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Effect of sound absorption on indoor sound environment of nursery school classrooms.

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ABSTRACT

This study attempted to investigate the effect of sound absorption on indoor environment for infants in nursery schools. The expected effects were reduction of noise level and improvement of speech intelligibility, and consequently lowered voice level of infants, which is known as Lombard effect. Polyester fiber boards were installed on the ceilings of three classrooms of a nursery school, which are the rooms for 0, 2, and 4 years age, and the noise levels were measured before the installation and over four months after the installation. Acoustic measurements before and after the installation were also conducted to see the physical effect of the sound absorption. The averaged absorption coefficients of the three rooms before and after installation, calculated from the measured reverberation time, were from 0.16-0.17 and 0.29-0.30 respectively at 1000Hz octave band. Noise levels in a day were analyzed with the L_{eq} of the three time periods of lunch, book reading, and nap, which represents the noisiest period with children's voice, teacher's voice, and background noise, respectively. The noise levels before the installation were around 75-79 dBA in lunch time. After the installation the lunch time noise level in 0 and 2 year age room became 6-8 dB lower than that of before the installation, while that of 4 years age room didn't change much over 4 months after the installation. Since the expected physical noise reduction by sound absorption was around 3 dB, observed noise reduction in 0 and 2 year age room was considered to be caused by the lowered voice levels of the children and teachers, which were possibly a consequence of speech clarity or Lombard effect.

1. INTRODUCTION

Recently classroom acoustics for from primary to high schools are recognized as an important factor of indoor environment and this movement resulted in the guidelines or regulations of acoustic plannings in several countries. In contrast to these schools, acoustics in kindergartens or nursery schools has been less discussed. In the classrooms of these schools, children are not given lectures but, especially in the nursery schools, spend considerably large part of their daily life. Consequently, the characteristics of acoustic environments in the nursery school classrooms are quite different from those of the schools for elder pulils or students as mostly filled not with organized speech communication between the teacher and students but rather uncontrolled voices from the free will of the children. It can be said that, from this aspect, the acoustic environment of nursery schools has some similarity with that of cafés or bistros. However, because of this characteristic, the target of the acoustic confort is less obvious compared to the other schools where quietness or speech intelligibility is essencial for the lectures and adequate reverberations are required for the music classes. It would need primary discussions on the acoustic comfort of nursery schools but at least it can be said that some sound absorption in the classrooms would reduce the noisiness caused by the children's lively voices, and would facilitate the aural communication between children and teachers/nurses by improving the speech intelligibility. Also, as known as the Lomberd effect, reduced noise level by the sound absorption could reduce the speach levels of the occupants.

There are a few studies on the acoustic environments of classrooms of kindergarten or nursery schools. The situation of teachers is discussed in terms of the occupational medicine [1]. Also considerable decrease in noise level resulted by sound absorption is reported for a primary school classroom [2]. The purpose of this study is to find the medium-/long-term effect of sound absorprtion on the acoustic environment of nursery school classrooms. An *in situ* experiment was carried out in which sound absorbing boards were installed on the ceilings of the classrooms and the acoustic characteristics and noise levels were measured both before and after the installation.

2. INSTALLATION OF SOUND ABSORBING BOARD

An in situ experiment was carried out in a nursery school in Kumamoto city, Japan. The school takes care of from zero to

Table 1. Dimensions of classrooms

Room (age)	N of children	WxDxH (m)	V (m^3)	S (m^2)	Absorption area (m^2)
0y	13	6.6x5.5x2.7	98	137	29
2y	25	6.6x6.5x2.4	102	148	33
4y	21	6.2x7.5x3.0	141	176	34

five years children from 7:00 to 19:00. There are five classrooms by each year age and three among them, namely the rooms for 0, 2, 4 years old (0y, 2y and 4y rooms), were selected for the experiment. This selection was done considering the levels of the growth of the children as the levels of without verbal communication, with verbal communication but rather unorganized activity, and rather organized activity.

The interior furnishing of the rooms was timber floor, walls of timber or plaster board, horizontal sliding sash windows, and plaster ceiling without sound absorption performance. In the experiment, polyester fiber sound absorbing boards were hung from eye bolts on the ceilings with threads as large area as possible to cover the surface. The air layer between the ceiling and the boards was roughly from 100 mm to 150 mm because of the method of installation. The installation was done in the end of October 2009 so that the effect could be examined in the condition of closed windows in the winter season.

3. CHANGES IN ACOUSTIC CHARACTERISTICS

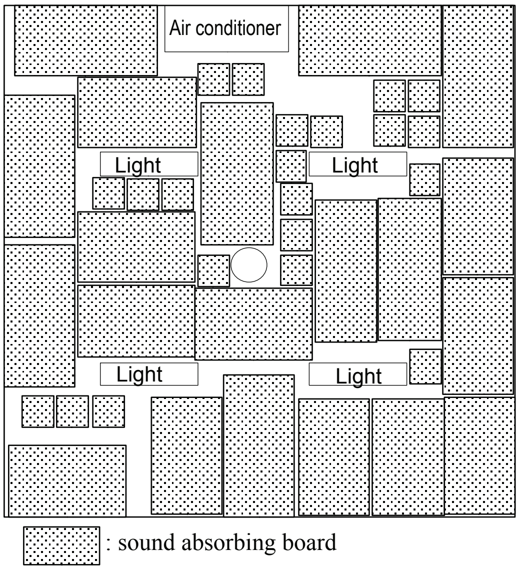
Acoustic characteristics were measures both before and after the installation. In the measurement, impulse response was measured for each of the rooms with maximal length sequence (MLS) method. MLS signals were produced by a omni-directional loudspeaker, received at four points per room, and processed into impulse responses. Then 1/3 octave band reverberation time (RT) was calculated from the impulse responses.

The RTs averaged over four points in a room were shown in Figure 2. The result indicated that the RT before the installation was the longest in 4y room, which has the largest volume due to the high ceiling, at approximately 0.8 s in from 500 Hz to 2 kHz bands, and around 0.6 s in the other rooms. After the installation, the RTs decreased by nearly half and were approximately at 0.4 s in 4y room and 0.33 s in the other two rooms. From the RTs, averaged absorption coefficients of the room were estimated using Eyring's formula. The result was from 0.15 to 0.18 before the installation and almost doubled values after that. Though not more than the subjective feeling, the spaces felt considerably dead after the installation. The RASTI induced from the impulse responses were around 0.72 and 0.84 respectively for before/after installation.

4. NOISE MEASUREMENT

Noise levels in the rooms were measured to examine the effect of sound absorption. Measurements were done three days in series before the installation and once in a week in the first month and once in a month in the following three months after the installation. A microphone was hung at 30 cm from the ceiling around the center of each of the rooms. From 7:00 to 19:00, $L_{Aeq,\ 1sec.}$were continuously recorded. The sound in the room was also recorded simultaneously to

Figure 1. Installation of sound absorbing board



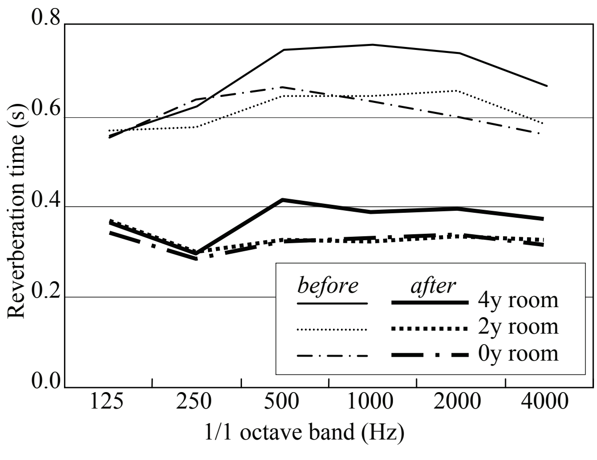


Figure 2. Reverberation time before/after the installation

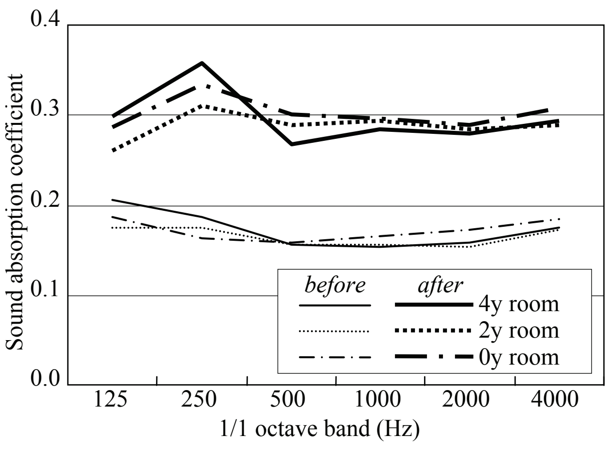


Figure 3. Estimated sound absorption coefficient before/after the installation

examine the noise events corresponding to the noise levels. While, unfortunately, several measurements were cancelled because of the closed class by the spread of influenza, in total, five days dataset were collected for the analysis.

The data of each day contain 12 hour noise levels with large fluctuation due to the types of activity inside/outside the rooms. Among them, therefore, three representative time periods were selected for the comparison of noise levels as follows: 1) lunch time in which childrens speech was among the loudest in a day; 2) reading time in which the teacher read books to children; and 3) nap time which represents the background noise level. For each of the periods, with the dulation of approximately 30 min, L_{eq} and L_{95} were calculated.

Figure 4 shows the frequency characteristics of the recorded sounds in lunch time when the sounds mainly consist of children's voices. It is seen that children's voice has its power in around 1 kHz band. Also another peak appeared in low frequency range and this was caused by the footsteps.

5. CHANGES IN NOISE LEVEL

Here the effect of sound absorption is discussed with the data of lunch time noise level. Figure 5 shows the L_{eq} and L_{95} before and after the installation. Also relative levels, with the level before the installation (averaged value over three day measurements) as 0 dB, were drawn in Figure 6. The expected physical noise reduction by sound absorption was calculated with an assumption of a diffused field and that was approximately 3dB for all the rooms (indicated in Figure 6).

$L_{eq,lunch}$ before the installation were 75, 77, 79 dB respectively for 0y, 2y, and 4y room. After the installation, the noise levels were obviously decreased. Especially for 0y and 2y rooms, the decrease were 6-8 dB and these were more than the expected physical reduction level of 3 dB. The sound sources in these rooms were mainly speeches or cries of children or teachers/nurses and, therefore, it can be concluded that the excessive decrease in L_{eq} was caused by the lowerd speech level of the occupants, probably due to the improvement of speech intelligibility or some kind of Lombard effect.

On the other hand, in 4y room, the decrease of L_{eq} was not such obvious as theother rooms and was more or less equivalent to the physical reduction. The L_{eq} 4 months after the installation was almost same as those before the installation while the L_{95} decreased by 5 dB. This result implied that the children's speech level didn't changed regardless of sound absorption, or the background noise level.The recorded sound of corresponding time period was cheched and the situation was, on the whole, full of childrens loud voices in the very lively atmosphere, while in the other two rooms, the sounds were the mixture of voices of children and teachers/nurses. 4y children seemed to be making their voice as loud as possible during their play regardless of the background noise level and this might be a reason of the unchanged noise levels.

5. CONCLUSIVE REMARKS

In this study, the effect of sound absorption on the acoustic environment of nursery school classrooms was examined through an in-situ experiment of installing sound absorbing board in the classrooms. As a result, the noise levels decreased more than the estimated physical reduction by sound absorption in the rooms of 0 and 2 years old children. Though the result is limited, this is an evident of possible effect of sound absorption on the physical or mental health of both teachers and children in the nursery school.

There are several points raised for the improvement of further studies. Actually an interview to the teachers/nurses was tried just before and after the installation but it seemed that they were unaware of the acoustic property of rooms and that childrens loud voices felt natural to them. Six months has past since the installation at the present time, and recently,

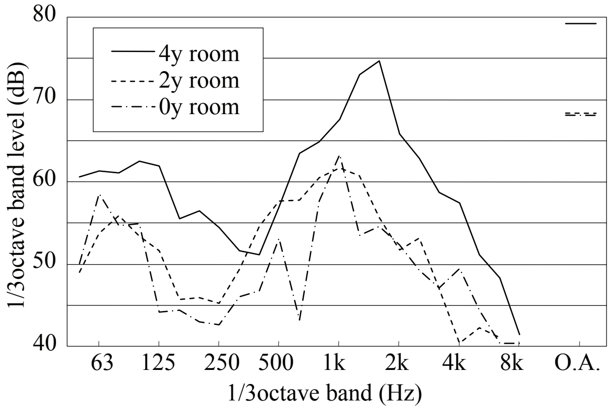


Figure 4. Frequency characteristics of children

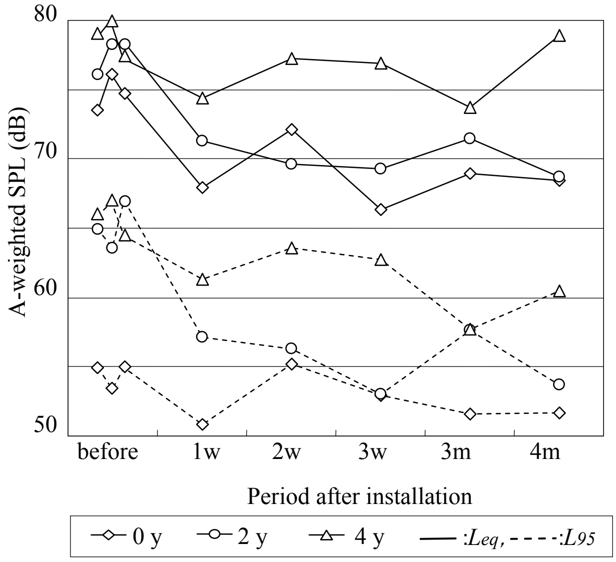


Figure 5. Noise level in the classrooms before and after installation

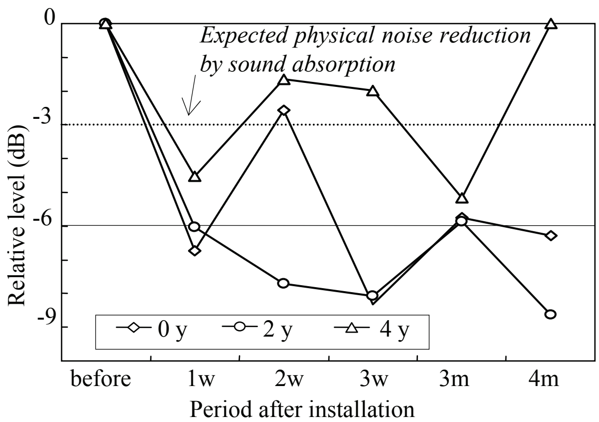


Figure 6. Decrease in noise level after installation

through an unofficial interview, positive answers to the sound absorption appeared from teachers, such as less need to speak loudly and consequently less damage to their throat. Therefore further study should include interviews or obserbation on the activity of teachers and children and this should be done at an appropriate timing. Also improvement of noise measurement, such as measurement of tearchers' speech level using a portable noise level logger, is needed to obtain more reliable findings.

REFERENCES

1 L.Grebennikov, "Preschool teachers' exposure to classroom noise" *Intl. J. Early Years Education* **14(1)**, 35-44 (2007)

2 M.Oberdörster, G.Tiesler, "Modern teaching" needs modern conditions –room acoustics as an ergonomic factor" Proceedings of ICA2007 (2007)