A Technique to Analyze and Predict the Shinkansen Noise Sources with Measurements

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To take effective measures to reduce the wayside noise of Shinkansen, it is important to develop a technique to analyze and predict noise sources at high precision.

As a means to analyze the noise sources of Shinkansen, allay-typed directional microphones are widely used to determine the distribution of noise sources in the longitudinal direction of Shinkansen cars, and provide profound knowledge on the noise sources. Based on this information, the author has classified the noise elements of the Shinkansen cars into those of the current collection system, car substructure, car superstructure, and structure of viaducts. Furthermore, the author established a measure to calculate the contribution of each noise source to the noise level at the measuring point. See Fig. 1. This measure determined the structure noise originated from the noise directly under a viaduct where the object train runs in consideration of the distance attenuation characteristics at the evaluation point first, and then separated the noise generated from the current collecting system by using the noise measured with an allay-typed directional microphone and an appropriate noise source model from the noise after structure noise removed therefrom. In this manner, noise sources are separated one by one. Figure 2 compares measured and calculated values of time history of the total noise level at the time-weighted characteristic S measured with a non-directional microphone at a 25 m-distant point, to prove that there is good agreement in between. Figure 2 also shows the component noise level of different noise sources. This fact verifies that the array of noise sources thus obtained appropriately expresses the distribution of noise sources of Shinkansen cars.

The author applied this technique to noise measurements, determined the contribution and characteristics of each noise source, and subsequently established a method to predict the noise level of Shinkansen cars based on an energy-base calculation model (Fig. 3). By this method, it becomes available to expect the noise levels of Shinkansen cars in service by inputting the conditions of track, structures, and train speed (Table 1). Application of an energy-base calculation model enables estimating not only the maximum noise level of the time-weighted characteristic S ($L_{pA,Smax}$), but also single noise exposure level (L_{AE}) and equivalent noise level ($L_{Aeq,T}$). In calculating such evaluated values, it is a rule to determine changes in the time series in the noise at the receiving point when the noise source moves (unit patterns) and its integrated value with respect to time. When the noise sources of Shinkansen cars are regarded as an array of a finite number of discrete noise sources, L_{AE} is the sum of the integrated values with respect to time of all unit patterns.

Statistical analysis of predicted and measured values indicates that the average value of the difference in between is 0.7 dB and the standard deviation is 1.5 dB, to prove that the technique can predict noise levels at sufficiently high precision (Fig. 4).

There are several subjects to be addressed in the future, including the review of power levels under different conditions, a technique to estimate the noise level near the tunnel entrance and when the structure profile changes into the longitudinal direction along the track, and introduction of a more detailed sound propagation model.

Table 1. Extent of Application of the Prediction Model

Type of car	All Shinkansen cars in operation
Velocity	150-km h^{-1} maximum velocity in operation
Track	Ballast track, slab track, and vibration-reducing track
Construction	Concrete bridge structure and embankment
Sound barrier	Straight type with or without absorbing materials
Measuring point	At the point at a horizontal distance of 12.5 to 50 m from the track and at a height lower than the upper end of the sound barrier

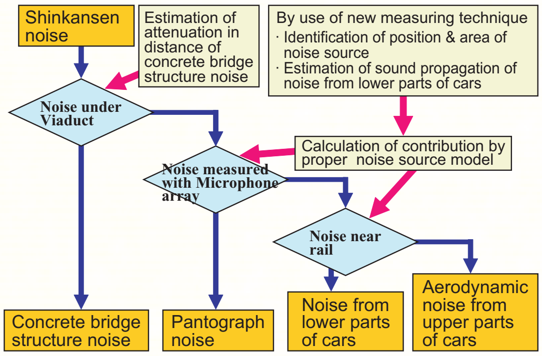
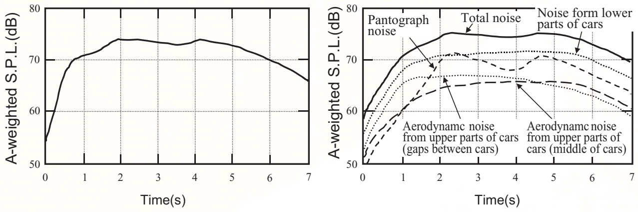


Figure 1. Method of Noise Analysis.



(a) Measured value (b) Calculated value

Figure 2. Comparison of measured and calculated data of time history of noise by sound level meters (25-m away from track).

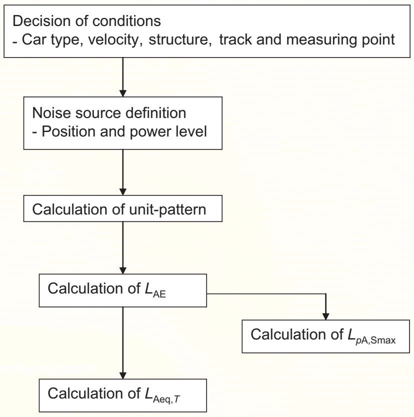


Figure 3. Flow chart of prediction model.

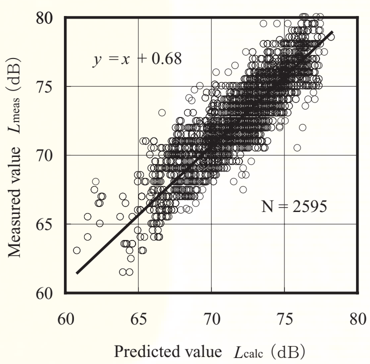


Figure 4. Result of case study.