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Investigation of the Speech Intelligibility of Classrooms Depending on the Sound Source Location

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Abstract

The present study aims to investigate the effects of speaker location on the speech intelligibility in a classroom. In order to this, acoustic measurements were undertaken in a classroom with three different sound source locations such as center of front wall (FC), both sides of front wall (FS) and the center of ceiling (CC). SPL, RT, D_{50}, RASTI were measured in the 9 measurement points with same sound power level of sound source and MLS was used as the sound source signal. Also, subjective listening tests were carried out using Korean language listening materials which were recorded in an anechoic chamber. The recorded syllables were replayed and recorded again in the classroom with same sound source at three different locations and listening tests were undertaken to 20 respondents who were asked to write the correct syllables which were recorded in the classroom. The results show that higher sound intelligibility (D_{50} of 47%, RASTI of 0.56) was obtained when sound source was located at the FS. The results also show that high sound intelligibility was obtained at the area nearby walls.

Keywords: *Sound Intelligibility, Classroom, Sound Source, Acoustic Measurements, Sound Definition, Subjective listening Tests*

I. Introduction

More aural information is transferred in a classroom nowadays as audio-visual facilities are widely used for the education purpose and many language listening tests have been carried out in the classrooms. In this situation, the location of the speakers become important matter since it is presumed to influence the aural environment in the classrooms.

The present study aims to investigate the effects of speaker location on the speech intelligibility in an ordinary rectangular classroom. As a pilot study, computer modeling was carried out to investigate the acoustic parameters in a classroom which has three different sound source locations[1]. Acoustic Measurements were undertaken to compare the acoustic parameters related to speech intelligibility with different sound source locations.

Also, Subjective syllable tests were carried out using Korean language listening materials which were recorded in an anechoic chamber. And the subjective listening tests were undertaken to investigate the preference of the sound location in the classroom.

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II. Acoustic Measurements

Acoustic parameters of speech intelligibility were measured using an ordinary empty rectangular classroom which has dimensions as listed in Table 1. The classroom used is a typical type of the university classroom which accommodates around 50 peoples. Most of wall material is cement blocks with painted mortar and the floor is covered by polished stone. The acoustic textiles are installed on ceiling with 150mm air cavity under the concrete slab. The materials applied to each area of the classroom are listed in Table 2.

Acoustic measurements were undertaken in the classroom with three different sound source locations such as center of front wall

Table 1. Dimension of the classroom.

Length	Width	Height	Floor Area	Surface Area	Volume
10.7 m	7.7 m	2.75 m	82.3 m^2	262.7 m^2	207.6 m^3

Table 2. Building materials of the classroom.

No.	Area	Structural material	Finishing material
1	Front wall	Cement block	Blackboard
2	Left-side wall	Cement block	Window
3	Right-side wall	Cement block	Painted mortar
4	Rear wall	Cement block	Painted mortar
5	Floor	Terrazzo	Terrazzo
6	Ceiling	150mm air cavity under the concrete slab	Acoustic textiles

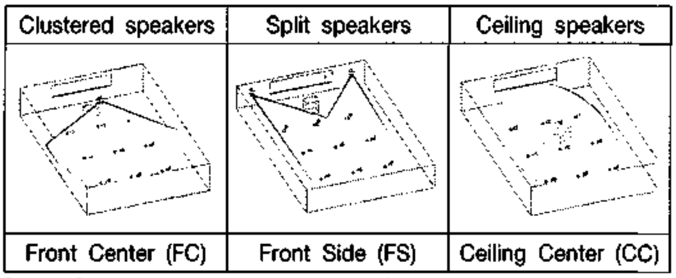


Fig. 1. Expected sound coverage area of sound speakers depending on the location.

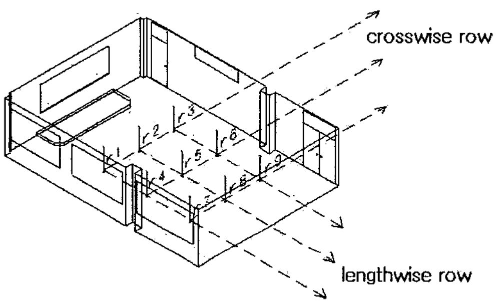
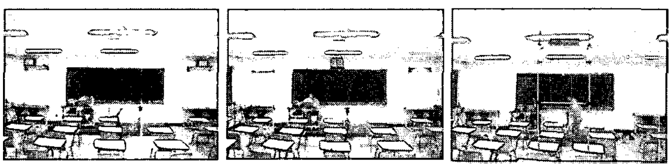


Fig. 2. Measurement positions in classroom.



a) FS b) FC c) CC

Fig. 3. Speaker settings in each measurement.

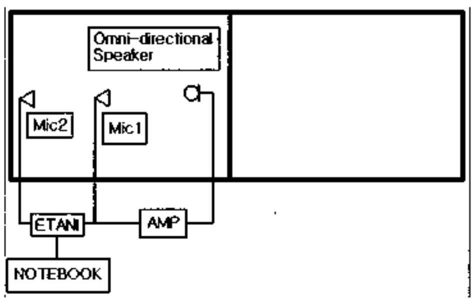


Fig. 4. Measurement set up for room acoustic parameters.

(FC), both sides of front wall (FS) and the center of ceiling (CC) which are widely used as speaker location in the current classrooms. Fig.1 illustrates the expected coverage of sound speakers in a classroom depending on the speaker location. The typical types of speakers in each location are written in the upper low of the Fig.1.

Acoustic parameters including SPL, RT, D_{50}, RASTI which relate with the sound intelligibility were measured in the 9 measurement points with same sound power level of sound source. The distance among measurement points is 2m away from each other. In each measurement, a set of two loudspeakers (APL-Sonata 1800 BW) was used as the sound source which is widely used as the speaker in classrooms. And MLS signal was used as the sound source signal. In each measurement, 80dB of sound energy was radiated and the signal was taken by microphones which were set at the height of 1.1m position from the floor. The measurements were carried out during the night and the background noise level was 31dB(A). Fig.2 shows the shape and measurement positions in the classroom. Also, Fig.3 illustrated the speaker settings in each measurement. Also, acoustic measurement set-up for room acoustical parameters is illustrated in Fig.4. Sound pressure levels were measured using B&K 2260 and other acoustic parameters were analyzed using ETANY ASA-2 audio sound analyzer.

III. Results of Acoustic Measurements

3.1 Sound Pressure Level (SPL)

SPL was analyzed according to the measurement positions and the adjacency to the walls. SPL of measurement positions r2 & r5 which are located at the center area of the classroom were separately analyzed since the SPL was increased at the positions nearby walls due to the reflected sound energy. Maximum difference of 1.8dB was occurred between center area and other

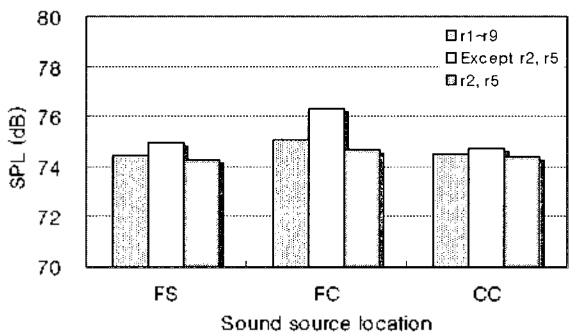


Fig. 5. Average SPL of each source location.

points. Fig.5 shows the average SPL of each sound source location depending on the measurement positions. It was found that high SPL values were obtained at the points where direct sound path is short and that the reflective walls play a role of increasing SPL value at the area nearby walls.

3.2 Reverberation Time (RT)

Sound definition is inversely affected by the reverberation time. Reverberation time of the classroom was measured with sound source at the three different locations. The average reverberation

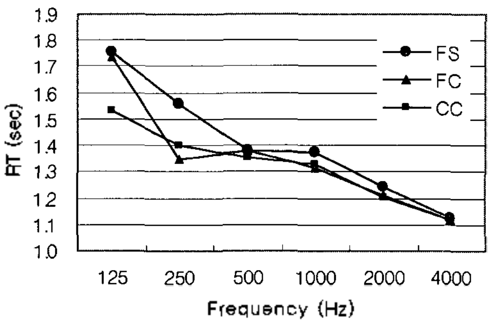


Fig. 6. Average reverberation time of each source location.

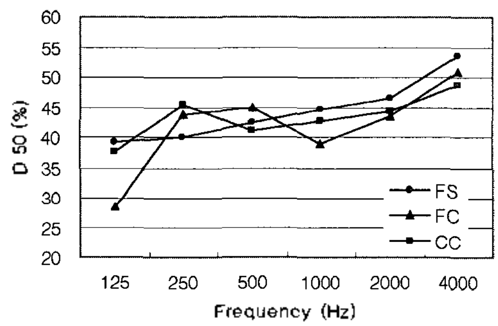


Fig. 7. Average D_{50} value of each source location.

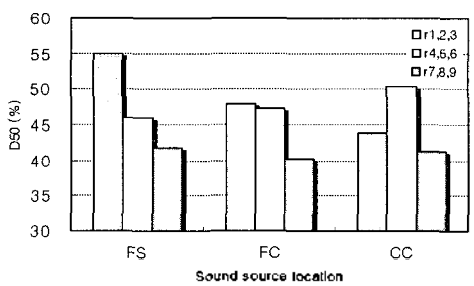


Fig. 8. D_{50} value of the each crosswise row.

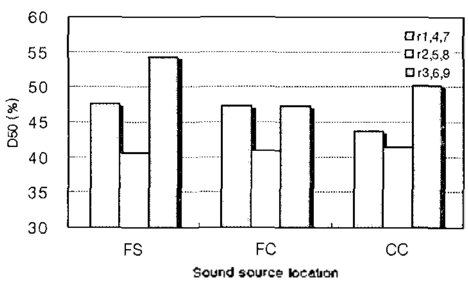


Fig. 9. D_{50} value of the each lengthwise row.

Table 3. RASTI Ratings.

Quality Score	RASTI
Bad	〈0.30
Poor	0.30 ~ 0.45
Fair	0.45 ~ 0.60
Good	0.60 ~ 0.75
Excellent	〉0.75

time was plotted as the function of frequency in Fig.6. It was found that reverberation time is generally decreasing with increasing frequencies. It was shown that reverberation times with different source location are similar at the frequency above 500Hz. However, maximum difference of 0.25 sec was measured at the low frequencies among source locations.

3.3 Sound Definition (D_{50}) and RASTI

The average sound definition (D_{50}) of three source locations are plotted as the function of frequency in Fig.7. It shows, in general, that the D_{50} value increases with increasing frequencies. The highest average value of D_{50} (47%) was acquired at FS location while the lowest value of 40% was obtained in FC location. This is because the average direct distance between the sound source at FS location and each receiver is shorter than others. Figures 8 & 9 show the average D_{50} values of the crosswise row and the lengthwise row in the classroom respectively.

Fig.8 implies that the D_{50} value is directly proportional to the source-receiver distance. And Fig.9 denotes that the D_{50} value is lower at the center line irrespective of sound source location.

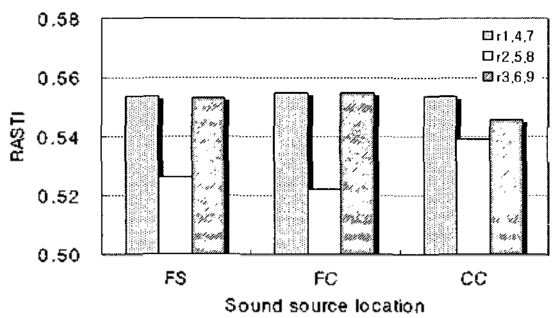


Fig. 10. RASTI value of the eachlengthwise row.

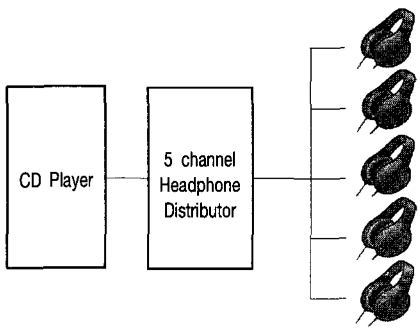


Fig. 11. Devices of the syllable listening test.

Table 4. Listening Test Material I.

Sheet 1				Sheet 2				Sheet 3				Sheet 4				Sheet 5			
1	락	26	꿇	1	루	26	관	1	버	26	워	1	은	26	결	1	손	26	색
2	꼬	27	뜸	2	채	27	뿔	2	끈	27	씬	2	만	27	린	2	째	27	변
3	겨	28	데	3	퉁	28	푸	3	삭	28	뒷	3	물	28	청	3	쌀	28	듬
4	깜	29	밥	4	홀	29	강	4	죽	29	안	4	회	29	산	4	트	29	까
5		30	잡	5		30	품	5	뭐	30	갈	5	풀	30	래	5	활	30	곳
6	쌍	31	르	6	안	31	비	6	연	31	바	6	숭	31	들	6	등	31	다
7	담	32	쭉	7	따	32	반	7	잠	32	큰	7	밀	32	짜	7	터	32	건
8	틀	33	멀	8	음	33	혹	8	선	33	백	8	창	33	티	8	디	33	퍼
9	율	34	님	9	더	34	깍	9	걸	34	처	9	얼	34		9	신	34	총
10	름	35	륵	10	시	35	쥐	10	우	35	룡	10	두	35	꿀	10	새	35	뻘
11	쇠	36	통	11	맛	36	전	11	득	36	잔	11	잘	36	딱	11	세	36	꾸
12	하	37	레	12	리	37	도	12	이	37	적	12	거	37	렁	12	지	37	미
13	깨	38	잿	13	되	38	솔	13	번	38	코	13	너	38	릿	13	단	38	
14	둑	39	깨	14	본	39	왕	14	멍	39	픔	14	끔	39	셈	14	물	39	즐
15	푼	40	꺽	15	봉	40	키	15	톱	40	납	15	설	40	숨	15	끌	40	턱
16	빈	41	승	16	흔	41	얼	16	괴	41	순	16	용	41	찬	16	팡	41	욱
17	란	42	엄	17	척	42	칠	17	충	42	칼	17	굳	42	악	17	원	42	뼈
18	임	43	뚱	18	쓰	43	걱	18	땅	43	려	18	뼈	43	검	18	몸	43	털
19	토	44	절	19	송	44		19	애	44	떡	19	콩	44	림	19	활	44	퉁
20	분	45	머	20	에	45	달	20	호	45	실	20	훤	45	매	20	김	45	방
21	씨	46	릉	21	륙	46	찔	21	차	46	표	21	골	46	광	21	한	46	뜰
22	오	47	꿈	22	소	47	읍	22	말	47	넘	22	라	47	밑	22	발	47	탈
23	질	48	짝	23	무	48	뒤	23	아	48	술	23	물	48	위	23	자	48	누
24	상	49	과	24	정	49		24	까	49	곽	24	로	49	악	24	달	49	호
25	식	50	습	25	싹	50	둘	25	뚱	50	물	25	는	50	계	25	뚜	50	낭

Sheet 6				Sheet 7				Sheet 8				Sheet 9				Sheet 10			
1	귀	26	회	1	덕	26	패	1	벌	26		1	줄	26	염	1	막	26	점
2	외	27	째	2	파	27	령	2	길	27	친	2	심	27	값	2	타	27	런
3	찰	28	매	3	공	28	깃	3	화	28	칠	3	태	28	꺼	3	쌕	28	를
4	용	29	게	4	의	29	중	4		29	양	4	튼	29	늘	4	천	29	피
5	긴	30	둥	5	따	30	돌	5	왜	30	날	5	궁	30	박	5	쟁	30	서
6	출	31	사	6	빨	31	구	6	혜	31	마	6	뚝	31	수	6	겹	31	개
7	돈	32	탕	7	엽	32	굴	7	삼	32	싸	7	벅	32	밤	7	참	32	설
8	느	33		8	초	33	영	8	재	33	번	8	팔	33	본	8	운	33	련
9	눈	34	몽	9	감	34	떼	9	목	34	못	9	먹	34	곰	9	잡	34	
10	살	35	뚝	10	스	35	쪽	10	주	35	짐	10	보	35	쑥	10	등	35	독
11	덩	36	각	11	성	36	덜	11	간	36	꾼	11	허	36	왕	11	석	36	생
12	기	37	내	12	가	37	불	12	나	37	량	12	치	37	히	12	어	37	드
13	난	38	경	13	국	38	딸	13	책	38	깔	13	진	38	때	13	직	38	곱
14	놀	39	넘	14	북	39	껄	14	요	39	딴	14	끄	39	커	14	포	39	퐁
15	묵	40	덜	15	카	40	펄	15	쌈	40	옥	15	짤	40	견	15	륵	40	물
16	힘	41	숙	16	굼	41	유	16	참	41	쭝	16	녹	41	덤	16	역	41	쩔
17	뜩	42	뿌	17	홍	42	엉	17	월	42	갈	17	열	42	총	17	별	42	휘
18	꺽	43	복	18	뻐	43	벙	18	압	43	군	18	병	43	면	18	경	43	른
19	편	44	뜨	19	투	44	여	19	벼	44	으	19	후	44	당	19	못	44	럭
20	종	45	조	20	질	45	작	20	암	45	니	20	떼	45	모	20	술	45	옴
21	추	46	또	21	노	46	채	21	일	46		21	제	46	뗑	21	속	46	뻥
22	죽	47	베	22	러	47	네	22	배	47	떠	22	글	47	뭉	22	근	47	왕
23	장	48	람	23	대	48	판	23	부	48	해	23	그	48	업	23	고	48	야
24	금	49	댕	24	알	49		24	반	49	넙	24	저	49	겹	24	럽	49	름
25	접	50	운	25	것	50	빗	25	옷	50	굽	25	남	50	옹	25	와	50	

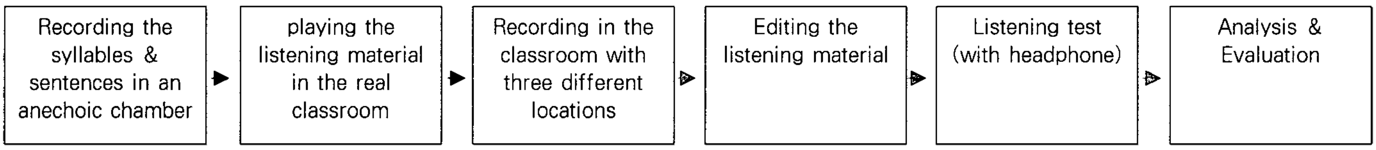


Fig. 12. Devices of the syllable listening test.

This means that the reflected sound from the both side walls help to increase the D_{50} value in the classroom.

Also, RASTI values of each lengthwise row were illustrated in Fig.10. As shown in Fig.9, RASTI values are lower at the longitudinal centerline in any sound source locations. In average, almost similar RASTI values were obtained at each sound source location in the rage of 0.54 to 0.56 which are still lower than the optimum value of 0.6 in the classroom.

IV. Subjective Listening Test

Subjective listening tests were carried out using Korean language listening materials which were recorded in an anechoic chamber. The recorded syllables and sentences were replayed and recorded again in the classroom with same sound source at three different locations. Using the sound recorded in the classroom, the listening tests were undertaken to 20 respondents who are all university students. They were asked to write the heard syllables correctly through the headphone. Listening tests were accomplished in the classroom with the background noise level of 27dB(A). Fig.11 shows the set-up of devices used in the syllable listening tests and the Fig.12 shows the total process of syllable listening tests.

5 different test materials were used to listening tests and each test material consists of 10 sheet with 500 syllables. Table 4 shows one of listening test materials used in the present tests.

In average, the correct ratio of syllables tests was almost 60%

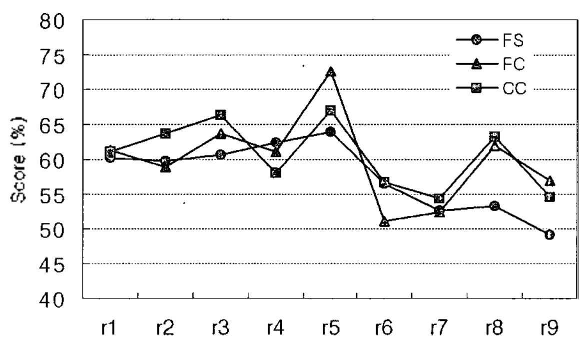


Fig. 13. Average score of syllable listening test at each measurement point.

when recorded sound in the classroom was used while 86.4% of correct ratio was obtained when sound recorded in an anechoic chamber was used as the listening materials. This implies that more absorption could improve the sound intelligibility in the classroom as a functional way.

Fig.13 shows the average score of syllable listening test at each measurement point. As shown in Fig.13 the scores at the center position (r5 and r8) are higher than the scores at the other measurement points on the same crosswise row. It was also found that the minimum score deviation of subjective syllable test is 23.1% when FS source location was used. This denotes that source at FS position gives more stable condition of sound intelligibility in the classroom.

V. Conclusions

The results show that higher D50 value was obtained when sound source was located at the both sides of front wall (FS). It also shows that high sound intelligibility was obtained at the area nearby walls and low values were found at the center area of the classroom. This means that reflective side walls help to increase D50 value. The results also denote that absorptive treatments on the ceiling and floor improve the sound intelligibility in the classroom.

It was also found that the little score deviation of subjective syllable test is acquired with the FS source location. This means that source at FS position gives more stable and higher speech intelligibility in the classrooms. Thus, it can be concluded that split two positions on the front wall is the appropriate sound source position for speech intelligibility in a classroom.

Acknowledgements

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