Expressway Traffic Noise for High Rise Building

Im, Moon Hyuk · Kim, Young Eun*
Dept. of Mechanical Engineering
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〈**Abstract**〉

The sound pressure levels (Leq) of the high rise buildings sited near Kyungbu expressway were in the range of 63–76 dBA and had a tendency to increase with height. The sound pressure level of the equivalent 9th floor is about 7.6 dBA higher than that of the equivalent ground floor. These measured values were over the limit of the domestic regulation. It was found that the apartments were sited too close to the road to reduce noise level, though several methods to reduce noise level were tried. Estimated minimum distances from the road were suggested by calculation.

고속도로에 인접한 건물의 차량소음

임 문 혁 · 김 영 은*
(기계공학과)
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〈요 약〉

경부 고속도로변의 고층 아파트에서 차량소음을 1층에서 옥상까지를 측정해 보았더니 Leq, TNI, L_{NP}가 각각 63—76 dBA, 54—65, 70—82의 값을 나타냈으며 층이 높아갈수록 증가하는 경향을 보였다. 9층 높이의 소음은 지상의 값에 비해 약 7.6 dBA 높게 나타났다. 또 각층에서 측정된 값들은 환경보존법상의 허용치를 상회하였다. 이러한 소음을 줄이기 위한 몇가지 방법은 시도해 보았으나 도로변에 너무 근접되어 있어서 별 효과가 없었다. 허용치를 만족하기 위한 최소거리를 구해 보았다.

I. Introduction

Nowadays noise pollution has rapidly grown due mainly to a progressive increase in traffic density. Most of residential areas in the large cities located close to expressway have serious problems in high noise level.

Noise, an unwanted sound, affects man physiologically and psychologically such as hearing loss, masking of wanted sound and bothersomeness.[1]

Noise has been studied very widely in foreign countries,[2][3] but there are a few studies in Korea. Thus the evaluation of our noise condition is important to give a basic information for making quiet surroundings, though it has no priority in Korea.

Recently large number of apartments and buildings have been constructed near Kyungbu expressway due to expansion of the city areas. High rise residents often complain that noise

*단국대학교 공과대학 기계공학과

is too loud to live and to spend leisure time such as watching TV or sleeping.

The main purpose of this work is to measure the sound pressure levels on residential areas close to expressway, to compare them with the sound levels at ground level and to suggest noise reduction methods.

II. Theoretical Background

1. Sound Evaluation

There are numerous different ratings and procedures intended for the evaluation of noise according to the predicted the subjective response to noise. The rating scales are A-weighted sound pressure (dBA), Loudness Level (LL), Perceived Noise Level (PNL), Speech Interference Level (SIL), Preferred Speech Interference Level (PSIL), Noise Criterion (NC), Traffic Noise Index (TNI), Noise Pollution Level(L_{NP}) and etc.

LL and PNL are based on loudness and noiseness respectively and their calculation procedures are somewhat complicated. NC and PNC provide to quantify sound levels in interior such as an office or a hospital. SIL and PSIL are based on speech interference and are frequently used to data what degree communication will be affected by noise.

The A-weighted sound level (dBA) correlates quite well with human response to noise, and is widely used for the assessment of community noise. The overall charateristics of this A-weighting curves are approximately equal to the Fletcher-Munson type equal-loudness contour for a loudness level of 40 phons. All the sound level meters have a function to measure noise in dBA. This rating is thus a simple method to evaluate noise.

The basic measure for the traffic noise is the A-weighted sound level sampled at numerous intervals. From the stastics of these sampled levels, several sound levels denoted L_{10}, L_{50} and L_{90}, are to be determined. The L_{10}, L_{50} and L_{90} are exceeded 10, 50, and 90 percent of the time respectively. In general the L_{10} level is an indication of the peak levels of the intruding noise, whereas the L_{90} level is an indicator of the ambient level into which L_{10} levels intrude.

The traffic noise index,[4] a weighted combination of L_{10} and L_{90}, is defined as

$$\mathrm{TNI}=4(L_{10}-L_{90})+L_{90}-30 \qquad (1)$$

The first term expresses the range of the "noise climate" and describes the variability of the noise and the second represents the background noise level; the third term is introduced to yield more convinient numbers.

The noise pollution level (L_{NP})[5] is based on two terms, one representing the equivalent continuous noise level and the other representing the annoyance due to the fluctuations of the noise level. It is determined from the expression

$$L_{NP}=L_{eq}+k\sigma \qquad (2)$$

where

$$L_{eq}=10\log_{10}[\Sigma P_j\times 10^{(L_j/10)}] \qquad (3)$$

$$\sigma=[\Sigma P_jL_j^2-\{\Sigma P_jL_j\}^2]^{1/2} \qquad (4)$$

L_j; A-weighted level of center of interval

P_j: fraction time spent in L_j class interval

The L_{eq} is the "energy mean" of the A-weighted noise level over a specified period. σ is the standard deviation of instaneous level, and k is a constant tentatively set equal 2.56 since this value leads to the best fit with currently available studies of subjective response to noise. The first term is determined largely by the intensity of the intruding noises (because of logarthmic averaging), unless these occur so seldom that the background noise comprise most of the total noise exposure. The second term is determined by the time dependence (specially the variability in level) of the sequence of intruding noise events, rather than on the mean energy content, and is thus greatly influenced by the prevailing background noise;

the lower the background noise, the greater the variability for a given sequence of intrusive events.

2. Community Noise Assessment

In the estimation of community response to noise, there are two recognized ratings used widely. One method utilizes the octave band sound pressure level noise rating curves,[6] and the other uses the A-weighted sound pressure level.[7]

The allowable limit in the domestic regulation,[8] which is modified by using two rating systems described above, is calculated as follows

$$L_r = L_{eq} + C$$

The correction factors, C, can be determined by using table I. The L_{eq} is defined in equation (3). According to the regulation, the corrected noise value (L_r) should be lower than 50.

III. Measurement and Results

The measurement quoted in this paper were taken with GR 1933-precision sound level meter fitted GR 1961—1″ eletret condenser type and wind screen.

The data were sampled manually for about

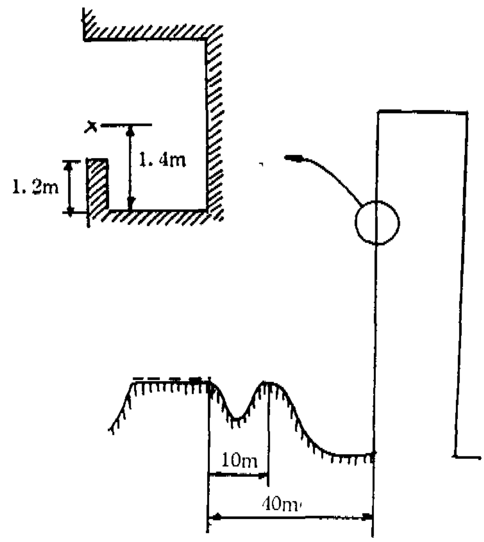

Fig. I. Measurement Location

Table I. Correction Factors for Community Noise

Influencing Factor	Possible Condition	Correction
Repetitiveness	Continuous to one/min.	0
	10—60 times/hr.	−5
	1—10 times/hr.	−10
	4—20 times/hr.	−15
	1—4 times/day	−20
	1 time/day	−25
Impulsiveness	Impulsive	+5
	Non-impulsive	0
Season	Winter only	−5
	Winter and summer	0
Time of Day	Daytime(06 : 00—18 : 00)	0
	Evening (18 : 00—24 : 00)	+5
	Night time(24 : 00—06 : 00)	+10
Type of Area	Rural Residential Area	+5
	Zones of Hospitals, 50m away from School Boundary	0
	Urban Residential Area	−5
	Area of Business, Trade	−10
	Area of Industry	−15

Table Ⅱ. Measured Statistical Sound Pressure Level on 12-Floor High Rise Building Near Kyungbu expressway*

	L_{90}	L_{50}	L_{10}	L_{eq}	L_{NP}	TNI
Roof	70.2	73.2	75.9	73.7	79.4	63.0
12	72.8	75.6	78.4	76.1	81.7	65.2
11	72.0	75.1	77.6	75.6	81.2	64.4
10	71.3	74.6	77.0	75.1	80.8	64.1
9	70.6	74.1	76.3	74.6	80.3	63.4
8	70.6	73.6	75.8	74.1	79.3	61.4
7	69.2	72.3	75.2	72.9	78.9	63.2
6	68.6	71.6	74.8	72.2	78.4	63.4
5	67.3	70.3	73.8	71.0	77.5	63.3
4	65.3	69.2	71.8	69.9	76.4	61.3
3**	64.3	67.9	70.5	68.0	74.7	59.1
2	60.2	64.1	68.0	65.1	72.9	61.4
1	59.4	62.8	65.5	63.4	69.5	53.8

*; 40m distance from the edge of the expressway
**; same height as the road surface

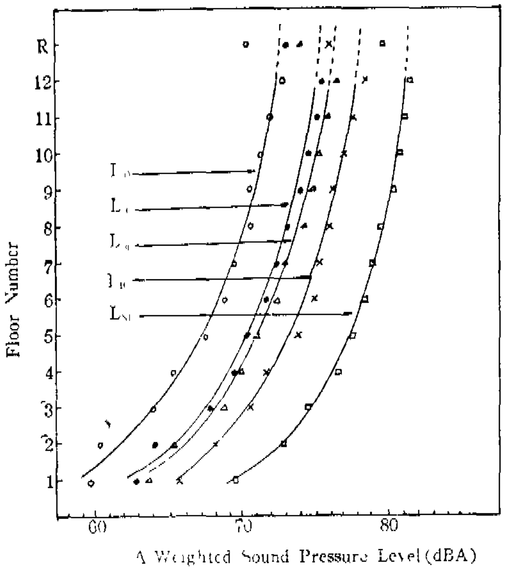

Fig. Ⅱ. Sound Pressure Level Variation with Height on a 12-Floor High Rise Building.

20 minutes and the sampling interval was about 5 seconds. All sound levels were measured in the A-weighted level with slow mode.(9)(10)

The measurement locations were on every railing of a 12-floor-apartment at the height 1.4m above the floor. (See Fig. Ⅰ)

The results are shown in Table Ⅱ and its graphical representation are shown in Fig. Ⅱ. The equivalent sound levels L_{eq} are in the range of 63—76 dBA, TNI in the range of 54—65 and L_{NP} in the range of 70—82 approximately. All of them have a tendency to increase with height, The L_{eq} on 12th floor is 7.6 dBA higher than that on 3rd floor which is the same height as the expressway road surface. This result is mainly caused by the line sound source effect because the higher floor has larger reception angle than the lower floor from noise sources and this effect was greater than the geometrical effect of the sound spreading to decrease the sound level. But the sound pressure level on the roof was lower than on the 12th floor. This was due to the difference the reverberant field and the free field. All measuring points except on the roof were in the reverberant sound field due to reflection of sound from the wall.

Most of all L_{eq}'s differences among on the floors were approximately 1.5 dBA except from on the first floor to on third floor. These were originated from the barrier effect, and were lower than the reduction level suggested by W.E. Schols.[11] It can be explained as follows (a) the earth berm act as the noise shield barrier and was not infinitely long (b) this was affected from the reverberant sound field.

D.E. May[12] has a similar results as shown in Fig II, although her measuring points were far from the building facade.

Ⅳ. Discussions

On the basis of the Environmental Protection Law, the L_{eq} of the residential areas near the expressway shown in TableII, is over the legal requirement. Judging from ISO/R1996—1971, "threat of community reaction" will be expected. Then how can one reduce the noise level level under the legal limit? What is the possible way to reduce the traffic noise? Assume the heighest noise level occured on the 12th floor be considered. There are three possible ways such as (a) Construction of a barrier: The barrier height will be expected 30m or higher and the maximum noise reduction level will be at most when the infinite length barrieris constructed. This is impossible in economics (b) Increase of transmission loss; The sound level will be decreased by 10—20 dBA if a openable window is installed. This largely depends on the precision of its quality. But this case will have serious problems in summer. (c) Lining of absorptive materials on the wall and the floor: Noise transmitted into indoors may be reflected sound rays. The estimated reduction level[13] will be about 5 dBA if the coefficient of sound absorptive material is 0.6.

Considering three methods prescribed above to reduce noise level within allowable limit, it can be known that using only one method is ineffective. Therefore combination of them is the most possible way—lining an absorptive materials and installation of an openable window. Total reduction will be expected in the range of 15—25 dBA in winter. Consquently the apartment, espically on the top floor, is located too close to reduce noise level satisfied the legal requirement.

Now one can have a question; how far this apartment should be located from the expressway? In the United Kingdom the Noise Advisory Council has recommended that L_{10} (18 hour) at the exposed of houses adjacent to new traffic routes should not, act as a conscious act of public policy, be allowed to exceed 70 dBA and a similar limit has been proposed for used in the United States. But with a noise level as high as 70 dBA it would prove difficult to engage in normal conversation and in any case there are other adverse factors to be considered such as visual intrusion, vibration, fumes and dust. Certainly in many cases a much higher standard for environmental noise will be demanded and maximum L_{10} levels lower than 60 dBA have been proposed as an acceptable criterion.[14]

According to the study,[15] L_{10} attenuates −4.5 dBA per double distance over open grass land, 3.1 dBA over concrete. Considering the worst places, in this case top floor equivalent to 9th floor of other buildings, the apartment surveyed here should have been located 700m away from the expressway, if the ground is covered by grass land. The estimated minimum distances for a single storey house and 5 storey building are 200m and 470m respectively if the measured data are used for calculation under open grass land condition. In fact noise propagation depends on meteorological such as wind direction, temperature gradient and weather. These factors will be fully be considered to yield more accurate results.

Ⅴ. Conclusion

Even though the data obtained in this paper are limited and some degree of error, nevertheless it clearly indicates that the apartment constructed near expressway is so close that the residents are exposed to high noise level which is over the legal allowble limit and affect their health.

The L_{eq} of the apartment about 40m from the edge-of-pavement of expressway is in the range of 63—76 dBA, TNI in the range of 54—65 and L_{NP} in the range of 70—82 approximately. All of them have a tendency to increase with height. The height of building should be considered when a distance, from a house to roads, to maintain quiet surroundings is required.

The present data are insufficient and extensive systematic measurement are needed to expect traffic noises and to formulate guidelines of compatible land-use planning.

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