Special edition paper

Study on the Acoustic Environment in Station Concourses for Elderly People

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Investigation was conducted on the noise level of station concourses due to the fact that the noise level in present stations has become increasingly large.

A subjective examination and questionnaire about the acoustical environment for elderly people was carried out in station concourses. Few differences in the word recognition score are seen in the listening comprehension examination at all the test site locations. We thus find that it is easy for elderly people to comprehend words when the signal-noise ratio is 10 dB or more at a station.

●Keywords: Elderly people, Station concourse, Acoustic environment, Listening comprehension test

1 Introduction

Japan is becoming a true aging society with a low birth rate; and as so, railways are sure to see a steady increase in elderly users. To maintain railways as an important mode of public transportation, measures taking elderly people in account are thus required. One point that must be considered is the acoustic environment in railway stations. However, there are no established performance targets and design methods for acoustic characteristics, which are needed to achieve an acoustic environment favorable for elderly people.

In light of that, we carried out measurement surveys of the acoustic environment in stations and two subjective assessment tests (questionnaire survey, listening comprehension examination)[1) 2)] on elderly people regarding the acoustic environment of station concourses. The aim of those is to establish an acoustic design method for stations.

2 Survey Method for Acoustic Environment in Station Concourses

We surveyed the acoustic environment at 26 points of 11 major stations with different structures (aboveground, underground, under-viaduct, over-track) in the greater Tokyo area. A brief description of the stations is shown in Table 1. Noise measurement was done in the daytime from 10:00 to 16:00, avoiding rush hours. At the same time, the number of people passing the measurement points was counted.

In the measurements, we recorded the results of 1/3 octave band analysis of the noise level (L_{PA}) per 100 msec. continuously for an hour, using a precise sound level meter (NA-28, manufactured by RION). The height of the microphone was 1.2 m above floor.

3 Results of Acoustic Environment Survey and Considerations

3.1 Survey Results

Fig. 1 shows the equivalent noise level ($L_{Aeq,1h}$) and the percentile noise level ($L_{A5,1h}$, $L_{A95,1h}$) at all surveyed points. Equivalent noise level is the average value of the total noise exposure amount divided by measurement time T. Percentile noise level is used as a criterion to differentiate between the condition where irregular noise such as guide announcements and train noise is generated ($L_{A5,1h}$) and the condition where constant noise—background noise—such as noise by pedestrians is generated ($L_{A95,1h}$). $L_{Aeq,1h}$ in the stations was 65 to 73 dB, with an average of 71 dB at 26 measurement points. At all points, noise sources included noise by passengers (footsteps, noise by wheels of trolley bags, conversations, etc.) and train noise as well as guide announcements, guide signals, and noise of ticket gates. In most stations, $L_{A95,1h}$ was 65 to 70 dB, while there was an acoustic environment in some stations with high noise level (A-3, A-4, and E-12) where it constantly exceeded 69 dB. This is because temporary and regular guide announcements and announcements for commercial purposes were always being made in those stations. In contrast, in the stations with low noise level (I-20, D-7, K-25, E-11, and I-21),

Table 1 Brief Description of Stations Surveyed at

Station	No.	Location	Concourse type	Ceiling height (m)	No. of passengers passing through	Notes
A	1	Central ticket gate	Under-viaduct	2.7	3200	
	2	South passageway	Under-viaduct	3.6	5800	
	3	Transfer ticket gate	Under-viaduct	2.6	2900	Near ticket gates
	4	Central passageway	Under-viaduct	3.2	7100	
B	5	Central ticket gate	Aboveground	9.0	5760	Near ticket gate, membrane roof
C	6	Central ticket gate	Over-track	8.3	5400	Near ticket gates, no finished ceiling
D	7	South free passageway	Under-viaduct	3.0	3640	Near ticket gates
	8	North free passageway	Under-viaduct	3.0	2820	Near ticket gates
	9	Central free passageway	Under-viaduct	2.9	8250	
	10	North concourse	Under-viaduct	2.5～3.0	2400	
E	11	Concourse	Over-track	4.0	2770	Ceiling partly with board and perforated metal panel
	12	Free passageway	Over-track	4.0～14.2	6110	Near ticket gates
F	13	Concourse	Under-viaduct	4.0	10140	
G	14	Central passageway	Under-viaduct	2.6	3730	
	15	South concourse	Over-track	4.0	3140	
H	16	Outside south ticket gate	Under-viaduct	2.9	5320	Near ticket gates
	17	South ticket gate	Under-viaduct	3.7	3980	Near ticket gates
	18	Central ticket gate	Over-track	2.8～4.3	5790	Near ticket gates
	19	Ticket gate	Under-viaduct	2.9	5840	Near ticket gates
I	20	South passageway	Over-track	4.2	5930	Perforated sound insulation metal panel
	21	Station plaza	Over-track	3.6	3300	
	22	Central free passageway	Over-track	8.7	3580	Near ticket gates, high ceiling
J	23	Ticket gate	Under-viaduct	3.2	3620	Near ticket gates
	24	Central ticket gate	Under-viaduct	4.5	9970	Near ticket gates
K	25	Ticket gate	Under-viaduct	2.6	2620	
	26	Central free passageway	Under-viaduct	2.6	5900	Near ticket gates

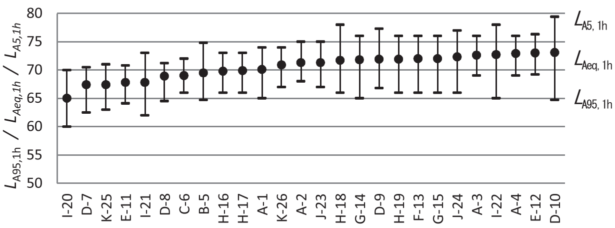

Fig. 1 Noise Level at Individual Survey Locations

*Frontier Service Development Laboratory, Research and Development Center of JR East Group there were few guide announcements from speakers.

Next, Fig. 2 shows the frequency characteristics of $L_{A5,1h}$ and $L_{A95,1h}$ in a space with a relatively low ceiling and more than 5,000 passengers passing through per hour. The shaded legend symbols of the graphs in Fig. 2 indicate measurement points at under-viaduct sections.

The graph revealed that $L_{A95,1h}$ at I-20 with a noise insulation ceiling was lower by 2 to 4 dB in the 250 Hz and higher frequency bands than at other points. The graph shows that the level of $L_{A5,1h}$ at I-20 was lower in lower frequency bands too, but this would be caused by the effect of solid borne sound of trains running under elevated viaducts other than at I-20.

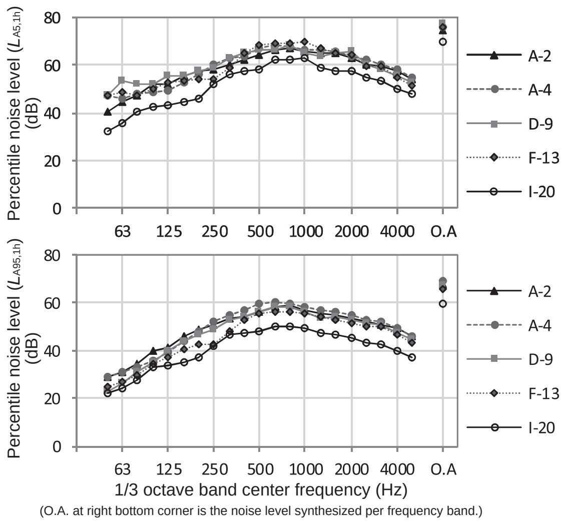

Fig. 2 Space with Low Ceiling (More Than 5,000 People Passing Through)

3.2 Comparison with Past Studies

The survey results of a past study (conducted in 1998)[3] states that noise level in the daytime was 57 to 74 dB, with an average of 67 dB. In comparison with Fig. 1, a tendency for noise level in stations to have risen can be seen. It must be noted, however, that measurement was done at locations and in stations different from those in the study of this paper.

Since standards for introduction of guide signals—guidelines covering acoustic mobility support for visually impaired persons (established in fiscal 2002) and those for introducing facilities for increased accessibility (established in fiscal 2007)—were set down, guide signals have been introduced to applicable places in stations. As with guide announcements, introduction of those facilities could be an factor in the difference of noise level from the results of the past study.[3] We are concerned about further increase of noise levels in stations because announcements to remind passengers about manners and other announcements tend to be made more often.

4 Stations Where Subjective Assessment Was Conducted

We carried out questionnaire surveys for test participants in five concourses of three stations at and around the center of the Tokyo. A brief description of those concourses is shown in Table 2. We selected those to include over-track, under-viaduct, aboveground, and underground structures.

The ceiling material of those is metal panel except for the membrane roof for B-29 and no ceiling finishing for C-31. No specific consideration of the acoustic environment is taken at any of the stations.

Table 2 Brief Description of Stations Surveyed at

Station	No.	Concourse type	Passengers (fiscal 2012, thousand persons)	Ceiling height	No. tracks accessed from concourse	$L_{Aeq,30s}$ [dB]	Notes
A	27	Under-viaduct	402	3 m	5 platforms 10 tracks	66	
	28	Underground		Less than 3 m	2 platforms 4 tracks	63	
B	29	Aboveground	183	9 m	3 platforms 5 tracks	69	Membrane roof
	30	Underground		8 m	2 platforms 4 tracks	70	
C	31	Over-track	329	6 m	8 platforms 15 tracks	70	No finished ceiling

5 Test Participants

We used ten male retired employees of an acoustic equipment manufacturer as test participants. Their age was 66 to 80 years, with an average age of 74.3 years. One person did not take part in the test at Station C, and accordingly, the number of participants was nine at Station C. Fig. 3 shows the results of the hearing tests of those participants conducted in advance. As shown, the hearing ability of the participants varied considerably, with a particularly larger individual difference at frequency bands of 2,000 Hz and higher. But no remarkable individual difference was observed in the average hearing ability of right and left ears among ten participants. In comparison with the minimum audible threshold in ISO 226:2003,[4] we can say that overall hearing ability of the participants is low.

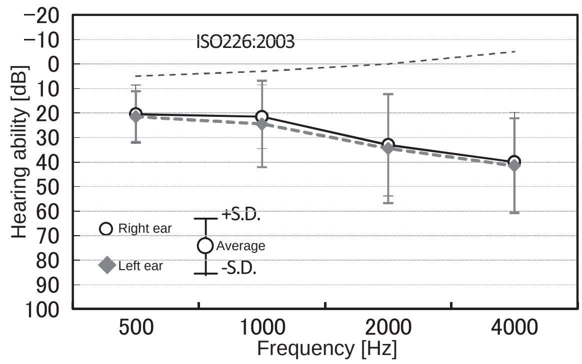

Fig. 3 Hearing Ability of Test Participants

6 Questionnaire Survey Methodology

We carried out a questionnaire survey at the points shown in Table 2. In that, we asked the participants about their impression of the acoustic environment of the station they usually used and about the level of discomfort and acceptability of the station where we carried out the questionnaire. Table 3 lists the questions on the impressions of the station the respondents used, and Table 4 lists the questions on the level of discomfort and acceptability of the station where they were. When the questionnaire survey was conducted, we also measured the noise level around the respondents at the same time.

Table 3 Questions on Impression of Acoustic Environment of the Station Usually Used

Evaluation item	No.	Question and evaluation
Consciousness of acoustic environment	Q.1	Are you conscious of the acoustic environment in the station? (1. Often 2. Sometimes 3. Seldom 4. Not at all)
Noisiness in stations	Q.2	Do you feel the station is noisy? (1. Often 2. Sometimes 3. Seldom 4. Not at all)
Difficulty of making out guide announcements	Q.3	Do you feel difficulty in making out what is said in guide announcements in the station due to noise? (1. Often 2. Sometimes 3. Seldom 4. Not at all)
	Q.4	Do you feel difficulty in making out what is said in guide announcements in the station due to sound reflection? (1. Often 2. Sometimes 3. Seldom 4. Not at all)

Table 4 Questions on Discomfort and Acceptability

Evaluation item	Evaluation
Impression of acoustic environment	Level of discomfort (1. Much discomfort 2. Some discomfort 3. A little discomfort 4. No discomfort)
Noise level	Acceptability (1. Acceptable 2. Not acceptable)

7 Questionnaire Survey Results

7.1 Results of Analysis of Acoustic Impression of Station Usually Used

Fig. 4 shows the response results of questions 1 through 4, in which we asked about the impression of the acoustic environment of the station the respondents usually used. The ratio of respondents who are conscious of the acoustic environment of the station and the ratio of those who feel the station is noisy (total ratio of respondents who replied "often" and "sometimes") was 80%, and the rate of respondents who feel comprehension of what is said in guide announcements is difficult was 50 to 60%. The questionnaire revealed that more than a half of the participants felt that stations are noisy.

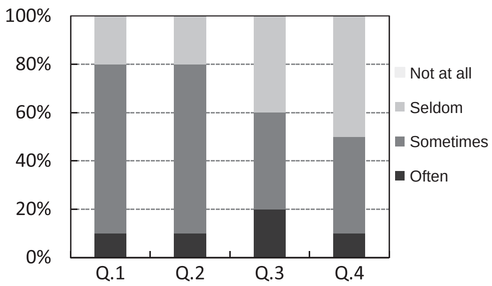

Fig. 4 Impression of Acoustic Environment of Station Usually Used

7.2 Results of Analysis of the Level of Discomfort and Acceptability

To find the relationship between $L_{Aeq,30s}$ at the measurement points (see Table 2) and the rate of acceptability, we conducted logistic regression analysis based on the level of discomfort of the acoustic environment in stations. The explanatory variable is the noise level at individual measurement points. The criterion variables are, from Table 4, "Unacceptable" ("1. Much discomfort" and "2. Some discomfort") and "Acceptable" ("3. A little discomfort" and "4. No discomfort") allocated with a dummy variable. The result of logistic regression is shown in Fig. 5. The graph shows a tendency for the ratio who can accept to sharply decrease at around 65 dB.

Comparing Fig. 5 with the results of the past assessment including respondents other than elderly people,[5] we found that the acceptability rate of Fig. 5 to be slightly lower.

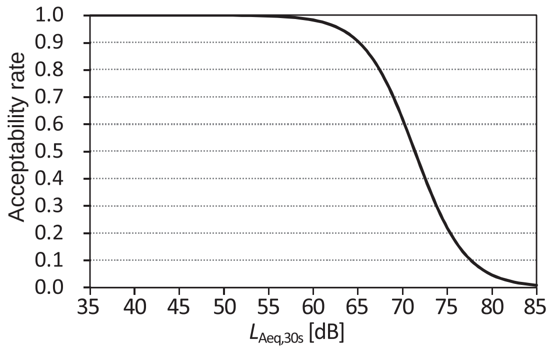

Fig. 5 Relationship between Noise Level and Acceptability Rate

8 Listening Comprehension Examination

At the measurement points of Table 2, we carried out an examination of ability of elderly people to comprehend what is said in guide announcements. The participants were the same as those of the test covered in Chapter 5.

We set a speaker (BOSE 101) at 3 m above the floor using a stand. The participants lined up in three rows, with the persons in front at 5 m apart from the speaker.

Table 5 shows the announcement text used in the examination and the responses. We randomly played one of the words in parentheses of the announcement text in Table 5 and had the participants select the word they thought they heard. We also asked the participants about their impression when they heard the announcement. Fig. 6 is a photo of the listening comprehension examination.

Separately, we measured at night after the station closed the Speech Transmission Index (STI), which is a physical index of clearness of sound. A speaker was set at the same position as that of the participants, and a sound level meter was placed at 5 m and 7 m horizontally from the speaker and 1.2 m above floor. We used a time-stretched pulse (TSP) signal as the sound source, and we calculated the STI using the transfer function obtained from the TSP signal the sound level meter received.

Table 5 Test Announcement Text and Hearing Impression Evaluation

Test announcement text
This is (notification/guidance/announcement) to (all/passengers/people) in transit. (Now/Today/From now), we will conduct a (Survey/Check/Test) of easiness comprehension for guide announcements. We are (very/sincerely) sorry for the (bother/trouble/inconvenience) caused. Thank you for your (Understanding/Cooperation).

One of the words in parentheses was randomly placed in every announcement. Participants selected the word they thought they heard.

Evaluation of impression on comprehensibility
1. Not easy at all 2. Not so easy 3. Easy to some extent 4. Easy 5. Very easy

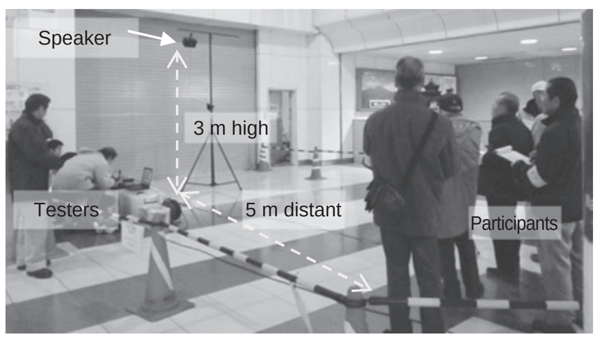

Fig. 6 Listening Comprehension Examination

9 Listening Comprehension Examination Results

9.1 STI Measurement Result

Table 6 shows the STI measured in a closed station at night. STI at 5 m from the speaker was 0.61 to 0.78, at 7 m 0.55 to 0.74.

Table 6 STI Measurement Results

Horizontal distance from speaker	Measurement point				
	A-27	A-28	B-29	B-30	C-31
5 m	0.68	0.65	0.71	0.61	0.78
7 m	0.66	0.63	0.65	0.55	0.74

9.2 Listening Comprehension Examination Results

Fig. 7 shows the relationship between the signal-noise ratio (S/N) of the test announcement text (S) and background noise (N) as well as the ease of comprehending what is said. The vertical axis is the average of the responses of the participants. The ease of comprehending what is said rose as the S/N increased. Variation by measurement points was small. The average response was “easy” at around a S/N of 10 dB and “very easy” at a S/N of 20 dB or higher.

Fig. 8 shows the relationship between the STI and the ease of comprehension. The STI on the horizontal axis is the value of the measurement at night in Table 6 compensated by the S/N at the listening comprehension examination. The ease of comprehension rose as the STI increased; however, variation according to the survey point was slightly large. The STI value at which the ease of comprehension exceeded “very easy” was approx. 0.50 at B-30 and approx. 0.70 at C-31.

Fig. 9 shows the relationship between the S/N and the level of word recognition. Recognition is the ratio of correctly answering what the words in parentheses are for the test announcement text shown in Table 5. The overall recognition was high, with little difference in correctness per survey point. This could be because we asked the question in a manner where the participant would choose the word from the given answers. For actual guide announcements in stations, however, it is important that the announcement can correctly convey information on train types, destinations, suspension of trains, and the like to passengers. We probably need to further consider the evaluation method for conveying audio information in station concourses.

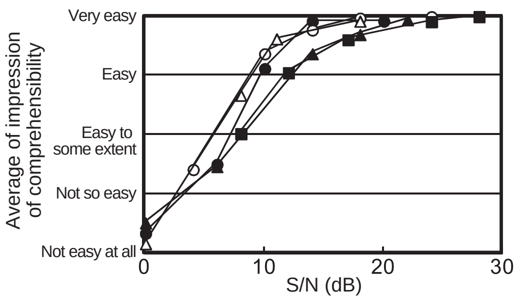

Fig. 7 Relationship between S/N and Impression of Announcement Comprehensibility

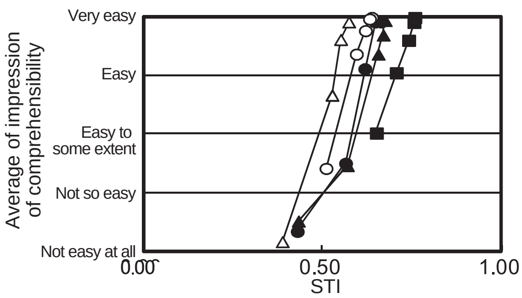

Fig. 8 Relationship between STI and Impression of Announcement Comprehensibility

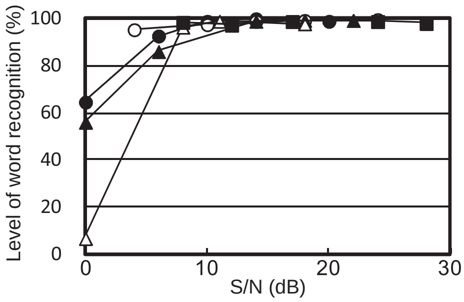

Fig. 9 Relationship between S/N and Level of Word Recognition

Legend ●A-27 ○A-28 ▲B-29 △B-30 ■C-31

10 Conclusion

In this study, we carried out measurement of the acoustic environment in station concourses and a listening comprehension examination of elderly people. From that, we obtained fundamental findings to establish a method of acoustic design for stations. We will develop that method from the perspective of facilities based on those findings.

To achieve a good acoustic environment in stations, however, efforts focusing only on the facilities will not be sufficient. We will also promote control of sound sources including guide announcements.

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Reference:

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