1. INTRODUCTION

From the viewpoint of noise control, the countermeasure on the noise source is more effective than that on the propagation paths. Various reduction measures of vehicle noise has been developed by motor industries and several kinds of drainage asphalt pavement having running noise reduction effects have been developed and they are used on many roads in Japan. On the other hand, noise mitigation measures on the propagation path is also important against road traffic noise because generally it is unable to arbitrarily control the volume amount of vehicles running on the road. In Japan, to cope with environmental noise problem which results from rapid motorization during Japanese economic growth in late 1960s and 1970s, noise control technologies, typical one of which is the noise barrier, have highly developed. In this report, the typical measures used in Japan are firstly described and our research outcomes regarding noise mitigation technology and noise prediction are introduced.

2. NOISE BARRIER

Noise barrier is the most popular countermeasure against noise. The effectiveness becomes larger as the height of a barrier is high. However, high rise noise barriers involve deterioration of living environment such as shading and damaging of scenery, and more serious economic problem in which its construction needs high cost. Since Fujiwara and Ono published that the reduction of edge potential is much effective to reduce sound diffraction in 1976, various Edge-Modified noise barriers have been developed and they are efficiently used along roads. Figure 1 (a) to 1 (d) show typical Edge-Modified noise barrier seen along roads with heavy traffic volumes. Such barriers having additional devices on their top can have around 2-3 dB more noise reduction compared with simple straight barrier with same height.

3. ROAD STRUCTURE

In Japan, depressed or semi-underground roads as shown in Fig. 2 (a) and 2 (b) are coming into use in suburban area for the aim of noise mitigation. To raise the noise reduction effect, road surface or inner walls are generally finished as absorptive by porous asphalt pavement or sidewall sound absorber. Figure 3 shows effectiveness of sidewall absorption obtained by numerical analysis. We can see that sound wave scattering from the mouth part of the semi-underground road structure is weakened by the sidewall absorption.
Noise propagation inside depressed or semi-underground road is much complicated due to multiple reflection and diffraction and therefore prediction of noise at their roadside areas is generally difficult. The authors have been developing two types of noise prediction methods for the aim of environmental assessment. As an example of accuracy validation of the developed prediction method, comparison of vertical distribution of noise level for a real semi-underground road shown in Fig. 4 (a) between calculation and in-situ experiment is shown in Fig. 4 (b). As a reference, Fig. 4 (c) is
the comparison of the unit-pattern at M1. The difference of the noise level is within 2 dB and this prediction method has sufficient accuracy.

For road traffic noise mitigation on the semi-underground road structure, further countermeasures are sometimes taken. Figure 5 (a) and 5 (b) show such examples; drainage asphalt, which has considerably large effect of noise reduction, is paved in the example of Fig. 5 (a), and a special device of sound absorptive louvers are covered on the mouth part of the road structure in the example of Fig. 5 (b). The authors made field experiments on the noise reduction effects of the measures. According to the experimental results, the drainage asphalt pavement has 2 or more decibels effectiveness of noise reduction at higher receiving positions than 4 m. The drainage asphalt pavement generally has a sound power reduction effect of about 1-3 decibels, and therefore total effectiveness that the drainage asphalt pavement in the semi-underground road has can be about 5 or more decibels. On the other hand, the authors revealed that the sound absorptive louvers have much more effectiveness exceeding 10 decibels.

4. NOISE REDUCTION MEASURES TAKEN ON BUILDING FAÇADE

Sound insulation performance of a building is considered to be about 25 dB on average. Now, let us suppose lower sound pressure level than 35 or 40 dB should be maintained indoor. (Here, 35 or 40 dB sound pressure level correspond to a WHO recommendation for community noise.) If the building is cited at an area with heavy noise exceeding 70 dB, ordinary 25dB sound insulation performance is insufficient to keep good quality of life, and further countermeasure is necessary. As such countermeasures from building side, double pane windows or double skin structures have been developed. More convenient measures which are achieved by contrivance on balcony spaces have been investigated numerically or experimentally. The authors have also focused on the contrivance of building façade, and the noise reduction effects by eaves and louvers attached on the façade of middle or high-rise buildings were investigated. The eaves are useful device from the viewpoint of environmental engineering and efficiently utilized as the thermal proofing device and the light shelf. Also from the viewpoint of acoustics, the eaves and louvers can be used as sound proofing devices.

In our research on the noise mitigation effects of eaves/louvers, combinations of three kinds of horizontal eaves/louvers and vertical eaves shown in Fig. 6 were taken as the objects, and their noise reduction performance were studied by wave-based numerical analysis and physical experiment. As examples of the noise reduction effects of the eaves/louvers, Fig. 7 shows calculation results of the effects of horizontal eaves/louvers when the noise source is located at a frontal point of evaluated rooms. In the graphs, vertical axes indicate...
insertion loss in decibels, in which the positive value shows noise reduction effectiveness and the negative value shows noise increase by existence of eaves/louvers. From the results, we can see that the effects of the eaves/louvers differ by eaves/louvers type and the story of the room. For the flat type eave, effects in low frequencies are dominant. On the other hand, for inclined eave and louvers, the effects in high frequencies are dominant. From the difference of frequency characteristics of the effectiveness, when assessing by A-weighted sound pressure level, the inclined type eaves and louvers are more effective than the flat type eaves. Figure 7 shows the insertion loss of eaves/louvers.

5. DEVELOPMENT OF ROAD TRAFFIC NOISE PREDICTION MODEL

As is shown in previous sections, there can be various countermeasures against road traffic noise problem. In order to efficiently utilize these measures, adequate and accurate prediction method of road traffic noise is required. As such a prediction model, in Japan, ASJ RTN-Model, a road traffic noise prediction model proposed by the Acoustical Society of Japan, has been developed and is being revised based on the latest scientific knowledge. Eqs. (1) and (2) shows the basic equations. As correction terms, diffraction effect, ground effect, air absorption effect, and so on are taken into consideration.

\[
L_A = L_{WA} - 8 - 20 \log_{10} r + \Delta L_{cor}
\]  

(1)

\[
\Delta L_{cor} = \Delta L_{dif} + \Delta L_{grnd} + \Delta L_{air}
\]  

(2)

where, \(L_A\): A-weighted sound pressure level at a prediction point, \(L_{WA}\): A-weighted sound power level of a vehicle, \(r\): distance from a source to a receiver, \(\Delta L_{dif}\), \(\Delta L_{grnd}\), \(\Delta L_{air}\): correction values due to diffraction, ground effect, and air absorption, respectively.

In Japan, there exist many cases where noise propagation becomes very complicated, as is shown in Fig. 10. Therefore, calculation methods for “special road sections” are individually specified in details in ASJ RTN-Models. Furthermore, to cope with the cases where an engineering model based on geometrical acoustics cannot be adopted because of complicity of the noise propagation, adaptation of the wave-based
Fig. 9  Correction terms in road traffic noise prediction model

Tunnel mouth  Overhead section  Semi-underground section

Fig. 10  Special road sections

Fig. 11  Comparison between the wave-based numerical analysis and in-situ measurement
numerical analysis is also described. Figure 11 shows an example in which the wave-based numerical analysis was applied in order to calculate road traffic noise. On this site, main noise sources exist on a flat road, and noise propagation becomes very complicated due to large noise barriers and overhead roads.

6. AURALIZATION - EFFECT OF SOUND INSULATION

For the aim of more elaborate evaluation of noise environment, especially in residential area, auralization can become a powerful tool\(^7\). In living environment, road traffic noise transmitting though the façade into the room is one of the typical problems. In such a case, sound transmitting characteristics of the façade should be carefully treated because both of transient and spectral characteristics vary by difference of structure and components of outside walls and windows. The authors have developed a vibro-acoustical numerical analysis method which is applied to road traffic sound transmitting through several types of window. Figure 12 shows an example of calculation result of road traffic noise in a room. When auralizing demonstration, listeners can recognize the difference of timbers of transmitting noise due to variation of windows.

7. CONCLUSIONS

In this report, noise mitigation technologies developing in Japan was described and advanced researches on noise reduction and noise prediction against road traffic were introduced. Noise is one of serious impacts which are generated from road traffic, and the countermeasures and the assessment methods are still important subjects to keep high quality of life in crowded and busy cities.

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REFERENCES


Fig. 12 Example of auralization of transmitting road traffic noise through a window into a room