MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Effects of the Time Related Absorption Changes of Materials on Room Acoustics

Türk Gürkan, Ezgi[1]
Yıldız Technical Universtiy, PhD Student,
34349 Besiktas, Istanbul, Turkey

Yüksel Can, Zerhan[2]
Yıldız Technical Universtiy, Prof. Dr.,
34349 Besiktas, Istanbul, Turkey

ABSTRACT

Temporal damages such as moisture, mechanical effects, dusting or factors related to renewals change the acoustic properties of the materials. This brings out the probability that the room acoustics will be affected. The effects of time related absorption changes on the acoustics of the rooms is the subject of this study.
Within the scope of the study, shoebox and fan shaped four halls for the purposes of speech and music are designed. Each hall has a volume of around 1000m^3. Data related to the time-varying acoustic behaviours of the materials are compiled from the literature and the changes on the room acoustics occurring according to these data are modeled in ODEON v.15.00
In the models, the changes in the room acoustics parameter values are investigated due to effects of the temporal damage factors of the materials. In modified statuses, while the reverberation time values in the halls remain within the acceptable range according to DIN18041:2016-03, the imbalance in the octave bands is found to cause acoustical defects.

Keywords: Room acoustics, Temporal damage, Absorption changes
I-INCE Classification of Subject Number: 76

1. INTRODUCTION

The acoustic properties of materials determine the acoustic comfort conditions of the halls in which they are used. In the halls with a long service life, it is an important requirement to ensure the continuity of the acoustic quality during the usage period. Alterations of the materials acoustical behavior may affect the acoustic comfort conditions of these spaces. The effects of time related absorption changes on the acoustics of the rooms is the subject of this study.

[1] ezgi.turkezgi@gmail.com
[2] zerhanyukselcan@gmail.com

Temporal damages that cause absorption changes are generally due to moisture, dusting and mechanical pressure. Therefore investigation of changes in the acoustic behavior of the surface materials caused by the mentioned effects will help to predict the change of the acoustic conditions of the halls over time.

2. CHANGES OF ABSORPTION COEFFICIENTS DUE TO THE TEMPORAL FACTORS

The rate of change in the absorption coefficients of the building materials exposed to different temporal factors which are shared in literature are investigated. The available studies are listed in Table 2.1.

Table 2.1 *Studies on the Effects of Temporal Factors on Acoustic Conditions*

No	Reference	Author	Year
1	Effect of Paint on the Sound Absorption of Acoustic Materials (1)	V.L. Chrisler	1940
2	Behavior of Acoustic Plates Made of Expanded Perlite Plates in Moist Environments (in Turkish) (2)	Semiha Yılmazer	1998
3	Effects of Compression on the Sound Absorption of Fibrous Materials (3)	Bernard Castagnede, Achour Aknine, Bruno Brouard, Viggo Tarnow	2000
4	The Effect of Moisture on Sound Absorption of Perlite Plates (in Turkish) (4)	Semiha Yılmazer	2002
5	The Effect of Moisture Content on Sound Absorption of Expanded Perlite Plates (5)	Semiha Yılmazer, Mesut B. Özdeniz	2005
6	Effects of Compression on the Sound Absorption of Porous Materials with an Elastic Frame (6)	Chao-Nan Wang, Yan-Min Kuo, Shih-Kai Chen	2008
7	Effects of Compression on Sound Absorption of Transversely Isotropic fibrous Materials at Oblique Incidence (7)	Reza Keshavarz, Abdolreza Ohadi	2013

The rate of change in absorption coefficients of materials after different factors' effects given in the studies are listed in Table 2.2. Some of the studies in Table 2.1 are interrelated so the given data is limited.

__Table 2.2__ Change Rates of Sound Absorption Coefficients of Materials Exposed to Different Factors

No	Material	Temporal Factor	Change Ratio in Absorption Coef. (%)					
			Frequency (Hz)					
			125	250	500	1000	2000	4000
1	Perforated-Porous Materials (Effect of Paint on the Sound Absorption of Acoustic Materials) (1)	Paint	**-53.9**	**35**	**54.4**	**65.1**	**70**	**66.2**
3	Porous Materials (Effects of Compression on the Sound Absorption of Fibrous Materials) (3)	Pressure	X	X	**28,6**	**27,3**	**52**	**43,4**
4	Perlite Plates (The Effect of Moisture on Sound Absorption of Perlite Plates (in Turkish)) (4)	Moisture	X	X	**0**	**-133,3**	**50**	X
7	Porous Materials (Effects of Compression on Sound Absorption of Transversely Isotropic Fibrous Materials at Oblique Incidence) (7)	Pressure	X	X	**27,3**	**4,7**	**-3,3**	X

The positive values given in the table above represent a decrease in absorption coefficient, while those marked with a negative value represent an increase. The values in the lines indicated by “X” are expressed as not being examined or shared because of neglect. Samples with the highest rate of variation are taken into consideration in the studies.

According to the data obtained from the experiments or theoretical studies, the changes in the sound absorption coefficients show great varieties due to the octave bands. This may cause a noticeable difference on the reverberation time (over 5%) depending on the surface area and the usage ratio of the material in the hall.

3. PROPERTIES OF THE HALLS DESIGNED

Within the scope of the study, shoebox and fan shaped four halls for the purposes of speech and music are designed. Each hall has around 1000m^3 of volume. The properties of the halls can be seen in Table 3.1. Plans and sections of the halls took place in Figure 3.1 and 3.2.

__Table 3.1__ Properties of the Halls Designed

HALL NAME	PLAN TYPE	FUNCTION	VOLUME (m^3) (V)	CAPACITY (N)	SURFACE AREA (m^2) (S)	V/N	V/S
S-1000S	Shoebox	Speech	1180	247	881.90	4.8	1.34
S-1000M	Shoebox	Music	1190	120	862,50	9,9	1,38
F-1000S	Fan	Speech	1115	246	844.80	4.5	1.32
F-1000M	Fan	Music	1151	100	845,90	11,5	1.36

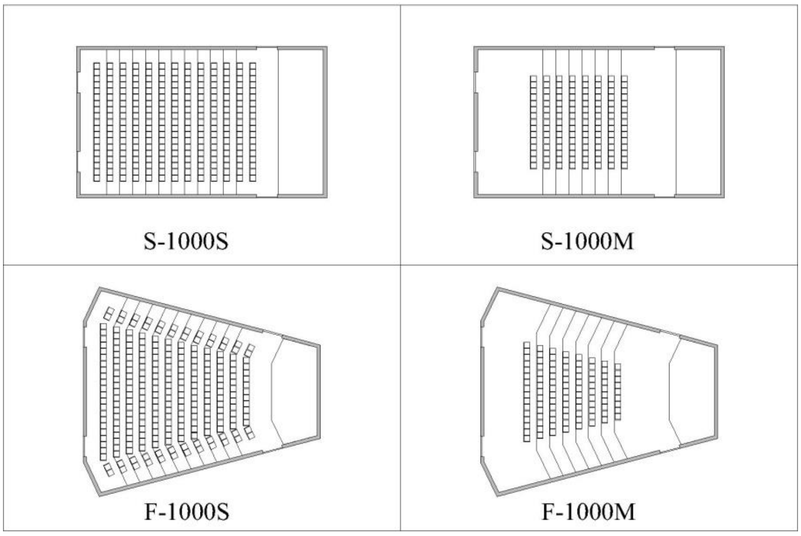

Figure 3.1 *Plans of the Halls*

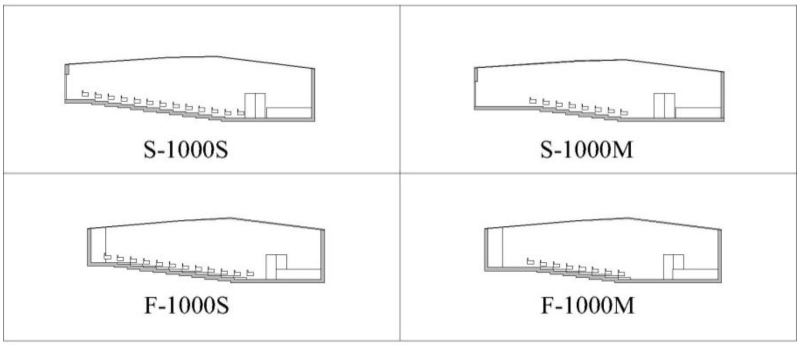

Figure 3.2 *Sections of the Halls*

The initial acoustic statuses of the halls are formed depending on the recommended reverberation time (RT) intervals proposed in DIN18041: 2016-03 (see Table 3.2.) according to the related function and volume sizes (8). The effects of plan type and function difference are also investigated in the study. The diversity in the study gives the possibility of making a comparison according to plan type and function.

Table 3.2 *Recommended Reverberation Time Intervals for the Halls*

Hall	**RT**	**Frequency (Hz)**					
		125	**250**	**500**	**1000**	**2000**	**4000**
S-1000S	Min	0.63	0.78	0.78	0.78	0.78	0.63
	Max	1.41	1.16	1.16	1.16	1.16	1.16
S-1000M	Min	0.92	1.14	1.14	1.14	1.14	0.92
	Max	2.10	1.70	1.70	1.70	1.70	1.70
F-1000S	Min	0.63	0.78	0.78	0.78	0.78	0.63
	Max	1.41	1.16	1.16	1.16	1.16	1.16
F-1000M	Min	0.92	1.14	1.14	1.14	1.14	0.92
	Max	2.10	1.70	1.70	1.70	1.70	1.70

4. COMPARISON OF THE INITIAL AND MODIFIED HALL STATUSES

ODEON v.15.00 is used for the halls' initial and modified status models. Initial status surface materials are as follows: Reflective wooden panels for side walls, and ceilings, perforated wooden panels for rear walls for both speech-function and music-function halls, carpet for speech-function halls and parquet for music-function halls. Similar materials are used to make comparison possible among the halls. The sound absorption coefficients of the ceiling, floor and wall surfaces of the halls are changed by the rates shared in Table 2.2. For the modified status, the criterion of humidity for reflective wooden surfaces, the staining criterion for perforated wood panels, and the mechanical pressure criterion for carpets are taken into consideration on the absorption coefficients alterations. With the assumption that the seats are fully occupied as a design principle, the absorption coefficients of the seat materials are not changed. The materials specified in the reference studies are not used in initial status models, the absorption coefficients of the materials alike are changed in these ratios. Reverberation Time (RT), Clarity (C_{50}, C_{80}), Sound Transmission Index (STI) and Late Lateral Sound Level (Lj) are examined in the initial and modified statuses and compared in order to determine the effects of the temporal changes of the materials acoustical properties.

The reverberation time values of initial and modified status models can be seen in Table 4.1 and Figures 4.1 – 4.4.

Table 4.1 *Reverberation Time Values of the Initial and Modified Statuses of the Halls*

Hall	RT	Frequency (Hz)					
		125	250	500	1000	2000	4000
S-1000S	Initial	1.01	0.97	0.97	1.01	1.00	0.90
	Modified	0.98	0.99	0.99	0.95	1.03	0.91
S-1000M	Initial	1.34	1.34	1.29	1.34	1.33	1.13
	Modified	1.50	1.77	1.48	1.15	1.59	1.30
F-1000S	Initial	0.87	0.89	0.95	0.97	0.97	0.90
	Modified	0.78	0.94	0.99	0.95	1.00	0.91
F-1000M	Initial	1.42	1.46	1.39	1.49	1.50	1.21
	Modified	1.32	1.54	1.54	1.24	1.85	1.33

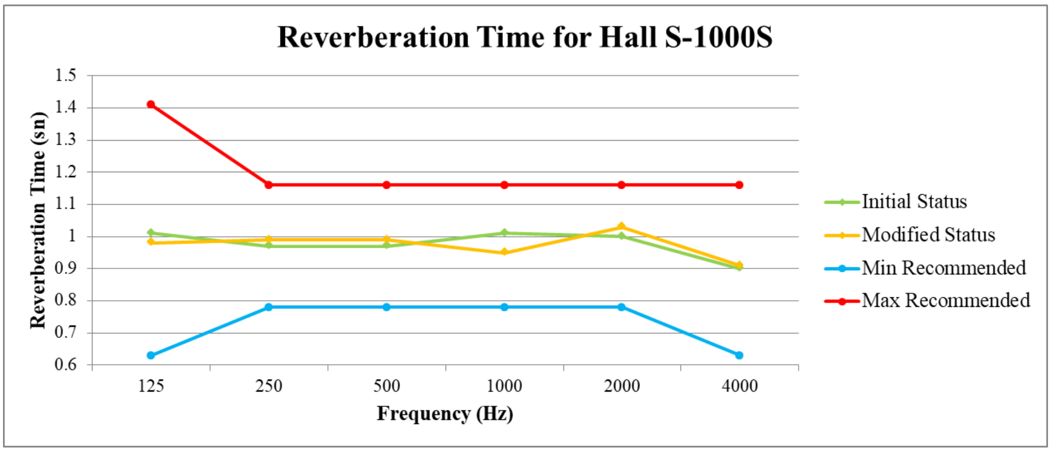

Figure 4.1 *Reverberation Time for Hall S-1000S (Initial and Modified Statuses)*

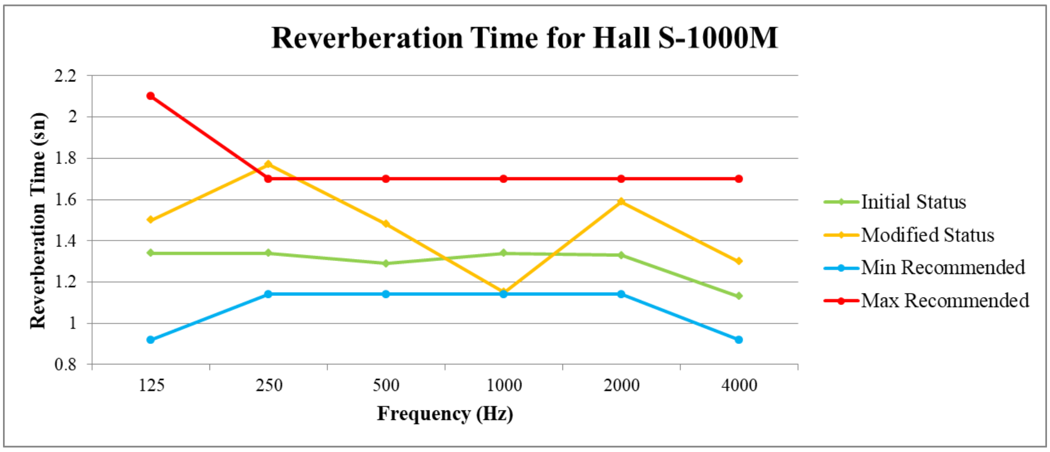

Figure 4.2 *Reverberation Time for Hall S-1000M (Initial and Modified Statuses)*

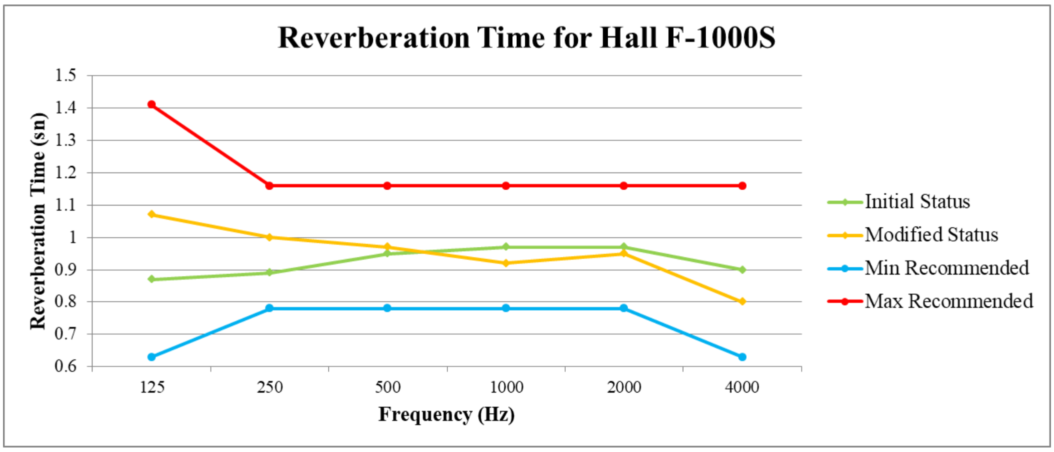

Figure 4.3 *Reverberation Time for Hall F-1000S (Initial and Modified Statuses)*

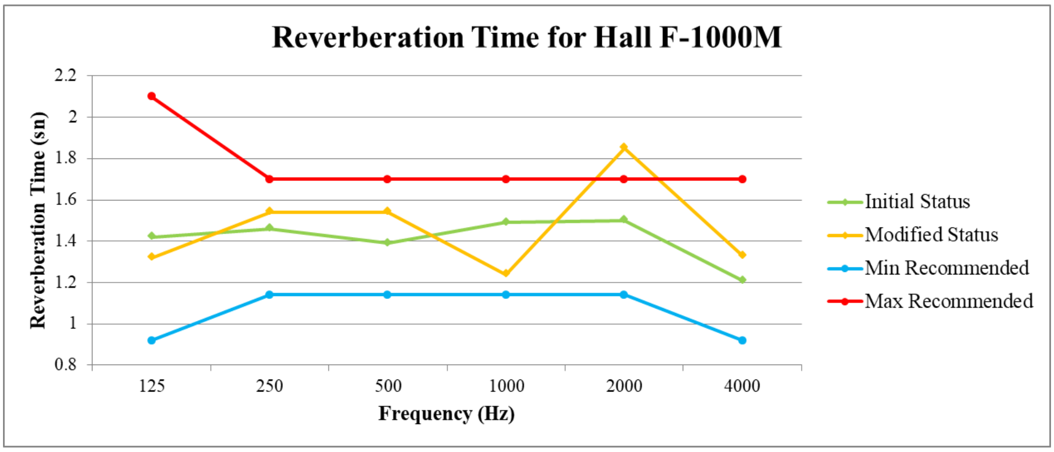

Figure 4.4 *Reverberation Time for Hall F-1000M (Initial and Modified Statuses)*

In the modified statuses, the change in reverberation time values is generally within the acceptable range of the related standard, although it is largely around or above 5%. The exchange ratios between initial and modified statuses models' reverberation time values can be seen in Table 4.2.

Table 4.2 *Exchange Ratios of Reverberation Time Values*

Hall	Frequency (Hz)					
	125	250	500	1000	2000	4000
S-1000S	2.97%	2.06%	2.06%	5.94%	3.00%	1.11%
S-1000M	11.94%	32.09%	14.73%	14.18%	19.55%	15.04%
F-1000S	10.34%	5.62%	4.21%	2.06%	3.09%	1.11%
F-1000M	7.04%	5.48%	10.79%	16.78%	23.33%	9.92%

The difference in reverberation time values of the halls before and after the temporal factors is more than noticeable difference, but it is not possible for the audience to notice this difference for the lack of repeatedly usage.

Although the reverberation time obtained in the modified statuses are in the range of DIN18041: 2016-03, it is out of the range for one octave band in halls with music function (250Hz in shoebox plan type hall, 2000Hz in fan plan type hall). However, the reverberation times are irregular in the octave bands, moving away from the horizontal tendency. This may cause an acoustical defect, distortion in the halls.

C_{50} and C_{80} parameters are also taken into consideration for the halls with different functions as well as the reverberation time. It is seen that, although the parameters remain within the recommended range (9), the clarity decreases in modified status models. $C_{50(3)}$ and $C_{80(3)}$ values for initial and modified status models of the halls can be seen in Table 4.3.

Table 4.3 *Clarity Values of the Initial and Modified Statuses of the Halls*

Hall	$C_{50(3)}$		Hall	$C_{80(3)}$	
S-1000S	Initial	2.40	S-1000M	Initial	0.89
	Modified	1.93		Modified	0.81
F-1000S	Initial	3.98	F-1000M	Initial	0.90
	Modified	3.77		Modified	0.71

For music-function halls the average value of the Lj and for speech-function halls STI room acoustic parameters thus, distribution of the intelligibility for speech function and the spaciousness for music function in the halls are examined. The distributions of STI and Lj can be seen in Figure 4.5 – 4.8.

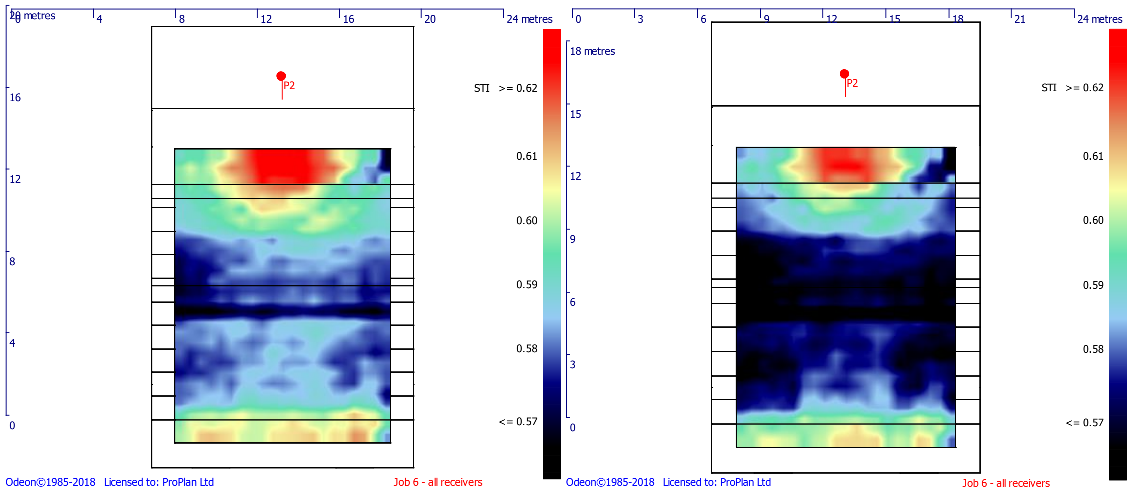

Figure 4.5 *Distribution of STI (Initial and Modified Statuses) (S-1000S) (0,59 – 0,58)*

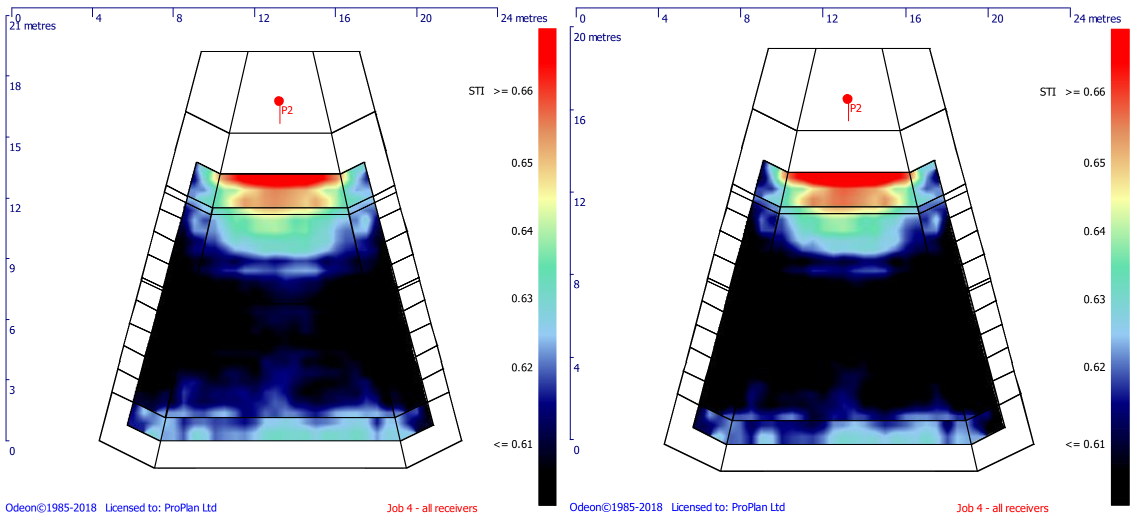

Figure 4.6 *Distribution of STI (Initial and Modified Statuses) (F-1000S) (0,61 – 0,61)*

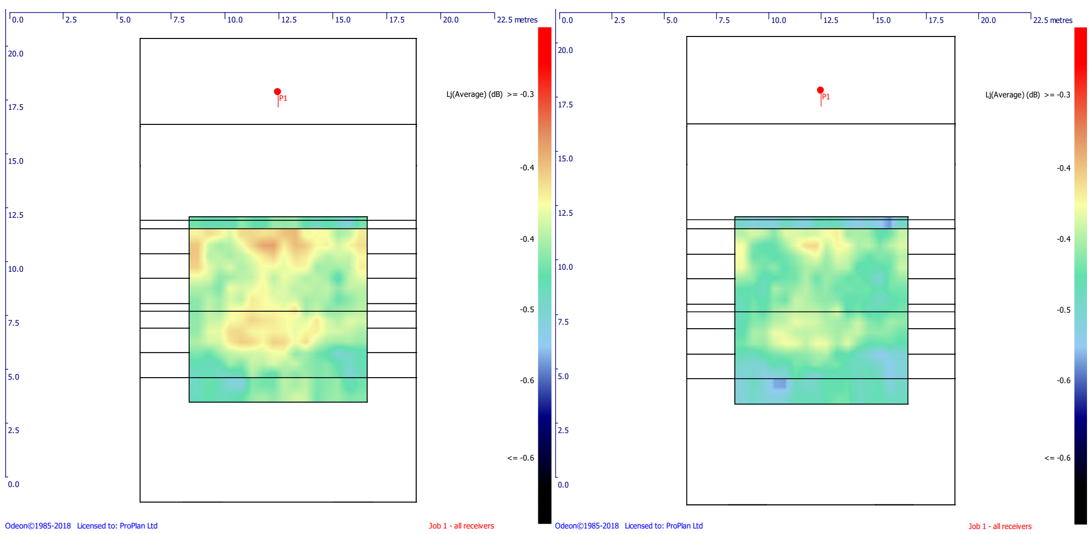

Figure 4.7 *Distribution of Lj (Initial and Modified Statuses) (S-1000M) (-0,4 – -0,5)*

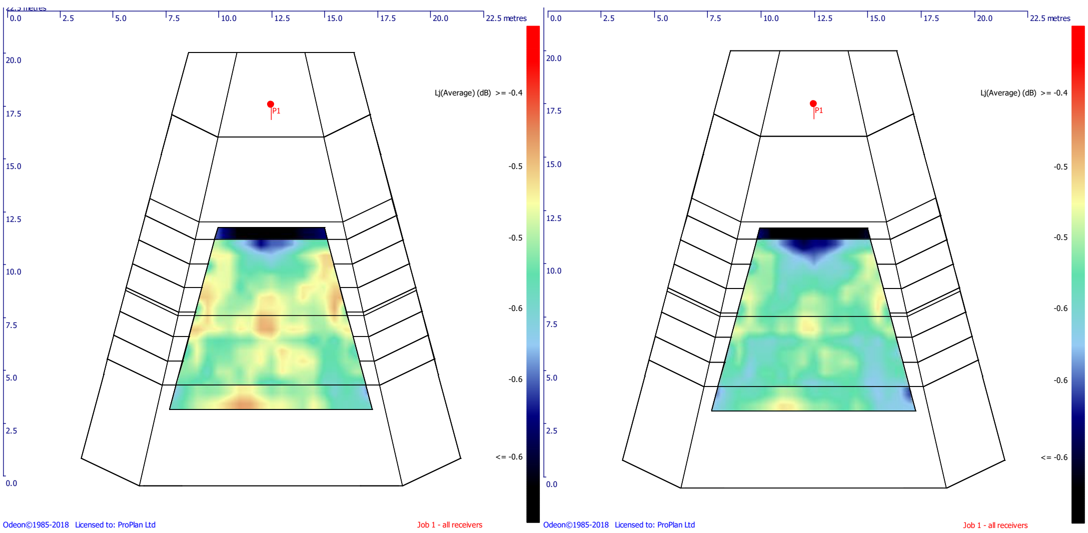

Figure 4.8 *Distribution of Lj (Initial and Modified Statuses) (F-1000M) (-0,5 – -0,5)*

It is seen that, STI and Lj parameters tend to decrease in the modified status of the halls. This means less intelligibility in halls for speech, and less spaciousness in halls for music (10, 11) depending on the settlements in the halls.

5. CONCLUSIONS

The temporal factors that the materials are exposed to, affect and change their sound absorption behaviors. The changes in halls with different plan types and functions are modeled and compared in this study, in which the effects of the changes on the general acoustic conditions of the halls are investigated.

When the changes in the reverberation time, C_{50} and C_{80} parameter values are examined, it is understood that the alterations in the halls having music function is more than those in the halls having speech function. The alteration rates in the fan plan typed halls are less than the shoebox plan typed halls.

Although the room acoustic parameters studied are mostly at the recommended intervals, it is predicted that the irregularity in the octave bands will cause acoustic defects and thus user dissatisfaction. In addition to the recommended reverberation time interval range in DIN18041:2016-03 (± 20%) is found sufficiently large to adversely affect the functions, it is thought that being of the reverberation time of the modified situations in the recommended interval, doesn’t mean that will not affect the general acoustic conditions of the halls.

In this narrow-scope study, the maximum sound absorption coefficient changes in the literature are integrated into the designed halls’ surfaces according to the acoustic tendencies of the materials and the changes in the general acoustic conditions of the halls are examined. Further investigating taking into account different hall sizes, shapes and materials diversities are planned in order to generalize the results. It is expected that this will contribute to the estimation of acoustic conditions of the halls over time and the renewal processes.

6. ACKNOWLEDGEMENTS

We wish to thank Yıldız Technical University and Pro-Plan Proje Mühendislik San. ve Tic. Ltd. Şti. for their contribution and valuable technical support to this study.

7. REFERENCES

1. V.L. Chrisler, *"Effect of Paint on the Sound Absorption of Acoustic Materials"*, Part of Journal of Research of the National Bureau of Standards, Volume 24 (1940)

2. Semiha Yılmazer, "*Perlitli Akustik Plakaların Nemli Ortamlardaki Davranışları"*, PhD Thesis, Karadeniz Technical University, Trabzon (1998)

3. Bernard Castagnede, Achour Aknine, Bruno Brouard, Viggo Tarnow, *"Effects of Compression on the Sound Absorption of Fibrous Materials"*, Applied Acoustics, Volume 61, 173-182, Elsevier (2000)

4. Semiha Yılmazer, "*Nemin Perlitli Akustik Plakaların Ses Yutuculuğu Üzerindeki Etkisi"*, İMO Teknik Dergi, 2002 2741-2759, Yazı 183 (2002)

5. Semiha Yılmazer, Mesut B. Özdeniz, *"The Effect of Moisture Content on Sound Absorption of Expanded Perlite Plates"*, Building and Environment, Volume 40, 311-318, Elsevier (2005)

6. Chao-Nan Wang, Yan-Min Kuo, Shih-Kai Chen, *"Effects of Compression on the Sound Absorption of Porous Materials with an Elastic Frame"*, Applied Acoustics, Volume 69, 31-39, Elsevier (2008)

7. Reza Keshavarz, Abdolreza Ohadi, *"Effects of Compression on Sound Absorption of Transversely Isotropic fibrous Materials at Oblique Incidence"*, Applied Acoustics, Volume 74, 383-395, Elsevier (2013)

8. Christian Nocke, *"New Standards in Architectural Acoustics - a German View"*, Proceedings of ACOUSTICS, Australia (2016)

9. Madan Mehta, Jim Johnson, Jorge Rocafort, *"Architectural Acoustics"*, Prentice Hall, New Jersey (1999)

10. Odeon A/S, "*ODEON Room Acoustics Software, User's Manual, Version 15"*, Denmark (2018)

11. British Standard, *"BS EN ISO 3382-1. Acoustics - Measurement of Room Acoustic Parameters - Part 1: Performance Spaces"*, Geneva: International Organization for Standardization (2009)