PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Road Traffic Noise Prediction Model "ASJ RTN-Model 2018" Proposed by The Acoustical Society of Japan – Part 4: Accuracy Verification of a Practical Method for Areas behind Buildings in Urban Districts

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ABSTRACT

The purpose of this study is to verify the ASJ RTN-Model for application to areas behind buildings, which is called a practical method in this paper, by comparing the calculated noise levels and the measured ones in urban districts. Two kinds of verification are explained in this paper. For one kind of verification, the maximum noise levels when passing an inspection vehicle at a steady speed on a plane road or a cut-earth road facing detached residential areas are employed in unit patterns. For the other kind of verification, equivalent noise levels are calculated along a city road by the practical method using road traffic census data. As a result, the differences between the calculated levels and the measured ones are found to be within plus or minus 3 dB for the investigation of the maximum noise levels and within plus or minus 3 dB to 5 dB for the investigation of the equivalent noise levels. These investigations verify that the practical method for application to areas behind buildings can also be used for various road structures, and that the method is accurate enough to create noise maps.

Keywords: Road traffic noise, Prediction method, Buildings, Accuracy, Unit pattern, Census data

1. INTRODUCTION

Road traffic noise is reduced in areas behind buildings, because the buildings obstruct the noise propagation from the road. To calculate the effect of the obstruction of such buildings, the Acoustical Society of Japan presented a method for areas behind buildings as a part of RTN-Model 2018. In this paper, the accuracy of the method is verified through investigations that compare calculated levels and measured ones in urban districts.

Using the method, the correction values for the amounts of noise reduced by the buildings are calculated from unit patterns of point sound sources, that is the general rule of the RTN-Model 2018. The number of parameters required to calculate the correction amounts is four; this is smaller than the eight that were required for RTN-Model 2013. The aim of the method in RTN-Model 2018 is to simplify the calculation process (1, 2); it is called "a practical method based on the point sound sources." The practical method includes processes for the omission of part of the calculation, and these omission processes can, in turn, reduce the calculation hours. However, the advanced calculation method (3) in RTN-Model 2013 is still recommended in certain situations, for example, when the unit patterns must be calculated more correctly for planning countermeasures against noise.

Two kinds of verification are explained in this paper; one involves the unit patterns behind buildings when passing an inspection vehicle on a plane road or a cut-earth road and the other involves equivalent noise levels based on road traffic census data.

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2. VERIFICATION BY MAXIMUM NOISE LEVELS IN UNIT PATTERNS

Unit patterns in areas behind buildings are verified for the situation in which an inspection vehicle runs on a plane road or a cut-earth road at a steady speed. District-M (4) and district-Sa are selected as the intended areas facing a plane road, and district-Sp is selected as the area facing a cut-earth road.

The inspection vehicles for district-M are a motor vehicle and a motorcycle. In districts-Sa and -Sp, only the motor vehicle is employed. The motor vehicle runs on a 3,000-cc diesel engine; it has a one-box design and two-wheel drive. The motorcycle has a 250-cc cowling engine and a genuine muffler.

2.1 Estimation of Acoustic Power Levels

The methods of maximum noise level and squared integrals are commonly used for estimating the acoustic power levels of vehicles. However, it is difficult to estimate the acoustic power levels of vehicles in areas with detached residences using these methods. This is because road lanes are few in number in these areas, the offset distance to a measuring point from the road is short and the noise sources of the vehicle are not assumed to be coming from just one point.

It would be better, therefore, to realistically estimate not only the power levels, but also the passing speeds and positions, because the estimated parameters can be used later on for calculating the unit patterns of the noise levels. In this study, the passing speed, the position and the power level of a single inspection vehicle are estimated by the least squares method in parallel with the measured unit patterns beside the road.

The noises emitted by a vehicle come from the engine, the tires and the muffler. In this study, however, just two noise sources are assumed. The total power level of the inspection vehicle is a simple energy summation of two sources on the assumption that the sources exist at the front and the rear of the vehicle, respectively, and have the same acoustic power.

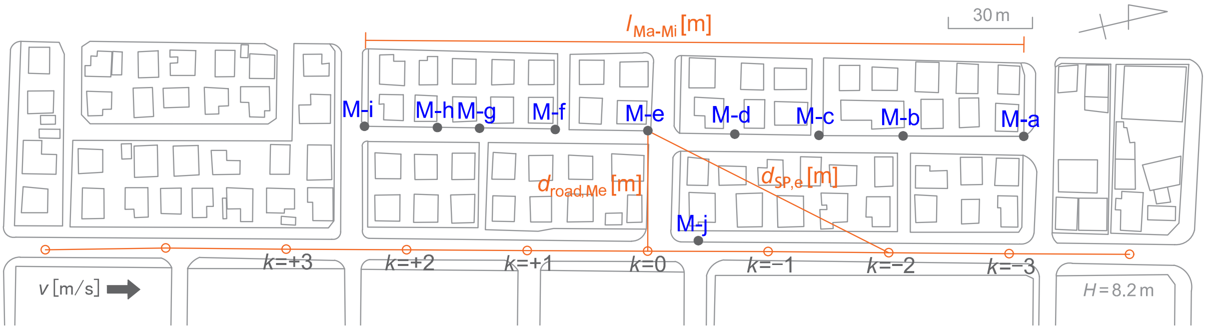

Figure 1 – Arrangement of residences and intended points in district-M facing a plane road

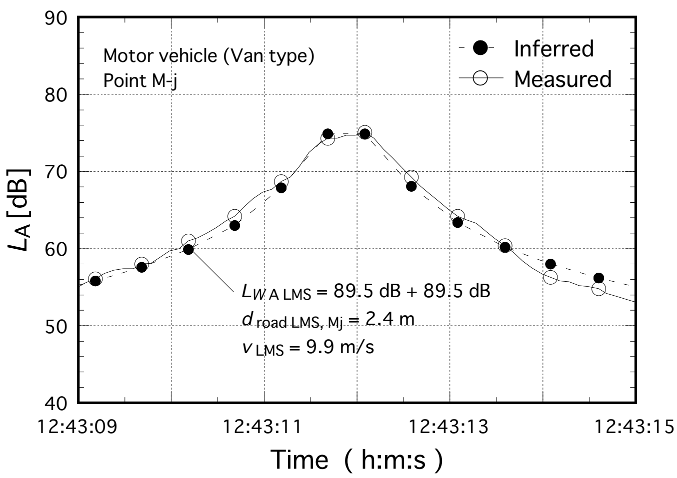

Figure 2 – Comparison of unit patterns based on estimated and measured power levels at point M-j at the end of the road

In the investigation of district-M, illustrated by the layout plan in Fig. 1, the results for the vehicle are a passing speed of v_{LMS} = 9.9 m/s and a position of $d_{\mathrm{road\ LMS}}$ = 2.4 m, and the power level of one source is 89.5 dB. The position of 2.4 m indicates that the passing vehicle is located around the center of a near side lane. The estimated and measured unit patterns after 6.0 seconds have similar characteristics, as shown in Fig. 2. The total power level is 92.5 dB.

The results for the motorcycle are a total power level estimated to be 97.4 dB, a passing speed of 12.8 m/s and a position of 3.2 m distance from point M-j. The position indicates that the inspection motorcycle passes near the centerline of the near side lane. The results are considered to be valid.

2.2 Unit Patterns from a Plane Road

In order to verify the practical areas as models behind buildings for detached residences facing a plane road, the calculated unit patterns are compared with the measured ones in two districts, referred to as M and Sa.

2.2.1 Unit Patterns in District-M

In district-M, there are front yards and carports between the residences, and the buildings are arranged spaciously. Nine investigation points, points M-a to M-i, are placed along public roads behind buildings. The single inspection vehicle or motorcycle on the plane road travels in the direction from point M-i to point M-a. Unit patterns for the investigation points calculated by the practical method are compared with the measured ones by omitting a part of the calculation (5). In addition, errors in appearance of the unit patterns calculated by the omitted calculation are verified. The acoustic power levels are estimated by the measured unit pattern for point M-j, which is located at the end of the road. The power levels of the inspection vehicle and the motorcycle are 97.4 dB and 92.5 dB, respectively.

Discrete source points are arranged at the closest point on the road as a reference and at intervals of $d_{\mathrm{road,x}}$. Comparisons of the calculations with the measurements are given in Figs. 3 and 4 as examples of the unit patterns of the motorcycle and the vehicle, respectively. Investigation points M-a and M-i have a clear view of the road from both points. However, investigation point M-c does not have any view of the road at all. The calculated maximum noise levels at every point in Figs. 3 and 4 approximately correspond to the measured ones irrespective of having a view of the road or not.

Next, the errors in appearance of the unit patterns calculated by the omitted practical method are explained for investigation points M-d and M-f. Two unit patterns are plotted in Fig. 5 with bullet and circle symbols that are calculated by the omitted practical method and by the original one, respectively. The values calculated by the omitted method appear outside of a zone bounded by dot-and-dash lines in Fig. 5. The largest errors appear very close to the dot-and-dash lines and can be found on horizontal axis k=-2. The omitted method calculates insignificantly smaller values than the original one. However, the errors are never more than 0.5 dB, and the influence of the errors on the equivalent level is exceedingly small.

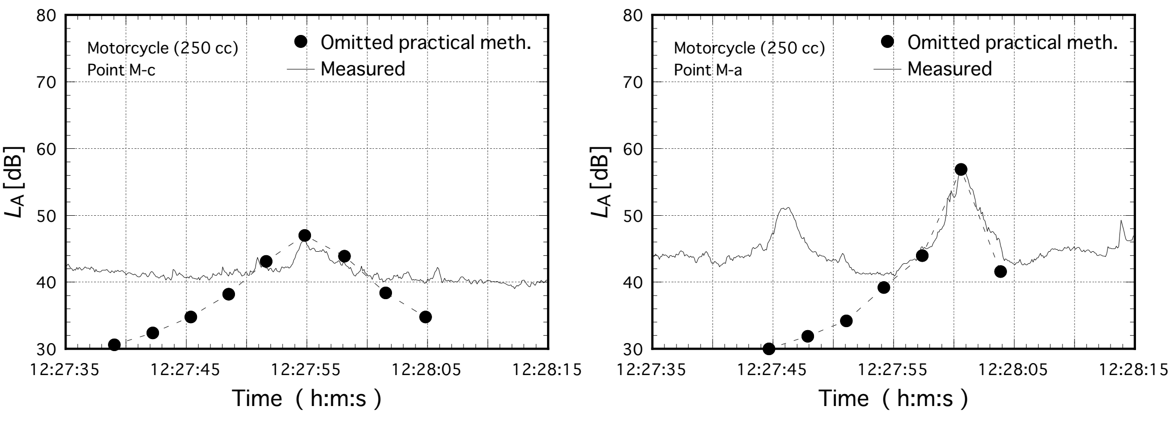

Figure 3 – Comparison of calculated unit patterns by the practical method and measured ones in district-M under conditions of the motorcycle passing

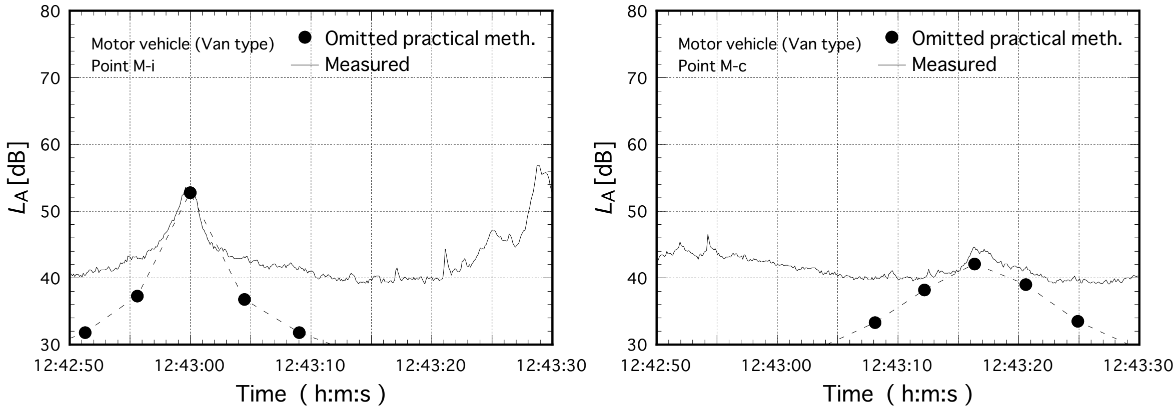

Figure 4 – Comparison of calculated unit patterns by the practical method and measured ones in district-M under conditions of the motor vehicle passing

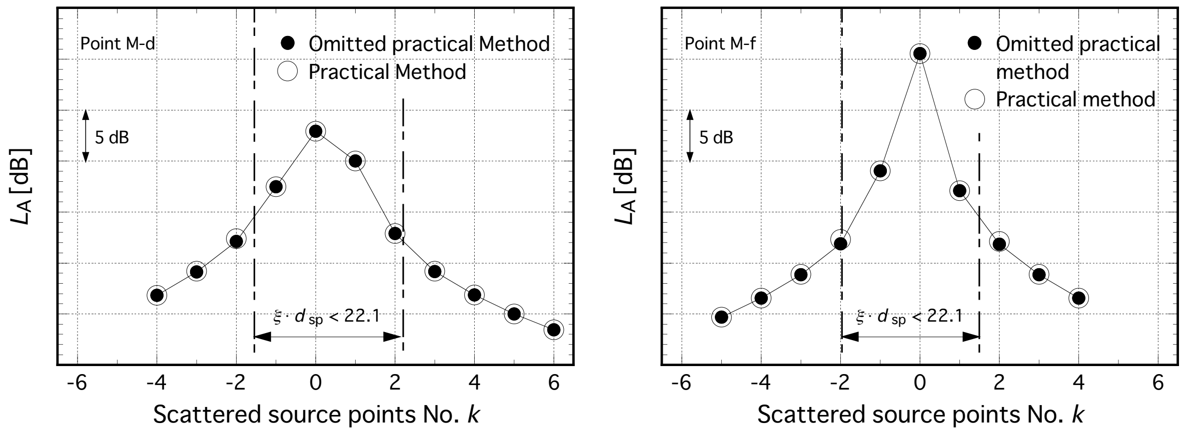

Figure 5 – Influence of the omitted calculation of the practical method on the unit patterns

2.2.2 Unit Patterns in District-Sa

An arrangement of residences and investigation points in district-Sa is illustrated in Fig. 6. In order to verify the omitted practical method for the area facing a plane road, the calculated unit patterns are compared with the measured ones. The acoustic power level of the inspection vehicle is 100.3 dB; it is estimated from a unit pattern at point Sa-j. The passing speed of the vehicle and the distance from point Sa-j are also estimated as 10.2 m/s and 2.6 m, respectively.

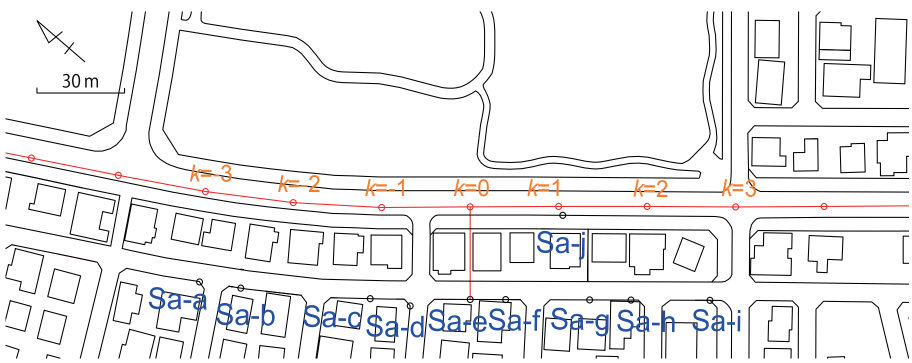

Figure 6 – Arrangement of residences and intended points in district-Sa facing a plane road

As examples of verified unit patterns, the comparison results for points Sa-e and Sa-a are drawn in Fig. 7. The calculated unit patterns are almost consistent with the measured ones at every investigation point, especially for the maximum noise levels.

All the maximum noise levels at the districts with plane roads, which are explained in sections 2.2.1 and 2.2.2, are shown in Fig. 8 in a distribution chart of the calculated values against the measured values. There are nine values each for the vehicle and the motorcycle in district-M, and nine values for the vehicle in district-Sa. All the calculated values have a high correlation with the measured ones, and the differences between them are around plus or minus 3.0 dB.

On the basis of these results, the omitted practical method was verified as being capable of calculating unit patterns relevantly in areas behind buildings, especially for large noise levels when vehicles are close to the investigation points.

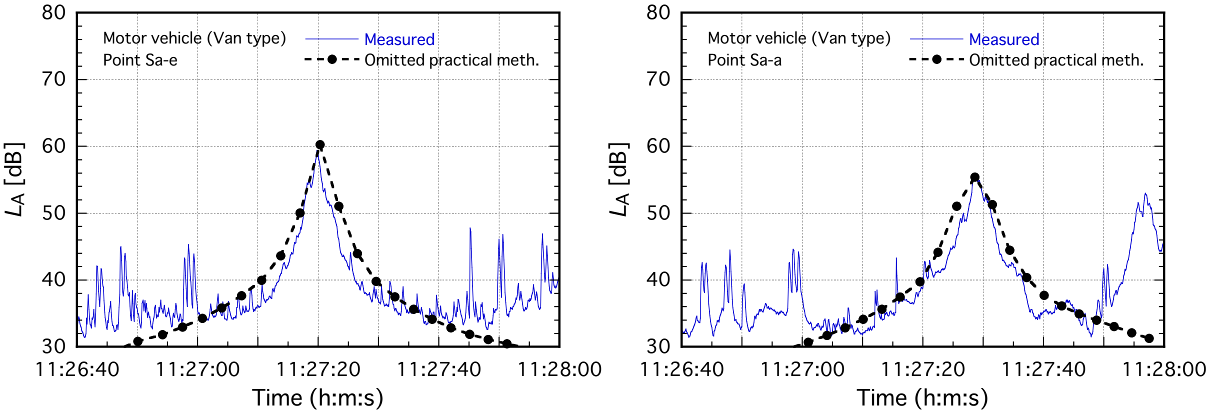

Figure 7 – Comparison of calculated unit patterns by the practical method and measured ones in district-Sa under conditions of the motor vehicle passing

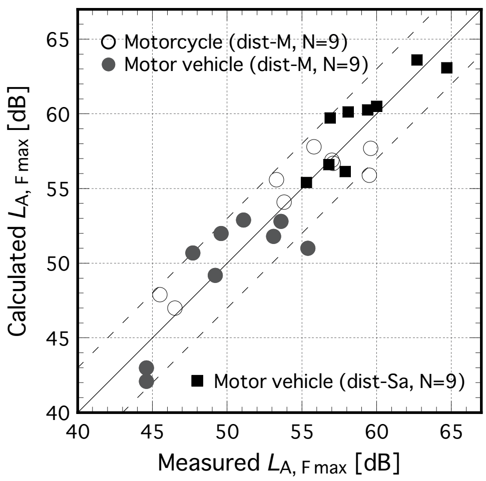

Figure 8 – Correspondence of maximum noise levels by the practical method with measured ones in areas behind buildings facing a plane road, called district-M and district-Sa

2.3 Unit Patterns from Cut-Earth Road in District-Sp

The road facing district-Sp is a two-way street with a gentle slope; therefore, part of the road is a cut-earth road, as illustrated in Fig. 9. Some investigation points would be influenced by the diffraction effects at the wedge of the cut-earth.

As examples of the investigation points that would be calculated by considering the diffraction effects (6), unit patterns at points Sp-h and Sp-i are drawn in Fig. 10. In this figure, the calculated values for the condition in which the road surface height is the same as that of the ground of the residences are shown by circle symbols. For the condition in which the diffraction by the wedge of the cut-earth is corrected, the calculated values are shown by bullet symbols in Fig. 10. Five noise levels out of the 45 predicted ones were corrected with the diffraction effects, as shown in the distribution chart in Fig. 11.

These results demonstrate that the omitted practical method can be applied to areas facing a cut-earth road by means of the correction of the diffraction effects on the wedge and the attenuation by buildings. The difference in levels between the calculated values and the measured ones decreased by within plus or minus 3.0 dB.

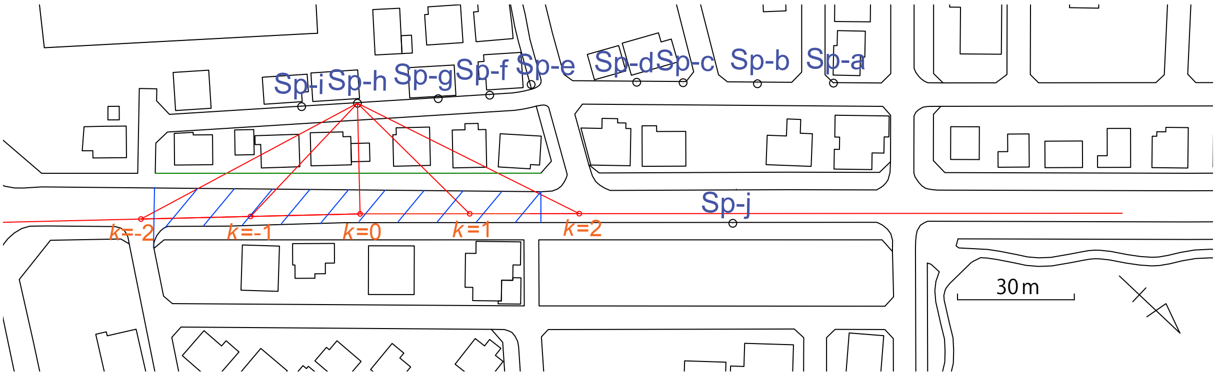

Figure 9 – Arrangement of residences and intended points in district-Sp facing a cut-earth road that is the shaded part on this figure

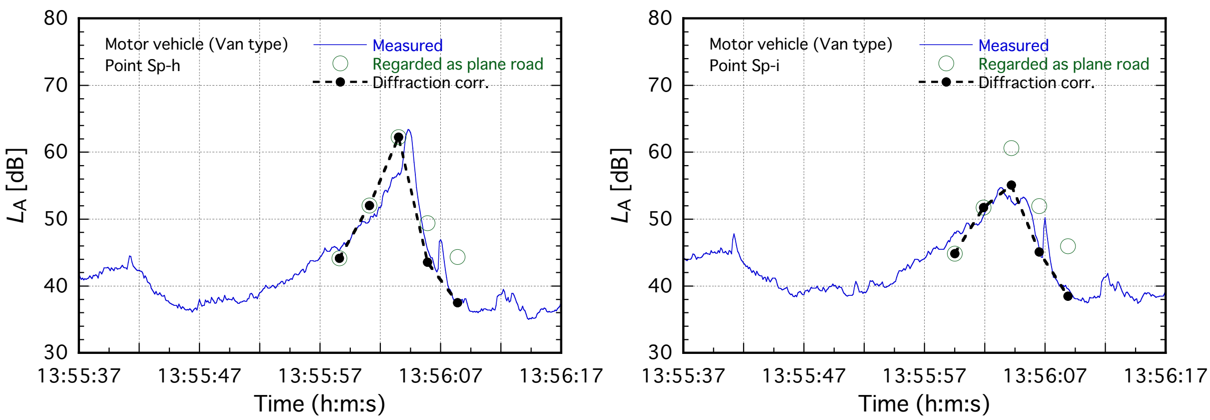

Figure 10 – Comparison of calculated unit patterns by the practical method and measured ones in district-Sp under conditions of the motor vehicle passing

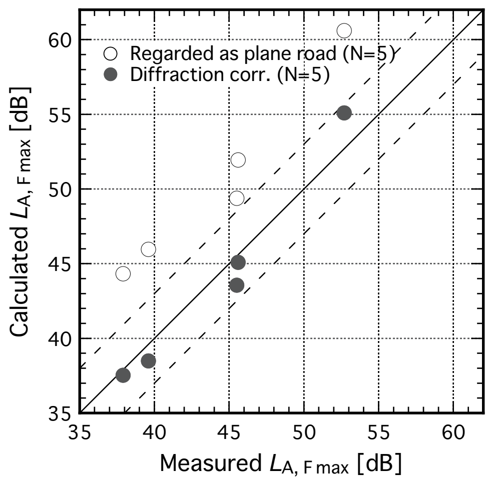

Figure 11 – Correspondence of maximum noise levels by the practical method and diffraction correction with the measured ones in areas behind buildings facing a cut-earth road, called district-Sp

3. VERIFICATION OF EQUIVALENT NOISE LEVELS FROM CENSUS DATA

The estimation of the exposed level of road traffic noise was conducted in Saitama City (7) by utilizing the practical method of RTN-Model 2018.

Equivalent noise levels are calculated in areas behind buildings facing plane roads, called A and B, for the purpose of making a comparative verification of the calculated values with the measured ones and then extending it to make a noise map. The arrangements of residences around roads A and B are shown in Fig. 12. In this calculation, road traffic census data are used for estimating the factors of the traffic conditions. As for the results of the estimations for road-A, the hourly traffic volumes are 3,370 small-size vehicles and 996 large-size vehicles, and the average passage speed is 36.7 km/h. The acoustic power levels of the vehicles are determined to be 92.7 dB for the small-size vehicles and 100.1 dB for the large-size vehicles on the assumption that the vehicles are running at a steady speed. As for the results of the estimations for road-B, the hourly traffic volumes are 768 small-size vehicles and 64 large-size vehicles, and the average passage speed is 19.9 km/h. The acoustic power levels are determined to be 95.3 dB for the small-size vehicles and 101.8 dB for the large-size vehicles on the assumption that the vehicles are not running at a steady speed due to the successive traffic signals along road-B.

Figure 13 shows that the differences in the calculated values and the measured ones on the intended road-A and road-B are around plus or minus 3 dB and 5 dB, respectively.

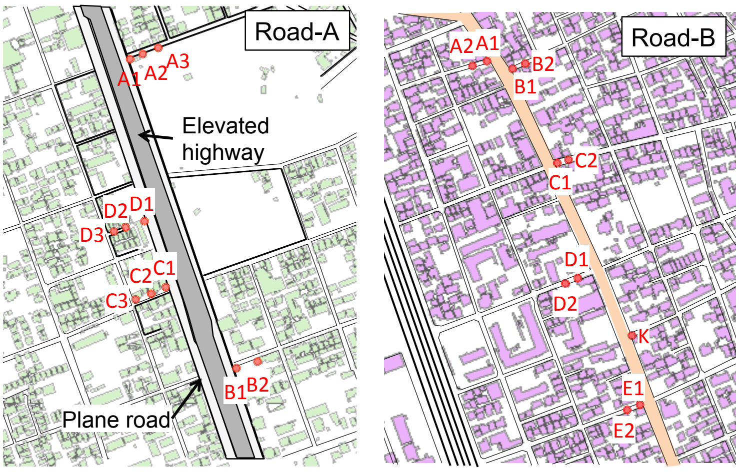

Figure 12 – Arrangement of residences and intended points for verification of equivalent noise levels calculated with census data

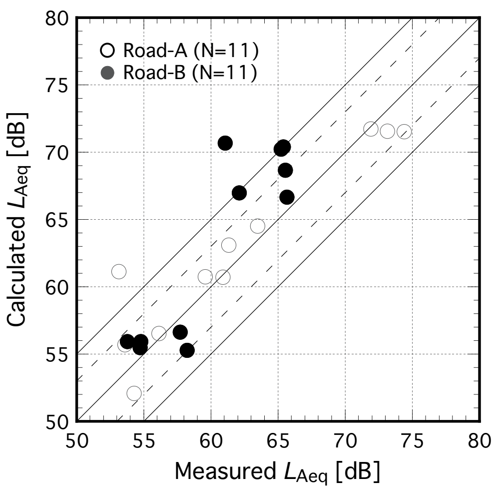

Figure 13 – Correspondence of equivalent noise levels by the practical method and census data with the measured ones in areas behind buildings facing a plane road

4. CONCLUSIONS

The practical method of RTN-Model 2018 for areas behind buildings was made to be more convenient than RTN-Model 2013 by reducing the parameters necessary for the calculation. Acceptable results for the verification were explained in this paper by examples in urban districts. The practical method had a certain degree of accuracy in areas behind buildings for every verification with the maximum noise level in unit patterns and the equivalent noise level based on the road traffic census data.

The practical method of RTN-Model 2018 is regarded as an accurate and convenient method for calculating equivalent noise levels in areas behind buildings.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Mr. Shunsuke Kouda of Kobayasi Institute of Physical Research, Mr. Ryosuke Kazama of RION Co. and many students belonging to Kyushu Institute of Technology or Fukuoka University in Japan for their support of the field surveys. The authors also acknowledge local governments, self-governing bodies and residents, who are owners or users of the investigated roads and districts.

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