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ROAD TRAFFIC NOISE PREDICTION WITH THE CONSIDERATION OF THE RELATION BETWEEN TRAFFIC VOLUME AND VEHICLE SPEED

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ABSTRACT
In the prediction of road traffic noise, the traffic volume (Q) and vehicle speed (V) are essential parameters for the calculation. These two parameters are highly correlated and the relationship between them is often expressed by so-called Q/C-V/V_{D} curve in traffic engineering. Based on this relationship, noise levels in L_{Aeq} were calculated for typical types of roads according to the road traffic noise prediction model "ASJ Model 1998" proposed by the Acoustical Society of Japan in 1998. As a result, it has been found that L_{Aeq} does not increase lineally with the increase of traffic volume and it has upper limits. The maximum value of L_{Aeq} is about 63 (1.2 m high for the bank) − 80 (12 m high for the cut) dB for freeways with 6-lanes, about 78 dB (1.2 m high) for urban flat roads with 4-lanes, and about 54 (with noise barrier of 1.5 m high) − 67 (without noise barrier) dB for access roads with 1-lane.

1 - INTRODUCTION
The Q/C-V/V_{D} curve (it is called Q-V curve in this paper) was proposed by the Japan Road Association to express the relationship between the traffic volume (Q) and vehicle speed (V). This curve is being often used for the design of roads in Japan in order to estimate the service level of roads. In this paper, using this relationship, noise levels in L_{Aeq} of typical types of roads are calculated according to the road traffic noise prediction method "ASJ Model 1998" [1-4]. From the result, the maximum value of L_{Aeq} and the relationship between traffic volume and L_{Aeq} is considered.

2 - SETTING OF TRAFFIC CONDITIONS BASED ON Q-V CURVE

2.1 - Q-V curve
Figure 1 shows the Q-V curve, in which the horizontal axis indicates the ratio of the traffic capacity (C) and the traffic volume (Q), and the vertical axis indicates the ratio of the vehicle speed (V) and the design speed (V_{D}). In this figure, it can be seen that the vehicle speed decreases monotonously as the traffic volume approaches to the traffic capacity of the road and when the traffic volume approaches the limit of the capacity a traffic jam occurs and both of the traffic volume and vehicle speed suddenly decrease.

2.2 - Calculation of the traffic capacity
The traffic capacity (C) is possible and the largest traffic volume in a certain time interval for a road. C is calculated by the following equation.
Freeways with multi-lanes:

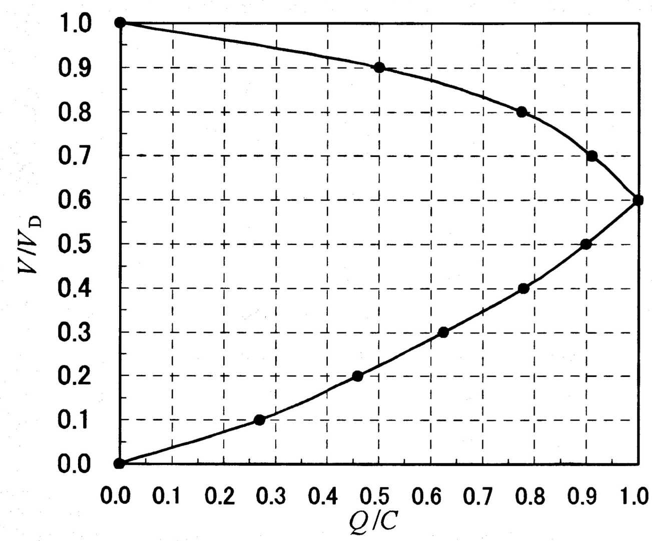

Figure 1: Q-V curve.

$$C = 2,200 \times \gamma_L \times \gamma_C \times \gamma_T \times N \tag{1}$$

Urban roads with multi-lanes without signalized intersection:

$$C = 2,200 \times \gamma_L \times \gamma_C \times \gamma_I \times \gamma_T \times N \tag{2}$$

Access roads with 1-lane.

$$C = \begin{cases} \dfrac{600}{(5.5-3.5)}(W{-}3.5)+50 & (3.5 < W < 5.5 \text{ m}) \\ 50 & (W > 3.5\text{m}) \end{cases} \tag{3}$$

where, γ_L, γ_C, γ_T and γ_I are the correction factors for the road width, lateral clearance, heavy vehicles ratio and roadside condition, respectively. N is the number of the lanes and W is the road width. Here, γ_T is calculated by the following equation.

$$\gamma_T = \frac{100}{(100-T)+E_T \cdot T} \tag{4}$$

where, E_T is the passenger car equivalent, and T is the heavy vehicles ratio.

2.3 - Setting of the design speed

The design speed (V_{D}) is decided according to the scale and structure of the road. Table 1 shows the examples of design speed generally used in Japan.

	Freeways	Urban roads
Inter-urban area	60 − 120 km/h	20 − 80 km/h
Urban area	60 − 80 km/h	20 − 60 km/h

Table 1: Examples of design speed used in Japan.

3 - THE CALCULATION CONDITIONS AND THE RESULTS

3.1 - Calculation conditions

In order to examine the relationship between L_{Aeq} and traffic volume, numerical study was performed using the Q-V relationship and the B-method specified in "ASJ Model 1998". In this study, the roads shown in Table 2 were chosen as the typical cases.

	Freeways with 6-lanes	Urban roads with 4-lanes	Access roads with 1-lane
Road structure	bank, cut, viaduct with noise barrier of 3 m high	flat road	flat road of 5 m wide
Design speed	V_D=120 km/h	V_D=80 km/h	-
Vehicle speed	$40 \leq V < 60$ km/h: unsteady running condition $60 \leq V < 120$ km/h: steady running condition	$10 \leq V < 60$ km/h: unsteady running condition $60 \leq V < 80$ km/h: steady running condition	V=30 km/h: unsteady running condition
Traffic capacity	$C = 13200 \times \lambda_T$	$C = 8800 \times \lambda_T$	C=500
Heavy vehicles ratio	0, 10, 20,40 %	0, 10, 20,40 %	0 %

Table 2: Characteristics of the roads chosen for the calculation.

3.2 - Calculation results

Fig. 2 to Fig. 6 show the calculation results for each type of road, respectively.

(1) Bank and cut freeways with 6-lanes

Figures 3 and 4 show the results for the bank and cut freeways, respectively. In these cases, it is seen that L_{Aeq} increases monotonously with the increase of traffic volume Q in the range where Q is smaller than the middle of the traffic capacity. When Q exceeds the range and approaches the capacity, L_{Aeq} slightly decreases, and finally when Q comes to the limit of the capacity, traffic jam occurs and L_{Aeq} suddenly decreases. In this process, L_{Aeq} becomes the maximum when Q is about 80 percent of the traffic capacity. The maximum value of L_{Aeq} at the receiving point of 12 m above the ground is about 74 dB for the bank and about 80 dB for the cut, and the value at the height of 1.2 m is about 63 dB for the bank and 69 dB for the cut. It is also seen that as the heavy vehicle ratio becomes twice, L_{Aeq} increases by about $1-2$ dB.

(2) Viaduct freeway with 6-lanes

In this case, the tendency of the change of L_{Aeq} is similar to the previous cases at the height of 12 m. At the height of 1.2 m, however, the curves are much different from those for the height of 12 m. This is because the noise generated by the vibration of the viaduct structure is included in the calculation of L_{Aeq} in the area lower than the slab of the viaduct. The maximum value of L_{Aeq} is about 69 dB at the height of 12 m and about 66 dB at the height of 1.2 m. As the heavy vehicle ratio becomes twice, L_{Aeq} increases by about $1-2$ dB at the height of 12 m and about $1-3$ dB at the height of 1.2 m. It much depends on the heavy vehicle ratio at the height of 1.2 m.

(3) Urban flat road with 4-lanes

In the calculation by the "ASJ Model 1998", two kinds of equations are used; for steady traffic flow ($V \geq 60$ km/h) and for unsteady flow ($V < 60$ km/h).

It is seen that L_{Aeq} becomes the maximum when Q is close to the traffic capacity and the running condition is unsteady. The maximum value of L_{Aeq} is about 78 dB at the height of 1.2 m. As the heavy vehicle ratio becomes twice, L_{Aeq} increases by about $1-2$ dB at the height of 12 m.

(4) Access roads with 1-lane

In the case of this type of road, the traffic capacity is decided by the road width. In the calculation result, it is seen that L_{Aeq} increases monotonously with the increase of traffic volume. The maximum value of L_{Aeq} is about 67 dB in the case of without noise barrier and about 54 dB in the case of with a barrier of 1.5 m high.

4 - CONCLUSIONS

Using the Q-V curve, noise levels in L_{Aeq} of typical types of roads were calculated according to the road traffic noise prediction method "ASJ Model 1998". As a result, it has been found that L_{Aeq} does not increase monotonously with the increase of traffic volume and it has upper limits. The maximum value of L_{Aeq} is about 63 (1.2 m high for the bank) $-$ 80 (12 m high for the cut) dB for freeways with 6-lanes, about 78 (1.2 m high) dB for urban flat roads with 4-lanes, and about 54 (with noise barrier of 1.5m high) $-$ 67 (without noise barrier) dB for access roads with 1-lane. It is also seen that as the heavy vehicle ratio becomes twice, L_{Aeq} increases by about $1-3$ dB.

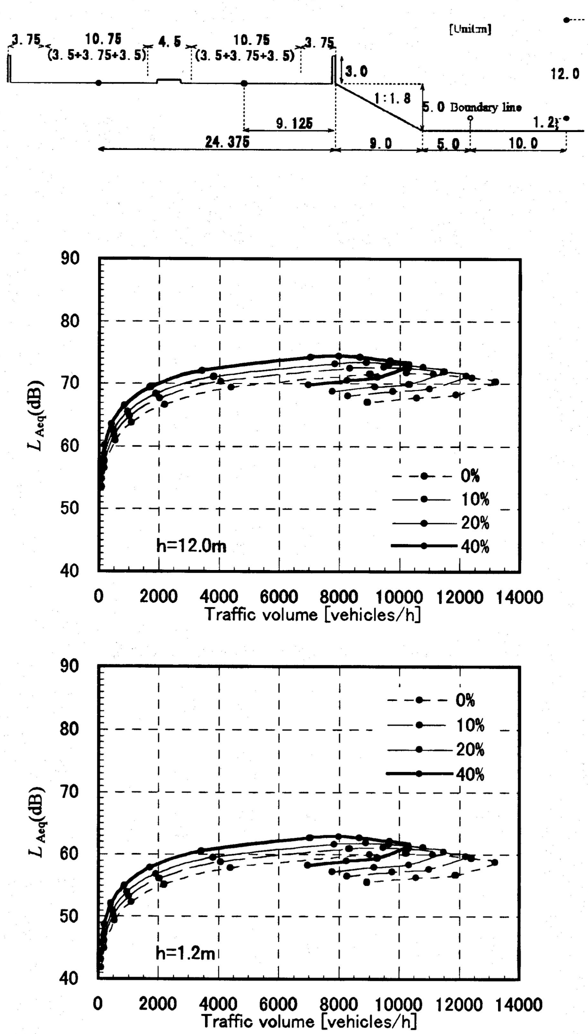

Figure 2: Traffic volume – L_{Aeq} (bank freeway with 6-lanes).

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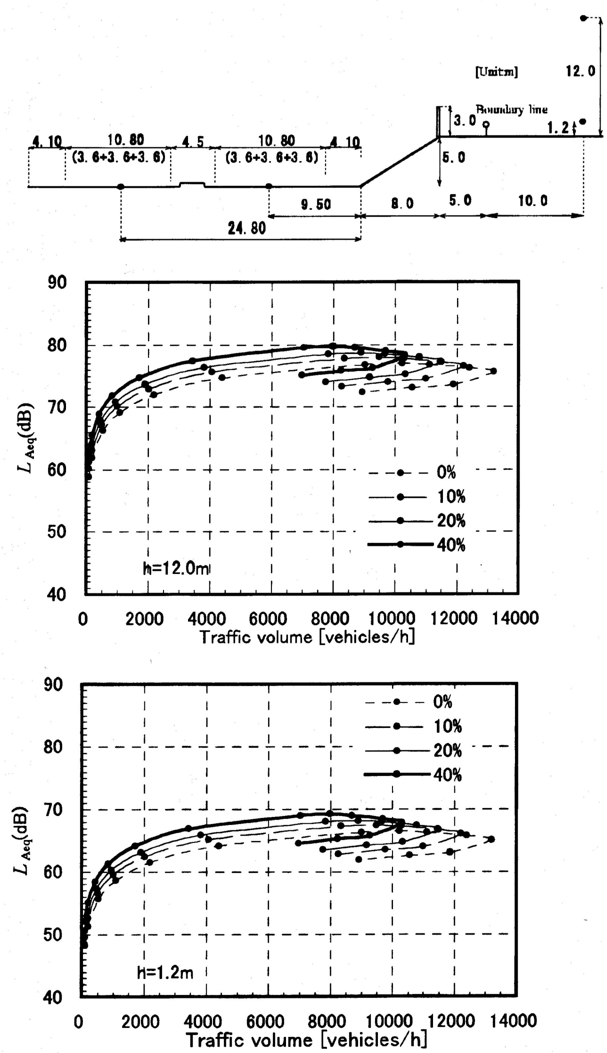

Figure 3: Traffic volume $-$ L_{Aeq} (cut freeway with 6-lanes).

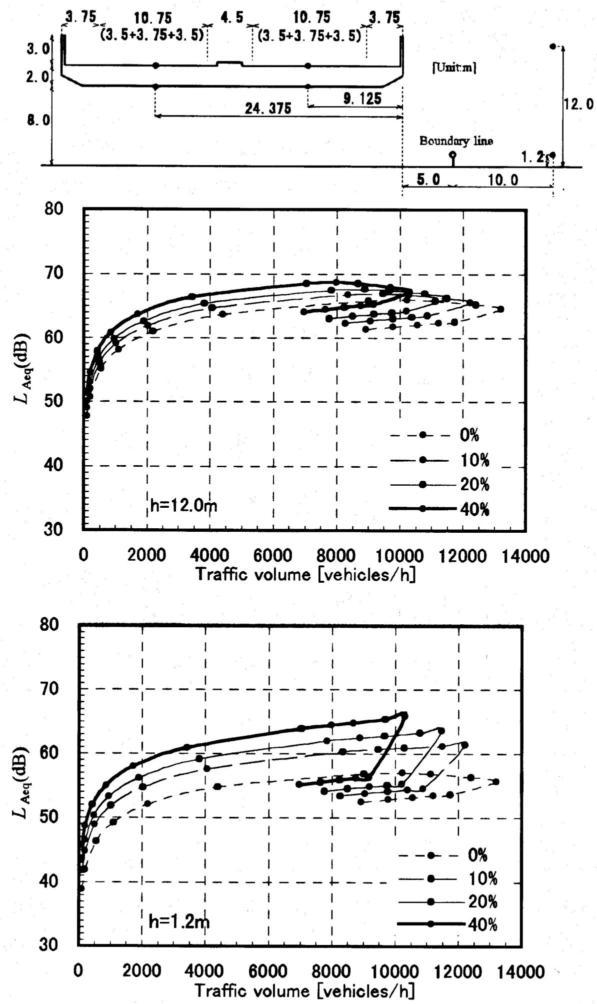

Figure 4: Traffic volume – L_{Aeq} (viaduct freeway with 6-lanes).

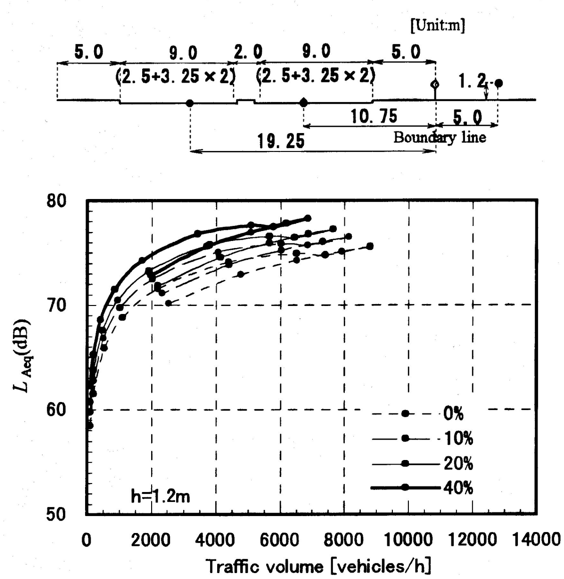

Figure 5: Traffic volume – L_{Aeq} (urban flat road with 4-lanes).

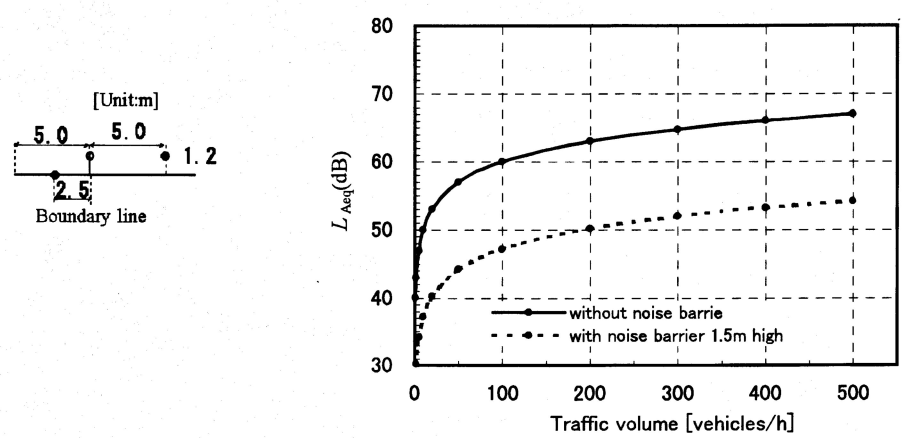

Figure 6: Traffic volume – L_{Aeq} (access roads with 1-lane).