reflecting surface with almost zero absorption coefficient.

$$R_0\left(f\right) = \overline{X^*\left(f\right) \cdot Y\left(f\right)} / \overline{X^*\left(f\right) \cdot X\left(f\right)} \tag{1}$$

where, $X^*(f)$, the conjugate complex of $X(f)$, and $\overline{A\left(f\right)}$ expresses the average of $A(f)$.
(3) The same measurement and computation are carried out for an actual road surface. The energy ratio for the objective road is expressed $R_x(f)$.
(4) The sound absorption coefficient is computed by the following equation:

$$\alpha\left(f\right) = 1 - R_X\left(f\right) / R_0\left(f\right) \tag{2}$$

The averaging process in Eq.(1) is not always necessary. It is experimentally confirmed that the absorption coefficient obtained only by a single measurement is the same as the value obtained with many times of averaging in our case.

4 - EXPERIMENTAL RESULTS

The distance between the microphone and the road surface may differ in the measurements obtaining $R_0(f)$ and $R_x(f)$. The effect of this distance change was first investigated. The distance in the case of measuring the object surface was changed from that in the case of measuring the reference surface. The experiment was carried out using the same reference surface as the object surface. Fig. 3 shows the results. The dependence of the obtained absorption coefficients on the distance change is significant. The error of 1 cm is not allowed when the distance is about 30 cm.
Fig. 4 shows the same experiment for the case of 75 cm distance between the microphone and the surface. It may be said that the distance error up to 1 cm may be allowed.
Fig. 5 shows the sound absorption coefficients of a glass fiber sheet of 5 cm thick measured at distances with 30 cm, 75 cm and 120 cm. It also shows results measured by the impedance tube method. Fig. 5 indicates that the distance should be more than 70 cm to obtain exact absorption coefficients in the frequency range above 500 Hz.

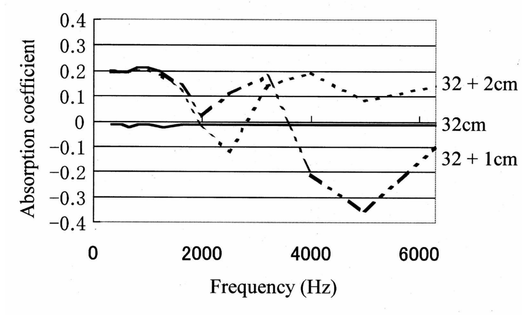

Figure 3: Case of 32 cm.

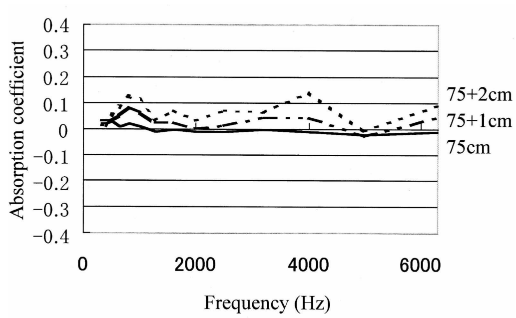

Figure 4: Case of 75 cm.

5 - CONCLUSION

An instrument for the measurement of the sound absorption coefficient of road surfaces, more generally a plane surface, has been developed. An electrical charge stored in a condenser is discharged through an electronic switch and impulse current of 10 micro second duration drives a loudspeaker. The peak sound pressure level reaches more than 130 dB, which gives an enough signal to noise ratio in most on the spot measurement. The ratio of the reflected wave and the incident wave in every 1/3 octave band is computed by use of FFT. The absorption coefficient is computed comparing the ratio to that of a reference surface with a negligible absorption. The effect of the height of the microphone was investigated. According to the result, the height of the microphone should be higher than 70 cm if 1/3 octave bands above 500 Hz must be measured.

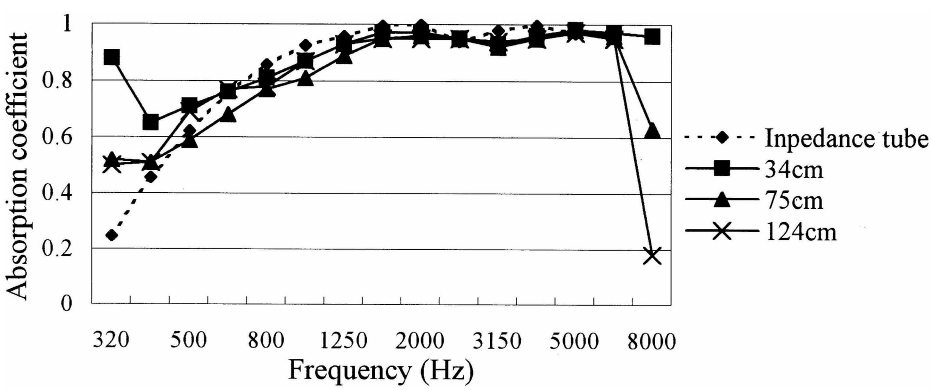

Figure 5: Sound absorption coefficients of a grass fiber sheet of 5 cm.