研究報告

The Noise of Highway and Counterplan for Reduction of it

고속도로 소음과 그 저감대책

정일룩, 강대준, 이우석, 석광설, 김양균
(Ilrock Chung, Daejoon Kang, Woosuck Lee, Kwangsul Seok, Yangkun Kim)
(국립환경연구원)

ABSTRACT

We investigate the equivalent noise level at 30 sites where the noise barrier has been built in highways, and develop the new prediction model of it in order to provide the reasonable guideline of construction of the noise barrier. We find the several interesting facts of many sided measurement and analysis.

요 약

합리적인 방음벽 설치지침을 제공하기 위하여 고속도로변에 방음벽이 설치되어 있는 30개 소를 대상으로 소음도를 조사하고, 그것을 사전에 예측할 수 있는 모델을 개발하였다. 방음벽의 소음도를 다각적으로 측정·분석한 결과로부터 여러가지 흥미있는 사실들을 발견하였다.

Ⅰ. INTRODUCTION

This study is for the reduction of the traffic noise among all noise pollution which is serious in damage.

We measure and analyze the amount of sound reduced by character of the traffic noise of the highway and the noise barrier for the 30 noise barriers in all highways over the country in order to provide the guideline of construction of the noise barrier especially. We compare the noise level from the prediction model with that from the measurement. We make the prediction diagrams of the diffraction attenuation by the height of the barrier and the field insertion loss by the ratio of the angle subtended by lines of sight from the observer to the ends of the roadway to that subtented by lines of sight from the observer to the ends of the barrier. We provide the materials for use when the noise barrier is designed.

Ⅱ. MEASUREMENT OF THE EFFECT OF NOISE BARRIER AND VERIFICATION OF IT

2.1 The Method and Contents of Measurement

A. The Method of Measurement

(1) Measurement Position

The measuement position is shown in Fig. 1. The microphone #1 shown in Fig. 1 is installed in the study site location (with the noise barrier) and the microphone #2 in the reference location (without the noise barrier). The method of measurement is as follows.

(a) The microphone-to-roadway distance for each location must be identical.

(b) The topography at each site should be similar.

(c) The measurements are made at both locations simultaneously.

(d) The reference measurement location should have as great an angle of view of the highway as possible. An angle of at least 160 degrees is recommended.

(2) The Period and Number of Times of Measurement

The measurement period is 128 seconds and the number of times of the measurement is 2.

B. The Contents of Measurement

(1) Speed and Flow of Vehicle

In order to grasp the variation of the noise level for the vehicle speed, traffic flow and percentage of heavy vehicles we measure the noise level, the vehicle speed and the traffic flow.

(2) Roadway Structure and Kind of Road Surface

In order to know the variation of the noise level by the roadway structure, the kind of road surface and the driving pattern we survey the number of lanes, geometry of the roadway, the roadway grade (G, %), and the sort of road surface. We measure the angle subtended by lines of sight from the observer to the ends of the roadway (θ), the angle subtended by lines of sight from the observer to the ends of the barrier (θ_B) and the angles exposed at the study site location(φ_1, φ_2) to get the correction of the view angle.

(3) Noise Barrier

For calculating the field insertion loss (IL) of the noise barrier we survey the length and height of the noise barrier and the topography at the measurement loaction in order to verify the following equation of prediction.

2.2 The Prediction Technique of the Effects of the Noise Barrier

A. Prediction of the Traffic Niose Level of Hihgway [1,2]

The equivalent noise level, Leq is

$$Leq = L + \triangle T + \triangle W + \triangle R + \triangle \theta - \triangle D, \ dB(A) \quad (1)$$

where L is the base noise level.

$$L = -7 + 10 \log \theta + 22 \log V, \quad (2)$$

$\triangle T$ is the noise increment of the heavy vehicle,

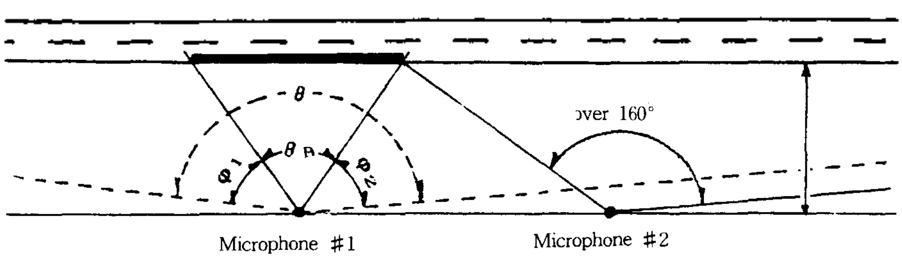


Fig. 1. The measurement position of the study site and the reference location.

$\triangle W$ is the road width correction,

$\triangle R$ is the distance adjustment,

$\triangle\theta$ is the correction to the view angle,

$\triangle D$ is the diffraction attenuation, and

V is the vehicle speed.

According to the grade of roadway, G the grade factor, F is

$$F=1 \text{ if } G \leqq 2\%,$$
$$F=1.4 \text{ if } 2<G \leqq 6\%, \qquad (3)$$
$$F=2 \text{ if } G>6\%.$$

$\triangle T$ as a function of the vehicle speed, V is

$$\triangle T=10\log\{1-(F\cdot t)+9.82\times(F\cdot t)(V/105)^{-3.2}\} \text{ for } V \leqq 56\text{km/hr},$$
$$\triangle T=10\log\{1-(F\cdot t)+33.7\times(F\cdot t)(V/105)^{-4.2}\} \text{ for } V>56\text{km/hr}, \qquad (4)$$

where t is the percentage of the heavy vehicles.

$\triangle W$ is

$$\triangle W=[1.31-8\{1+\log(O/R)\}]/3.54 \text{ for } O/R \leqq 0.6,$$
$$\triangle W=(0.51\times O/R-0.11)(I/O)^2-\{5.17(O/R)-1.37\}^{0.5} \text{ for } O/R>0.6. \qquad (5)$$

where I denotes the distance between centerlines of inner lanes, O denotes the distance between centerlines of outer lanes, and R denotes the distance between the measurement point and the centerline of the near traffic lane.

Suppose the elevation of noise source is 0.5m, H is the elevation of the reception point, and θ is the angle between the road surface and the top of the elevation of measurement at the center of the noise source, $\triangle R$ is

$$\triangle R=-13.3\log(R/15)-(R-15)/150 \text{ for } \theta<10°,$$
$$\triangle R=-10\log(R/15)-(R-15)/150 \text{ for } \theta \geqq 10°. \qquad (6)$$

The correction to the view angle, $\triangle\theta$ is

$$\triangle\theta=10\log(\theta/180) \qquad (7)$$

The diffraction attenuation which depends on the path length difference, δ is

$$\triangle D=-\log(-\delta) \text{ for } -0.2 \leqq \delta < 0,$$
$$\triangle D=3 \text{ for } \delta=0,$$
$$\triangle D=15.5+10\log\{\sqrt{1.2\delta}/2\cdot\tanh(10\sqrt{\delta})\} \text{ for } 0<\delta \leqq 0.2,$$
$$\triangle D=12+20\log\{\sqrt{2\pi\delta}/2\cdot\tanh\sqrt{1.2\pi\delta}\} \text{ for } 0.2<\delta \leqq 2,$$
$$\triangle D=14+12\log\{\sqrt{0.5\pi\delta}/\tanh\sqrt{1.2\pi\delta}\} \text{ for } 2<\delta \leqq 14,$$
$$\triangle D=22\ (\text{dB(A)}) \text{ for } \delta>14. \qquad (8)$$

B. The Prediction of the Field Insertion Loss(IL) of the Noise Barrier [3]

Suppose Leq is the noise level for the constructed noise barrier, the effect of the noise barrier, IL is expressed by Leq−Leq.

(1) The Noise Level at the Location with the Noise Barrier (Shielded Location, Study Site Location), Leq_I

Leq_I is determined by the way similar to the eqn(1) as follows

Substitute θ_B into eqn(7) instead of θ and $\triangle\theta$ becomes $\triangle\theta'$, Substitute δ which depends on the height of the barrier into eqn(8) instead of δ which depends on the shoulder of the roadway and $\triangle D$ becomes $\triangle D'$.

$$\triangle D_t=-10\log(10^{-\triangle D'/10}+10^{-TL/10} \qquad (9)$$

Therefore,

$$Leq_I=L+\triangle T+\triangle W+\triangle R-\triangle\theta'-\triangle D_t. \qquad (10)$$

(2) The Noise Level at the Location without

the Noise Barrier (Unshielded Location, Reference Location), Leq_2

Substitute $\varphi_1+\varphi_2$ into eqn(7) instead of θ and $\triangle\theta$ become $\triangle\theta''$.

$$Leq_2=L+\triangle T+\triangle W+\triangle R+\triangle\theta''-\triangle D. \quad (11)$$

Hence, the equivalent noise level after construction of the noise barrier, $L\acute{e}q$ is

$$L\acute{e}q=10\ \log(10^{Leq_1/10}+10^{Leq_2/10}). \quad (12)$$

(3) The Field Insertion Loss of the Noise Barrier

The effect of the noise barrier, IL is

$$IL=Leq-Leq.' \quad (13)$$

2.3 The Verification of the Effects of the Noise Barrier[2]

The prediction technique of the effects of the noise barrier which uses the calculation techuique of the field insertion loss recommended by Federal-Aid Highway Act(FHWA) is described briefly.

(1) First compute the calculated noise level from the predication model at the reference location and at the study site location.

(2) Compare the calculated noise level at the reference location, Leq_A^{R-C} with the measured noise level, Leq_A^R. If the two values agree within ±1 dB(A).

$$i.\ e.,\ |Leq_A^{R-C}-Leq_A^R|\leq 1dB(A) \quad (14)$$

it can be assumed that the emission data in FHWA prediction model correctly represents the traffic for this site and that the site around the reference location has been correctly modeled.

(3) Compare the calculated noise level at the study site location, Leq_A^{S-C} with the measured noise level, Leq_A^S.

If the two values agree within ±2.5dB(A),

$$i.\ e.,\ |Leq_A^{S-C}-Leq_A^S|\leq 2.5dB(A) \quad (15)$$

it can be assumed that the site has been correctly modeled.

(4) Calculate the noise level at the study site location, Leq_B^{S-C} as if the barrier has not been built.

(5) Compute the IL.

$$IL=Leq_B^{S-C}-Leq_A^S. \quad (16)$$

(6) If the measured and calculated values do not meet the tolerance requirements in eqns (14) and (15) locate the source of the discrepancies .

If the error still persists compute the IL as follows.

$$IL=Leq_B^{S-C}-(Leq_A^{R-C}-Leq_A^R)-Leq_A^S \quad (17)$$

Ⅲ. RESULTS and DISCUSSION

3.1 The Noise Status

A. The Reference Location

The equivalent noise level which depends on the road structure and the traffic data, Leq is shown in Table 1.

Table 1. The equivalent noise level at the reference location.

Distance (m)	Leq (5 min), dB(A)
1	79.0~84.8
20	57.8~83.4
40	53.7~69.7

This results are different according to the road structure, the traffic data, the height of the reception point and the view angle, so that the equal comparison is not easy. The results which analyze the noise variation for each condition are as follows.

(1) Traffic Data and Noise Level

If the vehicle flow is over 120 vehicles / 5 min and the percentage of heavy vehicle is over 15%, the equivalent noise level, Leq exceeds 80 dB(A) at the shoulder and shows the distance attenuation of the line sound source.

(2) Road Structure and Noise Level

The noise level of the concrete road is higher by 1 dB(A) than that of the asphalt road. The more the gradient of road increases, the more distinct is the noise level at the band above 1 kHz. This is that the engine noise due to acceleration affects the noise level significantly.

When the elevated and the depressed road are compared with the level road, the closer the elevated road is to the shoulder and the farther the depressed road is from it, the more significant is the distance attenuation. It is resonable that this is that the diffration attenuation due to the shoulder edge of the depressed road is added.

B. The Study Site Location

The equivalent noise level as a function of distance behind the center of the noise barrier is shown in Table 2. It is recognized that this is due to the environmental condition behind the noise barrier and the view angles. The field transmission loss using the traffic noise ranges from 18.2 to [illegible] dB(A).

Table 2. The equivalent noise level at the study site location as a function of distance

Distance (m)	Leq (dB(A))
1	55.4~66.2
10	55.5~64.2
20	52.0~62.9
40	52.0~61.9

3.2 Relation between the Measured and Calculated Noise Level

A. The Reference Location

(1) Correlationship

The correlation between the measured and the calculated noise level at the distance of 10 to 90 m from the highway edge and at the reception height of 7 to 12 m is 0.972, which is called the correlation coefficient R. Therefore it shows a good correlation. The two values also agree within ±2 dB(A).

(2) Distance Attenuation for the Reception Height

Fig. 2 shows the predicted distance attenation for the reception height and the horizontal distance from the shoulder based on the sound height(road surface height + 0.5m). The results are based on the following conditions of the straight road:

Road gradient=0%
Total traffic flow=200 vehicles / 5 min
Heavy vehicle flow =30 vehicles / 5 min
Mean speed of traffic =100 km / hr.
Number of road lane=4.

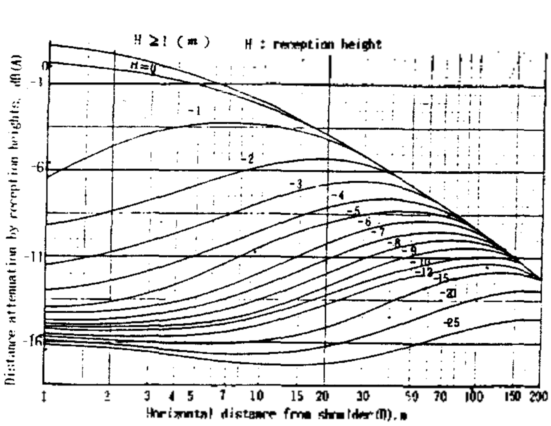


Fig. 2. Distance attenuation for the horizontal distance and reception height.

When the reception height H is 0_m which means that the height of reception is equal to that of sound and the road is level in Fig.2, the lower is the reception height(i. e., the higher is the elevated road) and the closer the reception point is to the shoulder, the more significant is the distance attenuation. For example the distance attenuation of the horizontal distance from the shoulder, D=20 m and the reception height, H=−10m is lower by about 9 dB(A) than that of H=0 m and D=20 m, and it is lower by about 5 dB(A) than that of H=0 m and D=50 m. This is that the diffraction attenuation by the shoulder of the elevated road is added. When the noise barrier is built over the shoulder, the IL of it is the value subtracting the IL by the shoulder from the total IL. This feature is similar to that of the depressed road. Therefore it is necessary to extend the length rather than the height of the noise barrier to reduce the noise level for the elevated and the depressed road.

B. The Study Site Location

Fig. 3 shows the correlationship between the calculated and the measured noise level at the hori-zontal distance farther than 10 m from the noise barrier. The coefficient of correlation, R is 0.942, which shows a good correlation. The two values agree within 2%. Therefore, it can be assumed that the prediction model is reasonable and the site has been correctly modeled.

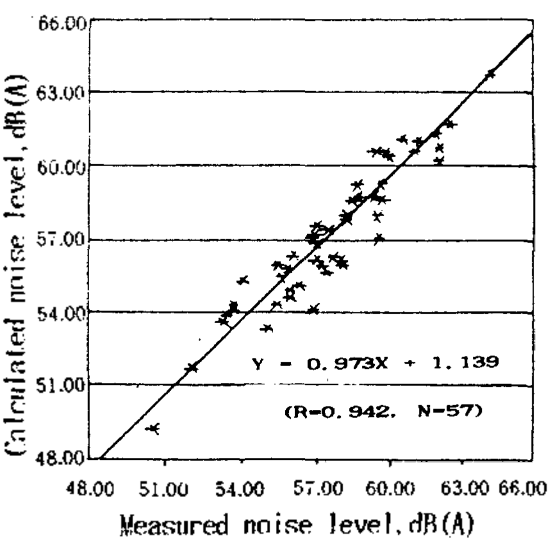


Fig. 3. Correlationship between the calculated and the measured noise level.

3.3 The Effects of the IL by Other Factors [4]

A. The Variation of the IL for the Structure of Road

Fig. 4 shows the variation of the IL for the

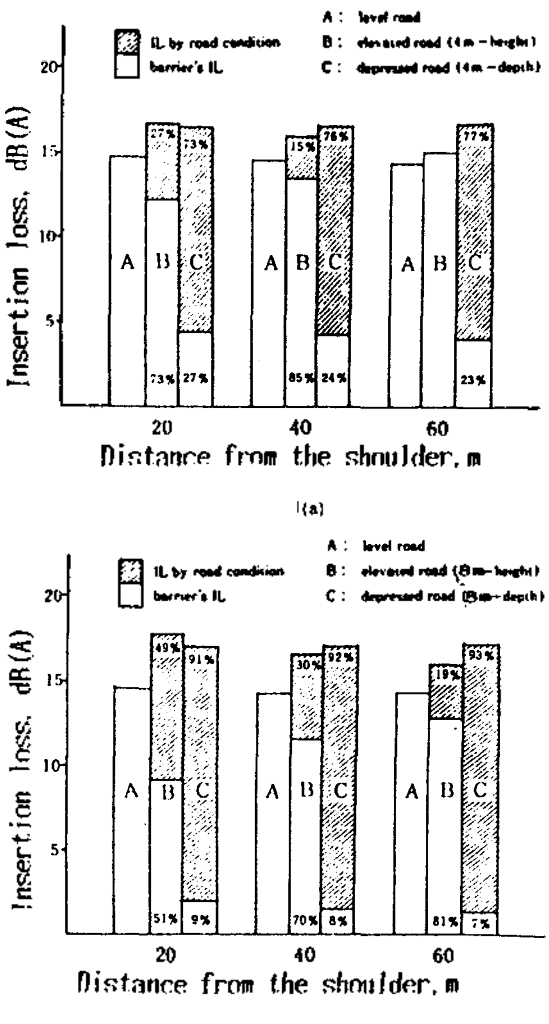


Fig. 4. Variation of IL for the height of the barrier=4.5 m.

structure of road and the distance from the sho ulder when the elevation of the noise barrier is [illegible]

Fig. 4-a shows the IL for the horizontal distance and the natural loss of noise by the shoulder, where A denotes the level road, B denotes the elevated road with the height of 4 m and C denotes the depressed road with the depth of 4 m. It is assumed that the transmission loss is 35 dB(A). While the IL of the only barrier for the level road is about 15 dB(A) irrespective of the distance, the closer the elevated road is to the barrier and the farther the depressed road is from it, the more the IL decreases. Especially the IL of the only barrier for the depressed road is within 25%, so that the effec ts of the construction of the noise barrier is not significant.

Fig. 4-b also shows the variation of the IL for the same condition as Fig. 4-a except for the height and the depth of 8 m respectivlely instead of those of 4 m. The feature mentioned in Fig. 4-a is more distinct in Fig. 4-b. The higher is the elevated road and the deeper is the depressed road, the more the value of the IL decrseases.Because the shoulder of the elevated road and the top edge of the depressed road take a part of the noise barrier. Even though the IL of the only noise barrier decreases, the natural loss by the road structure is added, so that the total IL increases compared with that in Fig. 4-a. Therefore it is necessary that the height of the noise barrier not be extended but its length be extended in order to improve its effects for the elevated and the depressed road. This feature is distinct compared with Fig. 5.

Fig. 5 has the same condition as Fig. 4 except that the elevation of the barrier is 2.25 m. The IL for the level road decreases significantly and that for the elevated and the depressed road does not change too much compared with that of Fig. 4.

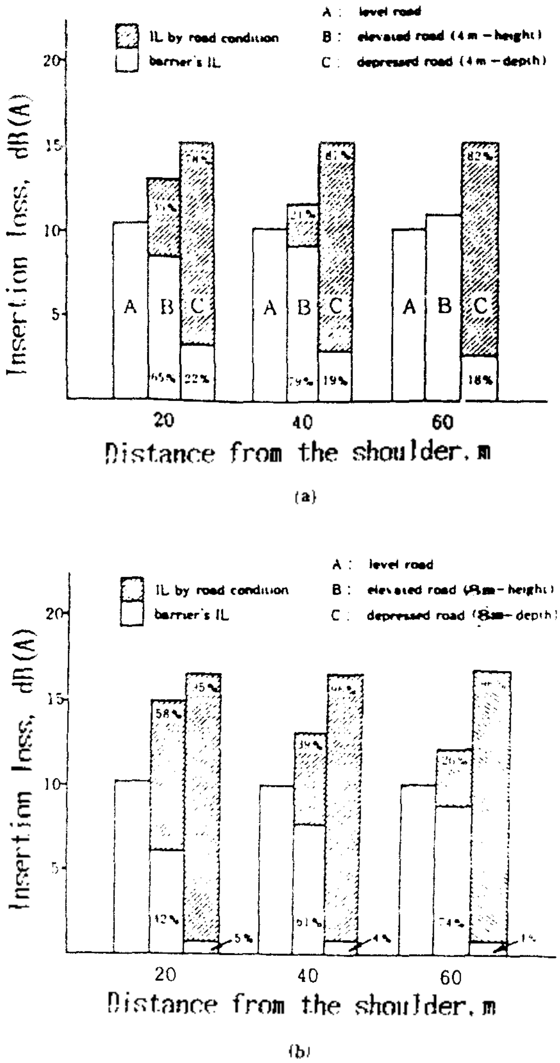


Fig. 5. Variation of IL for the height of the barier=2.25 m.

B. The Variation of the IL for the Size of the Noise Barrier

Fig. 6 shows the variation of the IL for the diffraction attenuation, $\triangle D$ and the ratio of Q_B to θ. It is assumed that the trasmission loss of the barrier is 30 dB(A). The more the ratio of θ_B to θ increases, *i. e.*, the longer is the barrier, the more the IL increases. For instance, δ should be over 0.022 and the value of θ_B / θ should be over 0.7

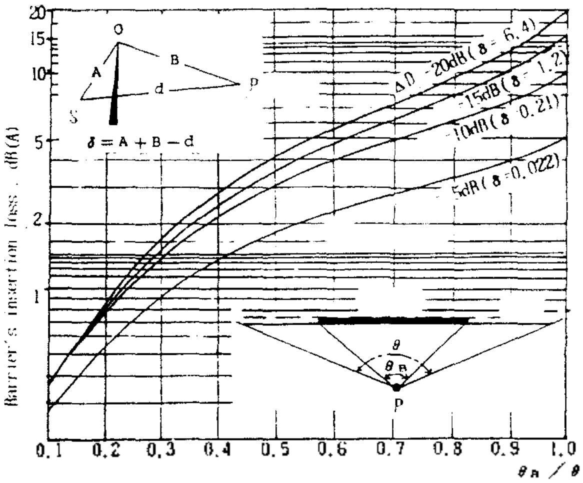


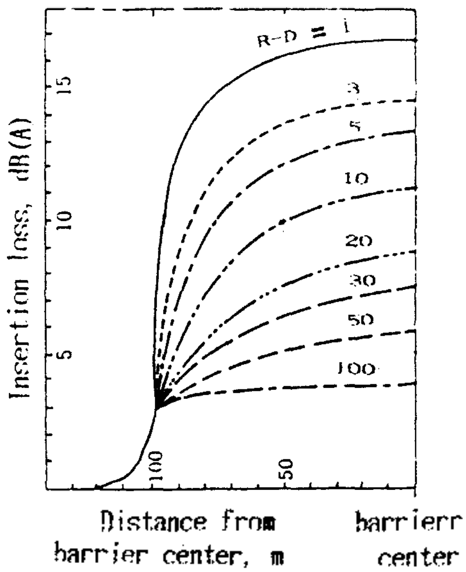
Fig. 6. Variation of IL for θ_B / θ and $\triangle$D.

to get the value of the IL=5 dB. That the value of θ_B / θ is 1 means that the length of the barrier is infinite. This is not realistic. Therfore reduce the value of θ_B / θ, choose somewhat large value of $\triangle$D and plot the variation of the IL. It is necessary to choose the economical size of the barrier in consideration of the area of the barrier corresponding to those values θ_B / θ, δ and IL, and the cost of the foundation work.

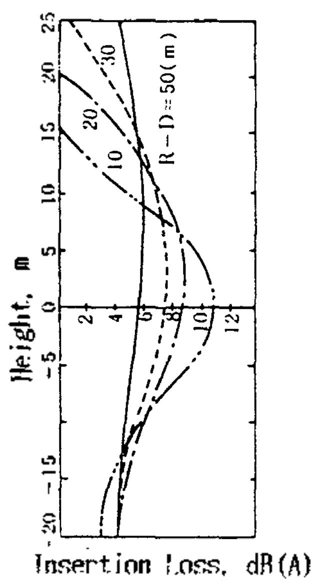
C. The Distribution of the Noise at the Study Site Location

Fig. 7 shows the distribution of the IL for the horizontal distance and the vertical height when the road is infinitely straight, the length of the barrier is 200 m and its height is 4.5 m. R-D in Fig. 7 denotes the norizontal distance from the noise barrier.

Fig. 7-a shows the distribution of IL for the horizontal distance from the barrier and the distance from the center of the barrier along it. The closer the location is to the center of the barrier and to the barrier for the horizontal distance, the larger is the IL. The farther the location is from the center of the barrier along it and from the barrier for the horizontal distance, the smaller is the IL. For instance, the IL at the point of 50 m along it and of 10 m from the barrier for the horizontal distance is 10 dB(A).



(a)



(b)

Fig. 7. Distribution of IL.

Fig. 7-b shows the distribution of the IL for the vertical elevation from the surface of road. We can see the maximum at the height of 0 m

that the height of the reception point agrees with the road surface. If the height of the reception point is higher or lower than the road surface the IL decreases. The farther the horizontal distance is from the barrier, the more the IL also decreases. This is that if the reception height is below zero the diffraction attenuation by the shoulder is produced. The pure IL for this case is the value subtracting the diffraction attenuation from the IL of the barrier of the level road where the reception height is zero. If the reception height is over zero the path length differennce, δ decreases. Hence the diffraction attenuation by the noise barrier decreases and the IL decreases in the end. It is necessary that the heigth and the length of the noise barrier be decided in consideration of the road structure (for example the level, the depressed and the elevated road) of the site having the facilities to be shielded. When the noise barrier is proposed to be built it is necessary to investigate the character of the road and traffic, and the factor of design of the barrier by the predicted IL and consider a counterplan for it.

Ⅳ. CONCLUSION

We investigate the equivalent noise level at 30 sites where the noise barrier has been built, develop the new predition model of it and find the following facts.

When the traffic flow is over 120 vehicles/5 min and the percentage of heavy vehicles is over 15% the noise level shows the distance attenuation of a line source of sound. It shows that of a simple source of sound for elsewhere.

The field transmission loss of the noise barrier ranges from 18.2 to 24.2 dB(A) and the IL of it ranges from 0.2 to 16.2 dB(A).

The coefficient of correlationship between the calculated and measured value for the field insertion loss is 0.912.

The level road has the best effects of the noise barrier among the 3 kinds of roads and the next is the elevated road.

The effects of the barrier for the depressed road is below 20%. Hence, it is necessary to extend the length rather than the height of the noise barrier when it is designed for the depressed and the elevated road.

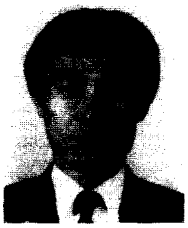
The horizontal distribution of the IL at the site behind the noise barrier has the feature of a sine function. The higher is the reception height or the lower is it, the more the vertical distribution of it decreases.

The effects of the noise barrier ranges from 5 to 10 dB(A) and the diagram of the IL is plotted as a function of the path length difference, δ by the height of the barrier and the ratio of the view angle, θ_B/θ by the length of it.

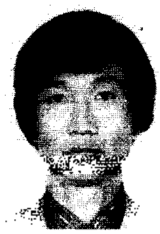
REFERENCES

1. EPA (USA), A Manual for the Review of Highway Noise Impact, Wyle Labs/Wyle Research, $A_1 \sim D_3$, 1977.
2. Department of Transport Welsh Office, Calculation of Road Traffic Noise, Her Majesty's Stationary Office, pp.1-87, 1988.
3. Louis F. Cohn, Highway Noise Barriers, TRB/NCHRP SYN 87, $A_3 \sim A_6$, 1981.
4. I.R. Chung *et al.* A Study on the Comprehensive Counterplan for the Reduction of Traffic Noise(Ⅲ), National Institue of Environmental Research, 1989.
5. D.N. May, "The Optimum Weight of Highway Noise Barriers", J. Sound and Vib., 68, pp.2 13, 1980.

▲Ilrock Chung M.S., Environmental Engineering Hanyang University Graduation : February 1984, B.S., Electrical Engineering Dongkuk University Graduation : February 1979, Senior Research Scientist and Chief Division of Noise and Vibration national Institute of Environmental Research 1 / 79-Present



▲Woosuck Lee B.S., Environmental Engineering Donga University Graduation : February 1978, Junior Research Scientist Division of Noise and Vibration National Institute of Environmental Research 12 / 80 Present



▲Yangkyun Kim B.S. Pharmacy Seoul National University Graduation : February 1955, Auditor and Inspector Korea Resources Recovery & Reutilization Co. 10 / 90 Present . Director Department of Air Quality National Institute of Environmental Research 4 / 82~10 / 90, Head Division of Special Environmental Pollution Environmental Agency 6 / 81~3 / 82, Head Institute of Kyungnam Health & Environment Research 1 / 69~5 / 81.

▲Daejoon Kang Ph.D., Mechanical Engineering Clarkson University, Potsdam, NY Graduation : August 1988 M.S., Mechanical Engineering Wayne State University, Detroit, MI Graduation : December 1983, Senior Research Scientist Division of Noise and Vibration National Institute of Environmental Research 5 / 90-Present, Postdoctoral Research Associate Institute for Nonlinear Studies Clarson University, Potsdam, NY 9 / 88-5 / 89, Mechanical Engineer Hyundai Moter Co. 1 / 82-7 / 82

▲Kwangsul Seok B.S., Environmental Engineering Kunkuk University Graduation : February 1987, Junior Research Scientist Division of Noise and Vibration National Institute of Environmental Research 10 / 88-Present