A STUDY ON SIMULATION OF ENVIRONMENTAL RESIDUAL NOISE

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ABSTRACT

Residual noise is composed of noises from distant sources, especially roads, and is considered largely influenced by wind, temperature, and humidity. It is necessary to predict wind effect to simulate the long-term environmental noise accurately. Noise levels were taken in conjunction with wind speed and wind direction measurements. These noise levels showed noticeable daily changes. Excess attenuations of noise levels were found to depend on the vector wind (U_{vec}). By taking relations of the vector wind and real sound attenuations under all wind conditions, the influence of wind can be more accurately predicted for purposes of simulation of noise propagation.

INTRODUCTION

It has been recognized that meteorological conditions have a major influence on the propagation of sound in the open air [1-7]. From the results of previous field and scale model experiments, the A.S.J. [8] proposed Eq.(1) to predict the excess attenuation of road traffic noises due to effects of wind (.$L_{m,line}$) .

$$.L_{m,line}=.0.88.\log_{10}.r/15...U_{vec}, \qquad \text{(dB)} \qquad (1)$$

where, U_{vec} is vector component of the wind along the direction sound travels (see Fig.1), r is the length of sound path from the center of the road to the receiving point. Many previous studies demonstrated that Eq.(1) can predict the effect of wind on the road traffic noise when the road has straight and simple structure. However, it is not clear whether the Eq.(1) can be applicable to predict the effect of wind when the road has complex structure and the surface of the ground is uneven. The annual average of the noise level ($L_{Aeq,1year}$) can be obtained from a

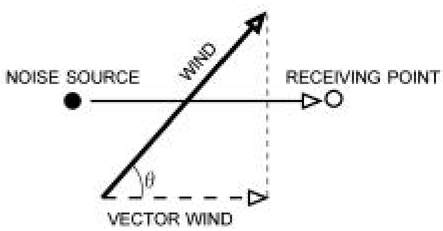

Fig.1 Vector Wind

continuous measurement through a year, but a lot of cost are necessary. The authors tried a practical predicting method of $L_{Aeq,1year}$ including the effect of wind.

EXPERIMENT

Noise Measurement

Figure.2 shows the measurement site and the locations of the receiving point and the wind sensor. The run of the road is south and north. The northern part of the road is a tunnel, and the southern part of the road is the bridge over the channel. The height of the road increases as it reaches close to the channel. The louvers are set up at the exit of the tunnel for shielding noise and sunshine. The traffic volume in a day of the road is about 25,000. Another road runs under the ground in this area along the seaside. Two railways run along the seaside, but effects of their noises on our measurements were not significant. Noise levels were measured for two continuous periods, one of 28 days in 1999, and one of 54 days in 2000. Noise levels were measured from 9 p.m. to 5 a.m. every day to avoid the effects of other noise sources. A microphone was set up at the height of 5.0 m above the ground. The length of the shortest path from the road to the receiving point was about 160 m. The distance from the exit of louver to the receiving point was about 400 m. The microphone was covered with wind screen of all-weather type. DC-output volts from the sound level meter were A/D converted every 0.25s, and $L_{Aeq,10min}$ were calculated every 10min by a handheld computer. $L_{Aeq,10min}$ and instantaneous levels were recorded on the hard disc of the computer.

Meteorology Measurement

Speeds and directions of the wind and precipitation were measured at the meteorologically representative point simultaneously with noise measurements. The location of the wind sensor is shown in Fig.2. It was set up at 5.0 m above the ground.

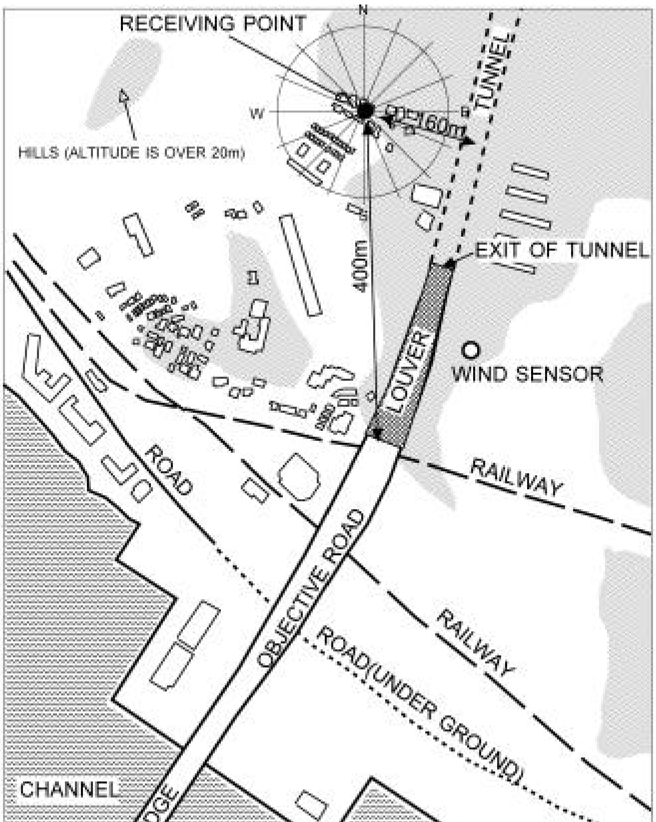

Fig.2.Measurement site, the noise receiving point, and the wind sensor

Traffic Volume of the Road

To offset the variations of noise levels due to the traffic volume, hourly traffic volume of the road and the numbers of the heavy vehicles were measured.

RESULTS AND DISCUSSIONS

Relation between $L_{Aeq,1h}$ and Traffic Volume

Figure.3 is a correlation diagram between noise levels ($L_{Aeq,1h}$) and traffic volume. In order to offset variations of acoustic power caused by heavy vehicles, Q is calculated as:

$$Q = 4.47.Nh + Nl \qquad (2)$$

where, Nh is volume of heavy vehicles, and Nl is the volume of light vehicles. This equation is based on the theory that acoustic power of one heavy vehicle is 4.47 times greater than that of a light vehicle [8]. As traffic volume increases, there is a slight concordant tendency for $L_{Aeq,1h}$ to increase. However, because there is a large dispersion of data, the correlation coefficient (r) is very small. Traffic volume is not a reliable sole predictor of traffic noise. To be able to make more accurate estimations of traffic noise, other conditions, especially meteorological conditions, must be taken into account.

Frequency of Wind Direction

Figure.4 shows the frequency of wind directions throughout the measuring period. Winds from

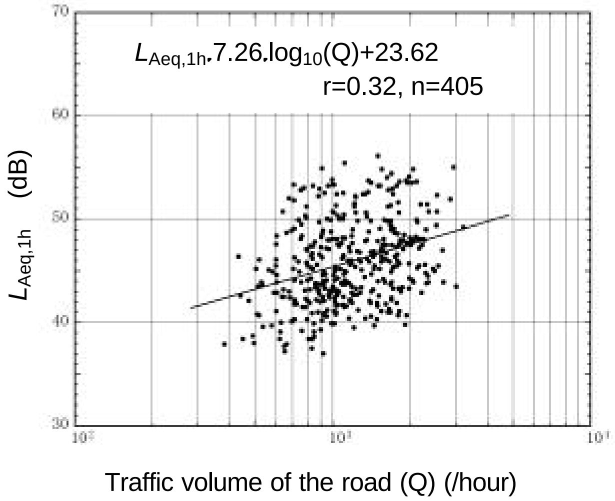

Fig.3. Relation between traffic volume and $L_{Aeq,1h}$

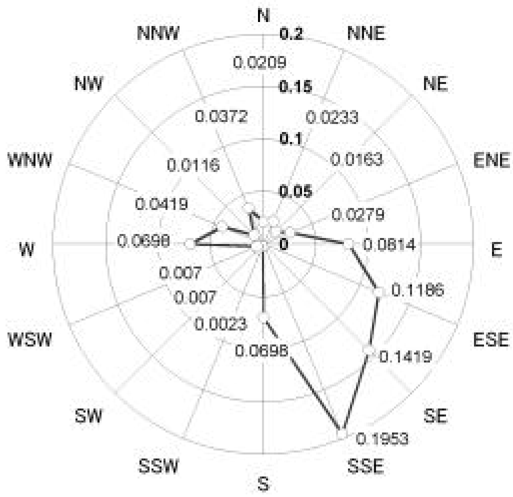

Fig.4. Frequency of wind-directions during noise measurements

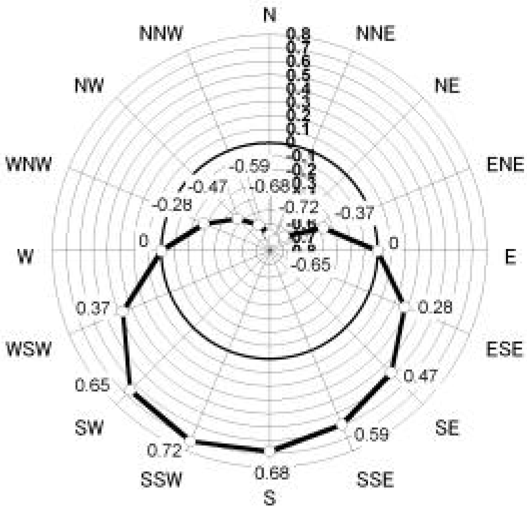

Fig.5. Correlation coefficient of U_{vec} and $L_{Aeq,10min,s}$ for each wind-direction

south-southeast and southeast predominate. Noise levels could be measured under almost all wind conditions.

Vector Wind (U_{vec})

In the case of a noise propagation experiment using a single point source, the location of the noise source and the receiving point are fixed. Therefore, the favorable wind direction is easily determined. In case of a line source such as simple straight road, a line perpendicular to the source always represents the favorable wind direction. In the current case, the favorable wind direction is not easily established, because the road is of a complex structure and the ground is uneven. In order to determine the favorable wind direction, the correlation between the vector wind (U_{vec}) and the average noise level per one light vehicle ($L_{Aeq,10min,s}$) was calculated under every possible wind direction. $L_{Aeq,10min,s}$ is calculated by;

$$L_{Aeq,10min,s}=10.\log_{10}[10^{(LAeq,10min/10)}/(Q/6)], \text{(dB)} \quad (3)$$

to offset changes in traffic volume. Figure.5 shows correlation coefficients between U_{vec} and $L_{Aeq,10min,s}$ for each favorable wind direction. The correlation coefficient is largest (=0.72) when the wind from the south-southwest is considered favorable. Thus, the effect of the wind on sound propagation is most accurately predicted using U_{vec}, which is calculated using the south-southwesterly wind as the favorable wind. Furthermore, the part of the road which is on the line from the receiving point to the south-southwest can be considered the acoustic center for noise simulation. When considering the east-southeasterly wind, which is along the perpendicular line toward the road, as the favorable wind, correlation coefficient between U_{vec} and $L_{Aeq,10min,s}$ is very small (=0.28). This is to be expected, because in this direction, the road runs under the ground and vehicles are completely shielded.

Changes of U_{vec} and $L_{Aeq,10min,s}$

Figure.6 shows the time history of the vector wind (U_{vec});, which is calculated using the south-southwesterly wind as the favorable wind, the noise level per one light vehicle ($L_{Aeq,10min,s}$), and wind speed, using continuous data from July to August in 2000. The horizontal axis indicates the measuring day and time. In the case of July 14 for example, data from 9 p.m. July 14 to 4 a.m. July 15 are illustrated. If precipitation was over 0.1mm per hour, hatching is drawn on the graph. It is clearly apparent that as the vector wind increases, the noise level per one light vehicle also increases. Values of $L_{Aeq,10min,s}$ change day by day, and they also change hour by hour in the same day. The maximum value of $L_{Aeq,10min,s}$ through the period is 33dB, and minimum value is 17 dB, so the fluctuation range of $L_{Aeq,10min,s}$ is 16dB. During almost all calm nights, as time passes, $L_{Aeq,10min,s}$ becomes louder. Early in the night, the vertical temperature pattern may be lapse, because the ground temperature is greater than the air temperature.

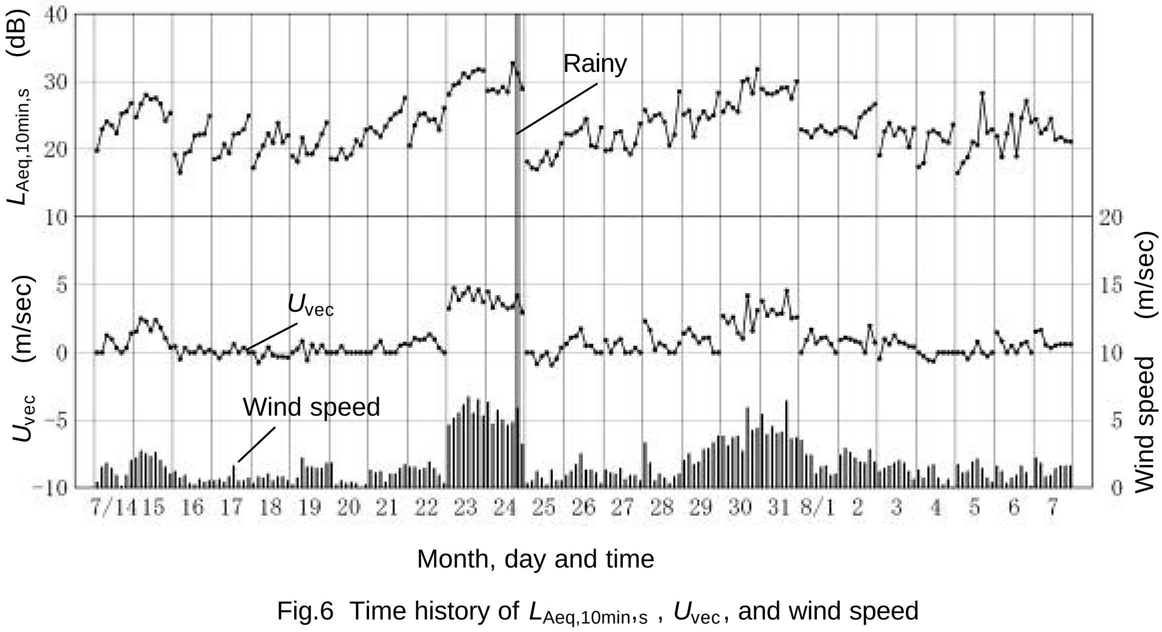

Fig.6 Time history of $L_{Aeq,10min,s}$, U_{vec}, and wind speed

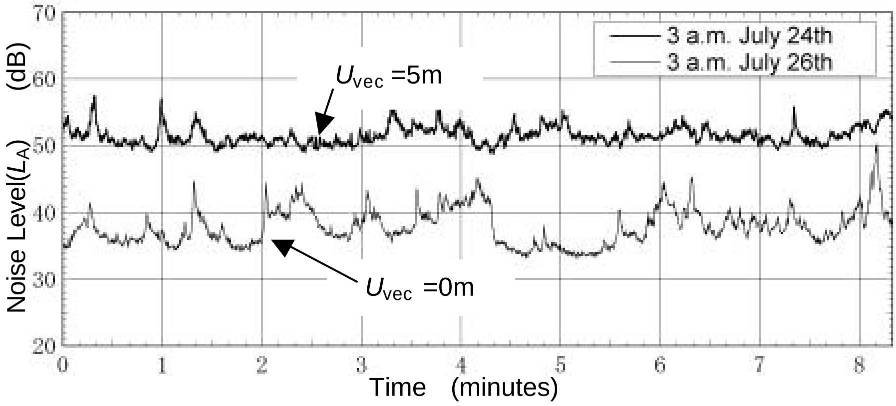

Fig.7 Time history of noise levels when U_{vec} is large and when U_{vec} is small

After then, it may become neutral and finally inverse late at night as the ground becomes cooler than the air. Figure.7 is a comparison of two time histories of noise levels measured at midnight. The bold line indicates the time history when U_{vec} is +5 m (3 a.m. July 24th), and the thin line indicates the time history when U_{vec} is 0 m (3 a.m. July 26th). When U_{vec} is large, noise levels are from 10-16 dB louder than when U_{vec} is small. The fluctuation range of noise levels also becomes small.

Relation between U_{vec} and $L_{Aeq,10min,s}$

Figure.8 shows the relation between the vector wind (U_{vec}), which is calculated on for the south-southwesterly wind is the favorable one, and the noise level per one light vehicle ($L_{Aeq,10min,s}$). As U_{vec} increases, $L_{Aeq,10min,s}$ becomes louder. As there is a little dispersion in data, the other effects on sound propagation should be examined, for example other roads or the hum from woods caused by the wind. From Eq.(1), if the distance the sound travels is approximately 200m, which is the upper limit of the application of this equation, noise levels are 5dB higher, when U_{vec} is about +5 m. However, the regression equation means a stronger effect of wind than that from Eq. (1). That is, when U_{vec} is +5 m, $L_{Aeq,10min,s}$ is +10 dB, because the gradient of the regression line is 2.0. In actual fact, the distance that noise travels may indeed be longer than 200 m. In addition, the distance from the receiving point to the part of the road, which is on the line from receiving point to south-southwest, is approximately 1300 m. From Eq.(1), the effect of the wind predicted about +5 dB when the length of noise path is 1300 m and U_{vec} is +3m. The predicted value is almost the same as that from our regression equation.

Prediction of Yearly Noise Level

If the correlation coefficient between U_{vec} and $L_{Aeq,10min,s}$ in every wind direction can be established by measuring noise and wind for several months and if the yearly or monthly frequency of wind directions and the yearly or monthly traffic volume of the road can be

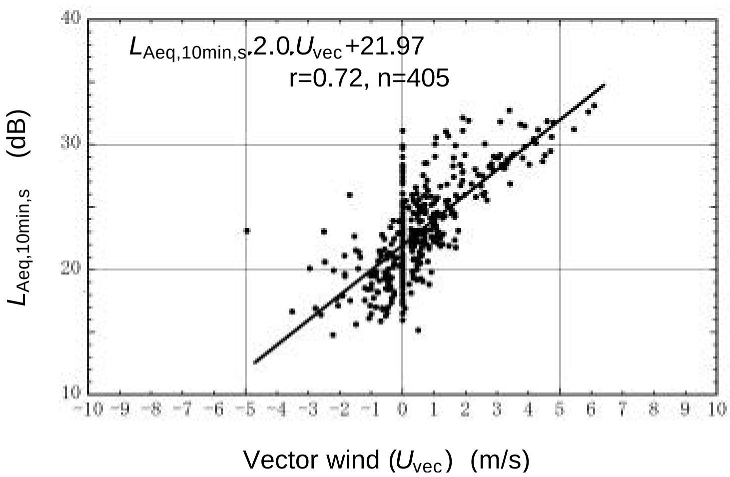

Fig.8 Relation of vector wind (U_{vec}) and $L_{Aeq,10min,s}$

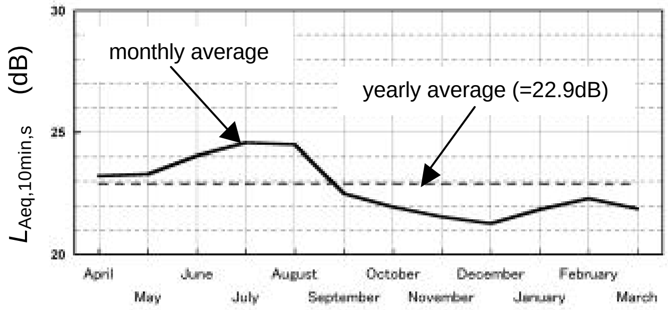

Fig.9. Predicted monthly average and yearly average of $L_{Aeq,10min,s}$

obtained, yearly or monthly average of noise level ($L_{Aeq,1month}$ or $L_{Aeq,1year}$) can be accurately estimated. Figure.9 shows predicted monthly and yearly averages of $L_{Aeq,10min,s}$. Monthly data detailing frequency of wind directions and average wind speed were taken from public records [9]. The monthly average of $L_{Aeq,10min,s}$ is large in summer when the frequency of southerly winds, the favorable wind direction of the road, is high. On the other hand, it is small in winter when the frequency of northerly winds, against the favorable wind direction of the road, is high. The annual fluctuation range of monthly average is approximately 3dB.

CONCLUSION

This paper proposes a practical method of predicting the effect of wind in simulating $L_{Aeq,1year}$, when the structure of the road is complex and the surface of the ground is uneven. The application of the method was investigated by a field experiment. The results indicate that $L_{Aeq,1year}$ for such roads can be accurately predicted by modifying treatments of the distance r and the vector wind Uvec in Eq.(1) proposed by A.S.J.

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