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An Experimental Investigation of Environmental Noise for High-rise Apartment in Urban Areas

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Abstract

As a part of acoustical design, it is often necessary to quantify the aspects of an existing environment noise in order to predict an appropriate acoustical treatment. Previous studies showed that the most common sources of exterior noise, also known as environmental noise (or community noise), were traffic noise, aircraft noise, industrial noise, etc. Transportation (air, road, and rail) noise was the dominant and most common source of noise exposed in residential neighborhoods. These days the road traffic noise becomes more aggravated due to the rapid increase of vehicles, and has great effects on the dwelling environment. Therefore this study investigated the characteristics and sources of the road traffic noise at each given time depending on the amount of the road traffic transportation. Noise levels of urban areas in Seoul were measured at first, fifth, tenth, and nineteenth floors for two days of weekday and two days of weekend. The results showed that the noise levels in the daytime were 10dB higher than those in the nighttime during the weekday. However, those differences of the noise levels between the daytime and the nighttime were decreased to 7dB during the weekend. Also, the highest noise levels were at the 5th floor and decreased as the measured places went up to top of the building.

Keywords: high-rise apartment; exterior noise; urban area; noise measurement

1. Introduction

The number of domestically registered vehicle was about one million in 1985, ten million in 1997, and fifteen million in 2003. Due to the rapid increase of the traffic vehicles, traffic noise is getting more serious than before. Besides, since the size of the urban area is strictly restricted to preserve green zones to construct favorable environment, the high-rise building's environmental annoyance related to the traffic noise is increasingly being perceived as the residential building is vertically expanded. Especially, the capital city, Seoul, which has the largest population among the domestic cities, is dangerously exposed to the road traffic noise than any other cities. The road traffic noise is mainly caused by automobiles and extended over a wide territory.

Due to the being extending traffic road system and increasing registered vehicles, the road traffic noise is the primary factor for urban environmental noise. The number of the registered vehicles in Seoul exceeded 2,700,000 in April 2004. Since the factors affecting the traffic noise depend on the vehicle itself, the amount of traffic, and the condition of the road, the characteristics of the traffic noise should be carefully identified. In order to systematically investigate the characteristics of the noise, the resource and transmission of the noise should be experimentally measured and accurately analyzed.

In this study, the environmental exterior noise of the high-rise residential building was experimentally measured since the residential building is vertically expanded. Then, the accurately measured results were carefully analyzed to provide additional important data for the researches related to the sound isolation of the high-rise residential building.

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2. Preliminary Study for Urban Noise

According to the 'Residential Building Construction Regulations' in the domestic construction law, the noise level of the newly constructed residential area should be lower than the level notified by Ministries of Construction and Transportation and Environment. Thus, this study tried to find out the actual condition of the taffic noise for urban main roads rather than Olympic Express Road, Riverside Road, and City Circulating Express Road. The preliminary results for

road noise levels for urban main roads are as follows.

2.1 The Present Condition of Traffic Noise for Seoul

Minister of Environment operates measurement network of environment noise to accurately maintain the status of the local enviromental noise levels. The measurement locations were selected 1m apart from the roads of resident buildings, schools, and hospitals. Times of the Measurements were 9, 12, 16, and 20 o'clock for daytimes and 23 o'clock for nighttime. The sampling period was within 5 seconds and the measurement duration was more than 5 minutes. The dates of the measurements were at the last month of the quater year. Table 1 shows the measured results [1].

Table 1. Traffic Noise Levels in Seoul [Leq dB(A)]

Year	1985	1986	1987	1988	1989	1990	1991	1992	Avg	Max	Min
Day	73	73	74	76	76	76	75	73			
Night	67	67	67	68	69	68	68	66	73	76	70
Year	1993	1994	1995	1996	1997	1998	1999				
Day	73	75	71	70	72	70	71		67	69	65
Night	67	67	65	66	67	65	65				

Housing & Urban Research Institute (HURI) of Korea National Housing Corporation intoduced the traffic noise levels for the vicinities of the city main roads in Oct. 1995 as shown in Table 2 [2].

Table 3 shows the noise levels measured at the apartments with the height of 1.2 [m] apart from the vicinities of near the city main roads. Measuring devices were NL-14 (RION, Japan), NL-05 (RION, Japan) (B&K 2231, Denmark) for sound level meters and SA-27 (RION, Japan) for a frequency analyzer. During one hour period equivalent sound level (Leq) and maximum sound level were measured to identify the traffic noise characteristics of the city main roads. Measured locations were 5, 10, 20, and 30 [m] apart from the roads. As can be seen from Table 3, the overall noise level for near city main roads was lower than that for city main roads. The maximum and minimum noise at the distance of 5 [m] were 78.2 and 74.4 [dB(A)] respectively [1].

Table 4 shows the traffic noise levels measured 1 [m] apart from normal roads and Table 5 shows the traffic noise levels measured inside of a residential building in Seoul. The measured locations were first and third floors of the residential building. Those measurements were done in two times in daytime and one time in nighttime with the duration of 5 minutes [3].

Leq is widely used in U.S.A., England, Denmark, etc. to standardize the environment noise, since it can easily represent the noise variations according to time. However, if there is a small noise variation according

Table 2. Traffic Noise Levels for Vicinities of City Main Roads (Measured before 1995)

Vicinities	Lanes	Noise levels depending on the distance from the road [dB(A)]				
		1 [m]	10 [m]	30 [m]	50 [m]	80 [m]
Umyeon-dong	8	82.9	67.2	67	65.8	62.8
Pyeongchon-dong	10	78.5	73.9	63.6	64.9	61.9
Gaepo-1dong	8	80.9	76.1	59.4	54.9	-
Gaepo-2dong	8	79.4	75.4	58.5	54.8	-
Sanggye-dong	6	75.7	70.2	63.3	59.7	60.7
Bundang-gu	6	73.8	68.6	50.0	56.0	60.9

Table 3. Traffic Noise Levels for Vicinities of Near City Main Roads (Measured in 1999)

Vicinities	Noise Levels depending on the distance from the road [Leq dB(A)]			
	5 [m]	10 [m]	20 [m]	30 [m]
Janghang-dong Goyang-si	78.2	72.8	68.7	65.0
Songpo-dong Goyang-si	74.4	72.2	67.0	63.8
Daeja-dong Goyang-si	74.6	70.7	66.0	62.9
Gaun-dong Namyangju-si	75.0	71.6	66.6	64.1
Geumgok-dong Namyangju-si	77.5	74.5	70.0	67.7
Bundang-gu Seongnam-si	75.4	73.7	70.7	68.3

Table 4. Traffic Noise Levels of normal Roads in Seoul with 10 min. Duration (Day/Night) [dB(A)]

No.	Location	Leq	L_{10}	L_{50}	L_{90}	Lmax	Lmin
1	Younghwa APT	76/75	79/77	74/73	69/69	88/89	65/62
2	Korea Univ. Guro Hospital	70/72	73/74	68/67	62/60	83/88	58/53
3	Guryong Middle School	71	75	67	59	91	54
4	Jungdong High School	68	72	66	60	83	85
5	Hyundai APT	73/71	74/74	71/69	68/59	86/84	55/54
6	Dongsung APT	73/72	76/75	69/67	61/57	91/93	56/53
7	Ewha Girls' High School	79	82	77	74	89	71
8	Ewha Womans Univ. Hospital	74/76	77/77	71/71	65/63	94/96	59/57
9	Daerim APT	74/72	77/76	72/70	69/68	87/87	68/66
10	Saehan Hospital	77/77	80/79	73/74	68/70	96/98	65/66
11	Whansung APT	74/74	78/78	68/68	61/61	90/90	54/55

Table 5. Traffic Noise Levels of Residential Buildings near the Normal Roads in Seoul with 5 min. Duration (Day/Night) [dB(A)]

No.	Leq	L_{10}	L_{50}	L_{90}	Lmax	Lmin
1	67/67	69/70	66/65	63/59	79/85	61/57
2	62/59	66/62	60/58	45/55	82/75	61/57
3	59	62	57	54	77	51
4	66	70	65	52	87	60
5	66/65	68/68	64/64	59/58	78/79	56/53
6	66/63	69/66	64/61	60/57	86/80	59/52
7	67	71	67	64	95	67
8	64/62	66/64	62/62	60/60	79/71	59/58
9	69/67	70/69	68/67	67/65	81/74	66/64
10	72/74	74/77	71/73	67/70	86/83	67/68
11	69/67	73/71	66/64	60/56	84/78	58/54

to time, Leq is modified to reflect the reaction of the human body. For instance, L_{10} is used in U.S.A. to evaluate the traffic noise level. They suggest allowable a maximum noise level in L_{10}. L_{50} is used in Japan to statistically represent the environmental noise level for the region located side of the traffic roads.

2.2 Trend of the Traffic Noise in Seoul

According to the reports published by Seoul in the first quarter of 2002, the highest noisy region among the normal residence regions was Hwagok-dong Gangseo-gu (60 dB). Because of the rapid commercialization resulted form the opening of Hwagok Station, the increase of pedestrians and vehicle traffic yielded the highest environmental noise level. Meanwhile, the lowest noisy region was Seongbuk-dong consisting of common residential buildings, embassies of several countries, and green forest zones. Since there is no population variation and smooth vehicle traffic, those noisy levels were almost same for past several years.

According to the reports in the first quarter of 2003, the overall noise level was increased by 1 dB than those for the same quarter of 2002. However, the regions satisfying the environmental regulations were increased than before. The lowest noisy region for both the normal residence area and the region near the traffic roads was Mok-dong and the highest region was Sillim-dong. The main reason for the highest noise was the increased traffic amounts due to the expansion of the road lanes.

Table 6 through Table 9 shows the day and night noise levels of Seoul for both the normal residence area and the region near the traffic roads in the third quarter of 2003. As can be seen from those tables, the levels of noise are almost same for the latest three years. However, during the nighttime, the noise levels in some of the regions exceeded the suggested environmental regulations. As we can see from Tables 8 and 9, it can be found that the amount of traffic and the speed of vehicles are quite related with the nighttime noise level.

Table 6. Noise levels of Normal Residence Area in Seoul (Daytime) [dB]

Year (quarter)	2001	2002 (1/4)	2002 (2/4)	2002 (3/4)	2002 (4/4)	2003 (1/4)	2003 (2/4)	2003 (3/4)
1st Measure	54.0	55.0	—	54.0	54.0	55.0	55.0	54.0
2nd Measure	54.0	55.0	52.0	54.0	55.0	53.0	55.0	54.0
3rd Measure	55.0	53.0	51.0	54.0	54.0	54.0	54.0	54.0
Average	54.3	54.3	51.5	54.0	54.3	54.0	54.7	54.0

Table 7. Noise levels of Area Near the Traffic Roads in Seoul (Daytime) [dB]

Year (quarter)	2001	2002 (1/4)	2002 (3/4)	2002 (4/4)	2003 (1/4)	2003 (2/4)	2003 (3/4)
1st Measure	71.0	71.0	71.0	71.0	71.0	70.0	70.0
2nd Measure	71.0	71.0	71.0	71.0	70.0	70.0	70.0
3rd Measure	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Average	70.7	70.7	70.7	70.7	70.3	70.0	70.0

Table 8. Noise levels of Normal Residence Area in Seoul (Nighttime) [dB]

Year (quarter)	2001	2002 (1/4)	2002 (3/4)	2002 (4/4)
1st Measure	44.0	44.0	65.0	44.0
2nd Measure	45.0	45.0	65.0	45.0
3rd Measure	45.0	45.0	65.0	45.0
Average	44.7	44.7	65.0	44.7

Table 9. Noise levels of Area Near the Traffic Roads in Seoul (Nighttime) [dB]

Year (quarter)	2001	2002 (1/4)	2002 (3/4)	2002 (4/4)
1st Measure	65.0	65.0	44.0	65.0
2nd Measure	65.0	65.0	44.0	65.0
3rd Measure	65.0	65.0	44.0	65.0
Average	65.0	65.0	44.0	65.0

3. Noise Measurements and Analysis for Seoul

3.1 Brief Summary of the Measurements

At the common residential buildings located near the traffic roads in Seoul, environmental noise levels were measured during weekday and weekend (see Fig. 1). Those measured locations can be chosen for constructing high-rise residential buildings in the near future.

Table 10 shows the brief summary of the measurements. SA-27 (RION, Japan) equipped with a frequency analyzer was used for the measurements of noise levels. Measured locations were 10 [m] away from the traffic roads that had six lanes. Measurements have been done from May 27, 2004 to May 30, 2004 with one-minute interval. The floor locations were selected following the conditions suggested by Housing & Urban Research Institute (HURI) of Korea National Housing Corporation [1]. As can be seen from Fig. 2, those floors were the 1st, 5th, 10th, and highest (19th) floors.

Table 10. Brief Summary of the Measurements

Date	May 27, 2004 ~ May 30, 2004			
Device	Manufacturer	CESVA SC-160	Country	Spain
	Model		Range	28 ~ 130dB(A)
Measurements	Noise levels at the first floor of the building near the traffic road (refer to Fig. 1)			
	Noise levels at the different floors of the building near the traffic road (refer to Fig. 2)			

3.2 Results and Discussion

Tables 11 through 14 show the noise levels measured at the common residential building located beside the traffic road in Seoul, where high-rise residential buildings can be constructed in the near future. Measured locations were the projecting part and the veranda of the building. Measurements were done at the office-going hour, the midday, the closing hour, and the midnight for weekdays and weekends.

Fig. 1. The Measured Location in Seoul

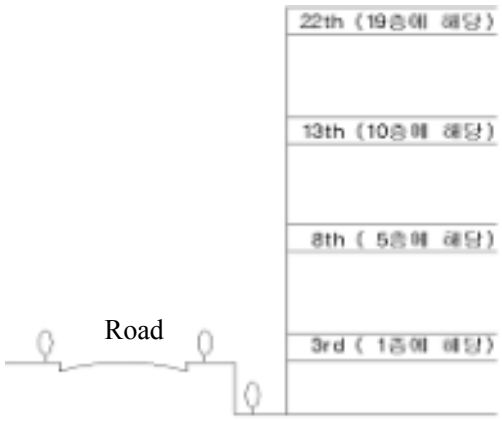

Fig. 2. The Measured Floor Locations Near the Traffic Road

Since at some of the projecting parts (more than 1 [m]) of the measured building the measurement device could not be installed, the veranda of the building was used to measure the noise. As we can see from Table 11, the difference of the noise levels between those measured at the projecting part and at the veranda was about 2 [dB] for the 1st floor. Regarding on the different frequencies in Table 12, the difference of the noise levels were also about 2 [dB].

Table 11. Noise Levels Measured at the Veranda and the Projecting Part of the Residential Building [dB]

Location	1st floor	5th floor	10th floor	19th floor
Veranda	73.39	73.89	73.65	73.24
Projecting part	75.59	75.92	76.15	75.66

Table 12. Comparisons of the Noise Levels Measured at the Veranda and the Projecting Part of the Residential Building depending on the Frequency [dB]

Location	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz
Veranda	62.92	58.93	58.88	58.47	55.67
Projecting part	64.95	60.62	60.76	60.67	57.94

Table 13. Measurements of Noise Levels Depending on Different times in Weekday [dB]

Time		dB	dB(A)	125	250	500	1k	2k
Midday	1st	78.6	69.0	66.5	62.5	61.6	62.4	63.8
	2nd	77.6	68.4	65.8	60.7	61.2	61.9	63.2
	3rd	77.8	69.3	66.3	62.3	62.0	62.7	63.8
Closing hour	1st	82.4	66.9	67.0	59.8	61.0	61.7	61.2
	2nd	81.0	64.9	65.6	59.1	59.1	59.5	59.1
	3rd	79.8	65.2	65.4	58.9	59.3	60.0	59.2
Midnight	1st	69.8	64.0	60.3	56.5	58.8	61.2	57.5
	2nd	70.3	64.0	59.0	56.4	58.8	61.2	57.6
	3rd	71.6	64.4	60.7	56.9	59.2	61.5	57.9

Table 14. Measurements of Noise Levels Depending on Different times in Weekend [dB]

Time		dB	dB(A)	125	250	500	1k	2k
Going hour	1st	74.9	66.7	66.3	61.7	62.4	63.0	59.9
	2nd	76.4	66.4	67.6	63.9	62.9	62.2	59.3
	3rd	74.9	65.7	65.2	60.6	62.0	62.0	58.6
Midday	1st	75.9	63.8	65.0	60.7	60.5	59.6	56.5
	2nd	75.6	63.9	64.9	60.0	60.4	59.9	56.8
	3rd	75.2	64.1	64.7	60.8	61.0	60.0	56.9
Closing hour	1st	77.2	63.6	65.1	60.3	59.7	59.6	56.6
	2nd	77.3	63.1	65.0	60.0	59.8	58.9	56.0
	3rd	77.0	61.5	63.8	58.1	57.9	57.7	54.0
Midnight	1st	70.4	62.4	60.7	56.2	58.1	59.4	55.4
	2nd	71.1	62.4	59.6	56.2	58.0	59.2	55.5
	3rd	70.7	62.9	60.9	56.6	58.6	59.8	56.0

Tables 13 and 14 show the noise levels of the building measured for the weekday and the weekend depending on the different times of the day. The highest noise level was appeared at the closing hour among those different times. The order of the next highest noise levels were at the midday, at the office-going hour, and at the midnight. During the midnight in the weekend, the noise levels were substantially decreased. Since there are small and medium sized passenger cars in urban areas rather than large size luggage trucks, it can be drawn a conclusion that the increase of the passenger cars directly affect on the traffic noise level.

Figs. 3 through 5 show the noise level variations according to time depending on different frequencies. Based on the noise levels at the office-going hour and at the midday, the noise levels were low at the high frequency ranges. Additionally, as can be seen from those figures, the fluctuating ranges of the noise levels were getting small in high frequency ranges. Another interesting result was that at the closing hour the noise level fluctuations according to time variations were

quite similar in the frequency ranges from 250 to 2,000 [Hz] (see Fig. 5).

As we can see from Fig. 6, the highest noise levels were at the closing hour rather than the office-going hour, the midday, and the midnight. In addition, it can be confirmed that the noise levels at the midday were higher than those at office-going hour. However, those differences in noise levels were shrunken in the weekend. The lowest noise levels were at the midnight, and the midnight noise in the weekend was a little higher than that in the weekday.

In order to investigate the variations of the noise levels depending on the floor location of a high-rise residential building, the sound level meter (SC-160, CESVA, Spain) was installed and the noise was measured at the 1st, 5th, 10th, and 19th floors for four full days (see Fig. 2). The measured results were shown in Figs. 7 and 8.

As can be seen from Fig. 7, the noise levels at Room 808 were the highest values. Room 808 was equivalent to 5th floor of a normal residential building (refer to Fig. 2). The 2nd highest noisy location was Room 308 that was corresponded to 1st floor of a normal building. At the highest floor of Room 2208 showed the lowest noise levels. However, if we consider the human being's sense of hearing, then Fig. 8 shows the resulted noise levels in the unit of dB(A). Noise levels at Room 308 were a little higher than

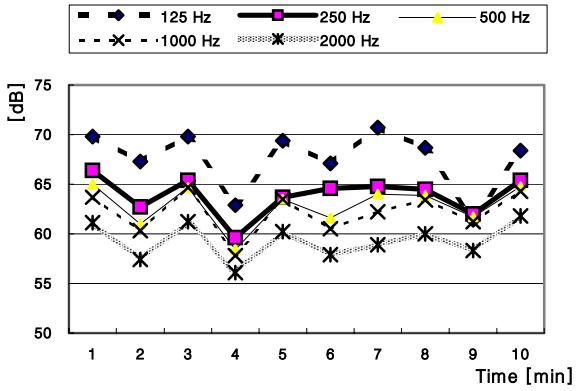

Fig. 3. Noise Levels Based on the Time Variation Measured at the Office-Going Hour in Weekend

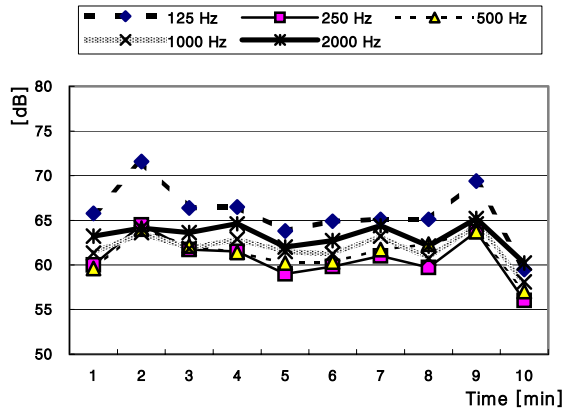

Fig. 4. Noise Levels Based on the Time Variation Measured at the Midday in Weekday

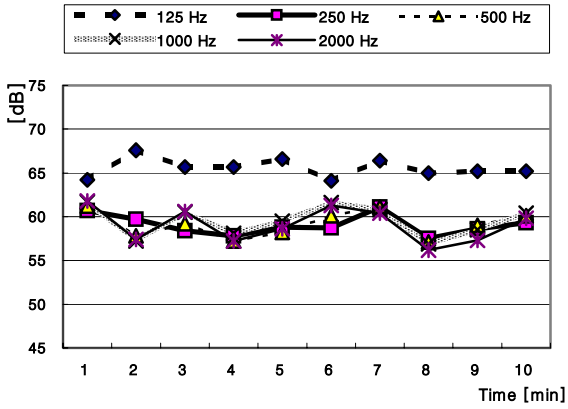

Fig. 5. Noise Levels Based on the Time Variation Measured at the Closing Hour in Weekday

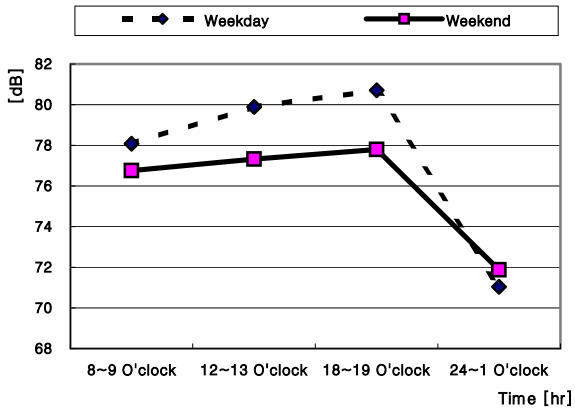

Fig. 6. Noise Levels Based on the Time Variations Measured in Weekday and Weekend

those at Room 808, and the noise levels decreased as the measured locations went to upstairs.

Figs. 9 through 12 show the variations of the noise levels according to the time changes. When the noise levels in the unit of dB were changed to those in the unit of dB(A), the noise levels at the low decibels were less pronounced. The main reason for the rapid decrease of the low noise levels in dB(A) was that the traffic noise might be substantial at the low decibels. As can be seen from Figs. 9 and 11, since the sound more diffracts when the temperature of air in atmosphere goes up, the noise levels became higher as the time went to the daytime. Fig. 11 confirms that as time went to the nighttime, the noise levels decreased.

4. Conclusions

This study was undertaken to systematically investigate the characteristics of the urban traffic noise. In order to achieve the goal successfully, noise levels were measured at the common residential building located beside a traffic road in Seoul, where high-rise common residential buildings can be constructed in the near future. The measured results showed that the noise levels at Gangnam-gu were substantially higher

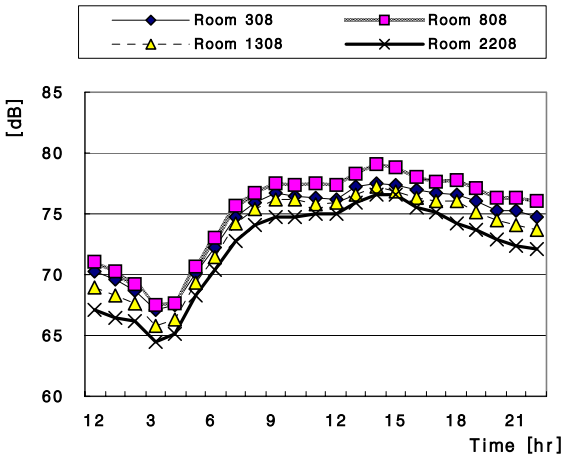

Fig. 7. Noise Levels Based on Different Floors with 24 hours of Time Variation [dB]

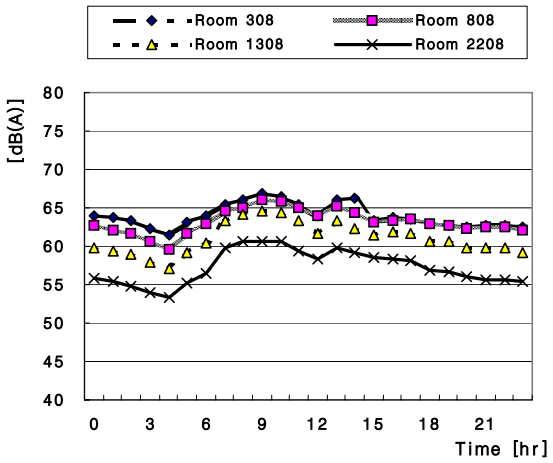

Fig. 8. Noise Levels Based on Different Floors with 24 hours of Time Variation [dB(A)]

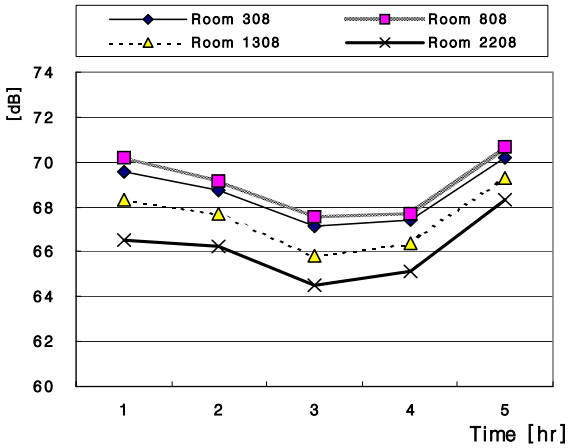

Fig. 9. Noise Levels Based on Different Floors Measured Early in the Morning [dB]

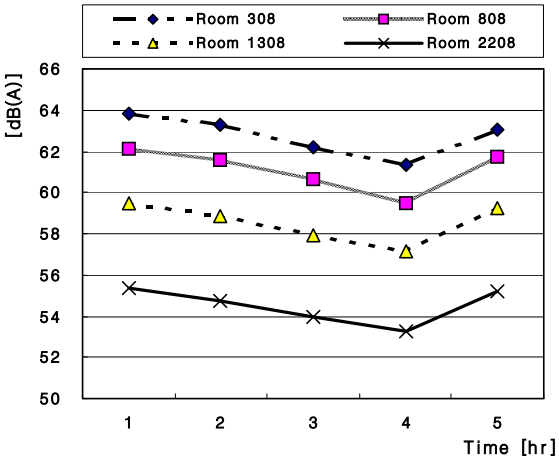

Fig. 10. Noise Levels Based on Different Floors Measured Early in the Morning [dB(A)]

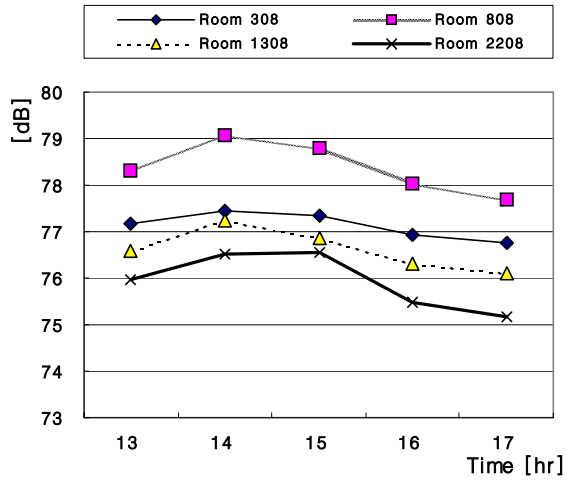

Fig. 11. Noise Levels Based on Different Floors Measured in the Afternoon [dB]

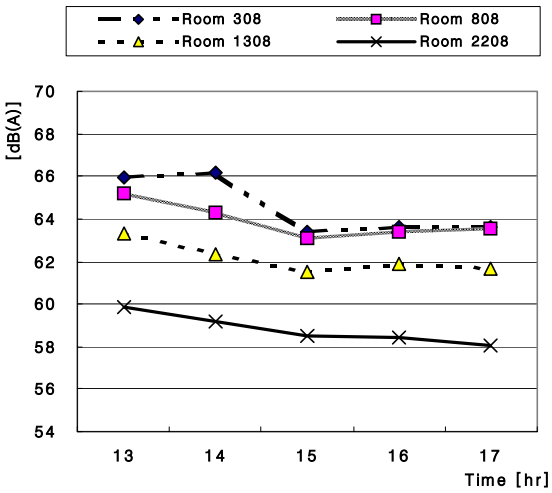

Fig. 12. Noise Levels Based on Different Floors Measured in the Afternoon [dB(A)]

than those at other regions. Based on the comparisons of the measured noise levels depending on the different times of the day, the noise levels at the closing hour were the highest values. Meanwhile, the difference of the noise levels between the daytime and the nighttime was about 10 [dB]. In addition, the difference of the noise levels between the weekday and the weekend were about 7 [dB] at the closing hour. However, the noise levels for the weekday and the weekend were almost same at the midnight.

Based on the comparisons of the noise levels measured at the different floor locations, the noise levels for the 5th floor were appeared to be the highest values. As the measured locations of the noise levels moved upstairs, the noise levels in the unit of [dB] gradually decreased. However, comparing the noise levels in the unit of [dB(A)] to reflect the human being's sense of hearing, the noise levels at the 1st floor were the highest values, and the levels gradually decreased as the measured locations went upstairs.

In the future work, it is planned to continue this study by experimentally measuring more environmental noise to provide additional important data for the researches related to the favorable high-rise residential building construction.

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