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Acoustic Improvement Proposal in Historical Building: The Example of The Main Lecture Hall at The Beyazıt Campus of Istanbul University

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Abstract

In the restoration of historical buildings, it is essential to preserve the design decisions of the original period of the buildings. The interior richness of historical buildings should be preserved and the interior volumes of historical buildings should not be reduced, contrary to their original period. In addition, current standards and current needs should be taken into account in the restoration of historical buildings. In this study, the acoustic improvement study of the main lecture hall in Istanbul University Beyazıt central campus was detailed. Acoustic improvement decisions determined in line with the original period of the main lecture hall were explained. In the acoustic improvement proposal, which was carried out without reducing the volume of the main lecture hall, it was suggested to increase the total sound absorption rate in the space. The design decisions of the original period of the main lecture hall were tried to be preserved as much as possible and the acoustic improvement work was detailed in this direction. In line with the DIN18041 standard, it was observed that the reverberation time values required to be provided indoors were within the desired range, and thus, the auditory comfort conditions in the interior were increased. In addition, the main lecture hall was modeled in 3D and analyzed with the help of the acoustic program. With the acoustic improvement proposal, the intelligibility level of the speech was improved in the space.

1. INTRODUCTION

Interventions to be made in historical buildings should be compatible with the original state of the building and the historical identity of the building should be preserved [1]. Improper interventions in historical buildings will not only damage the historical building itself but may also negatively affect the relationship between the historical building and its immediate surroundings. The relationship between historical buildings and their surroundings should be preserved, and the original period design decisions of the building should not be harmed. In addition, considering the requirements of current standards, it is necessary to offer solutions that will not harm the identity of the historical building. In this study, acoustic improvement of the large lecture hall in Istanbul University Beyazıt Central Campus was investigated. The acoustic project of the lecture hall with the largest volume in the Faculty of Law building was detailed. Recommendations for improvement in line with the projects approved by the Conservation Board were presented without giving damage to the original period. To be able to analyze the law faculty building, it is of great importance to explain the development process of the historical Beyazıt Central campus and the place of the Faculty of Law and Faculty of Economics buildings in the development process.

Buildings belonging to Istanbul University Law and Economics Faculties are located in Istanbul province, Fatih District, 618 blocks 19 parcels, and Istanbul University Faculty of Law and Economics buildings are used in connection with the central rectorate building. Law and Economics Faculties buildings were registered as cultural assets to be protected by the conservation board decision dated 09.04.1977 and numbered 9776. In addition, Beyazıt central campus was decided to be located in the Urban and historical site with the conservation board decision dated 12.07.1995 and numbered 6848.

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In the evaluation of Istanbul University Faculty of Law and Economics Buildings, the change of the Beyazıt campus in the historical process should be taken into consideration. Istanbul University Central Building is located on the site of the Old Palace, the first palace built by the Ottoman Turks in Istanbul [2]. The construction of the Old Palace was completed in 1458. The old palace consisted of wooden structures (harem rooms and various pavilions). After the Ottoman emperor Fatih Sultan Mehmet had built the Topkapı Palace and moved to the new Palace, which dominates the Marmara Sea, the old palace continued to be used. While the Ottoman sultan on the throne lived with his family in Topkapı Palace, the old palace was used by the families of the deceased sultans. The Old Palace and the mansions around it suffered a fire in the sixteenth and seventeenth centuries and were rebuilt after each fire. The old palace was used in the management of the military affairs of the Ottoman Empire after the Janissary Corps was abolished in 1826 [2].

Beyazıt Square, located at the entrance of the Beyazıt Campus, has an important place in the modernization history of Istanbul [3]. The renovation of the main gate (Figure 1a and 1b), called the serasker gate in 1864 and 1866, and the construction of the gate used by Istanbul University, is seen as one of the most important changes that took place in Beyazıt Square [3]. The fire tower (Figure 1c), which is often found in historical pictures together with the main gate and is located inside the Beyazıt campus, was built by Sultan II.Mahmud to Senekerim Balyan in 1828 [2] . Its height is 85 meters and it was used to notice the fire quickly. In addition, the central rectorate building (Figure 1d), one of the iconic buildings of the Beyazıt campus, was designed by the French architect Bourgeois and the construction of the masonry building was completed between 1865 and 1866. When the Serasker organization was transformed into the Ministry of War in 1879, the building was used as the Ministry of War [2].

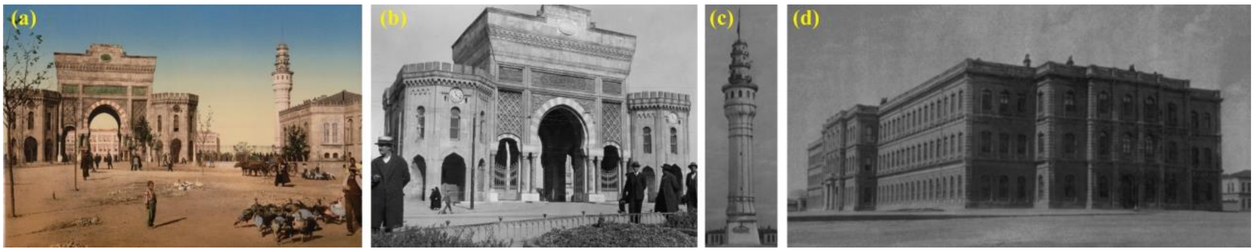

***Figure 1**. Important structures in the Beyazıt Campus, a) Main gate and front of Beyazıt square, between 1890 and 1900 [4], b) Main gate, approximately 1920 [5], c) Fire tower, between 1890 and 1893 [6], d) Central rectorate building, between 1890 and 1893 [7]*

In the historical german blue map of 1913, it can be seen in Figure 2a that the Beyazıt central campus was used by the Ministry of War. It is seen in Figure 2b that the empty spaces provided large areas for military training at the time when the Beyazıt campus was used by the Ministry of War.

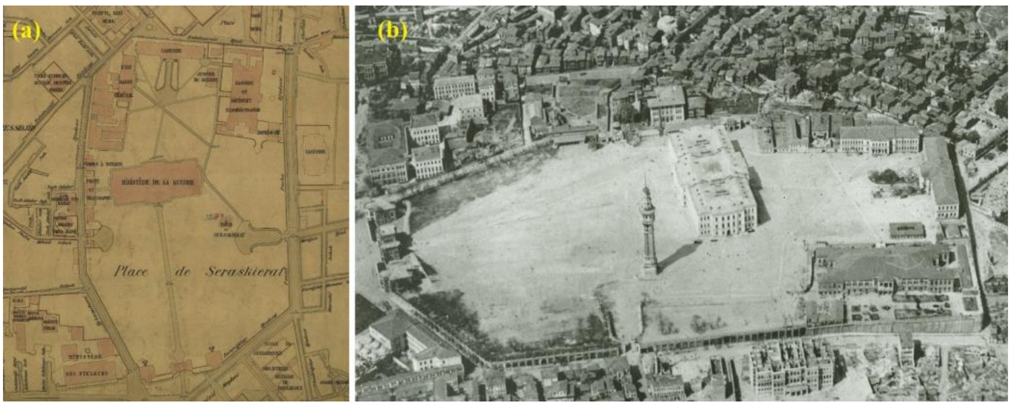

***Figure 2.** Documents belonging to Beyazıt campus used by the Ministry of War, a) German blue historical map (1913) [8], b) Buildings belonging to the Ministry of War in Beyazıt campus (1918) [9]*

With the proclamation of the Republic of Turkey and Ankara becoming the capital, the ministries were moved from Istanbul to Ankara in 1924 and the Ministry of War building in the Beyazıt campus was given to the Darülfünun. In the University Reform carried out in 1933, Darülfünun was closed and Istanbul University was established. In accordance with the decision taken by the Turkish Grand National Assembly on May 31, 1933, Darülfünun was closed on July 31, 1933, and Istanbul University was established on August 1, 1933. Istanbul University, which was opened with a ceremony on November 19, 1933, consisted of the Faculties of Medicine, Law, Science, and Literature [2]. With the establishment of Istanbul University, education activities were carried out in the Beyazıt campus and modern individuals educated for the Republic of Turkey were trained. At the same time, Beyazıt Square, located at the entrance of the Beyazıt campus, was used for social celebrations and became one of the important city centers of the Republic of Turkey. In the photograph, which is predicted to belong to 1933, it is understood that Beyazıt Square was used for the republic celebrations and there was large public participation (Figure 3a). Between 1930 and 1950, it is seen that there was a tram line in Beyazıt Square and vehicle transportation was provided (Figure 3b). In this context, Beyazıt Square, the main entrance gate, and Beyazıt campus have a very important place in the city's memory.

Figure 3. *Photos of Beyazıt Square, a) Republic celebrations of 1933 [10], b) Picture showing Beyazıt tram line and vehicle transportation between 1930-1950 [11]*

Depending on the development strategy at Istanbul University, the needs of the faculties were taken into account and new construction activities were carried out. When there was a need to construct the Istanbul University Faculty of Law and Economics buildings, it was decided to open a competition project within the Beyazıt campus by Istanbul University. The projects participating in the competition project were examined by the jury consisting of 8 people in 1947 and it was decided to construct the first selected project. The first selected project was prepared by Architects Bülent Serbes and Süheyl Üryani [12]. The perspective of the first selected project at the submission of the competition is given in Figure 4. The first selected project was prepared with an integrated design strategy with the Central Rectorate building, the economics and law faculties buildings were positioned to consist of four different building blocks and the buildings were designed to be interconnected [12]. The main building block of the Faculty of Law has 3 floors, including the basement, and has a building area of approximately 12310 m^2. Four different building blocks belonging to the Faculties of Law and Economics have a total area of approximately 28260 m^2. The drawings of the ground-floor and first-floor plan of the first selected project were given in Figure 5.

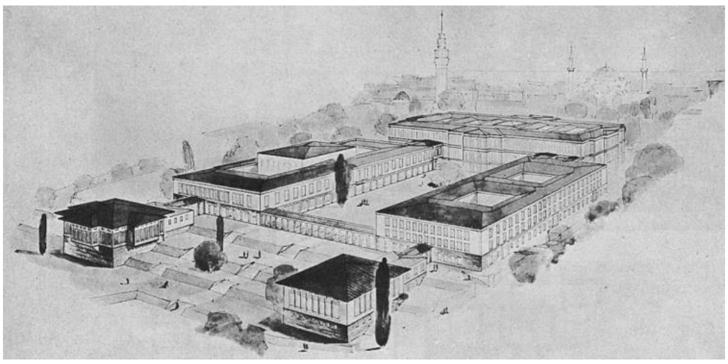

Figure 4. *The project that was selected first in the competition for Istanbul University Faculty of Law and Economics Buildings, the perspective drawing submitted at the delivery of the competition [12]*

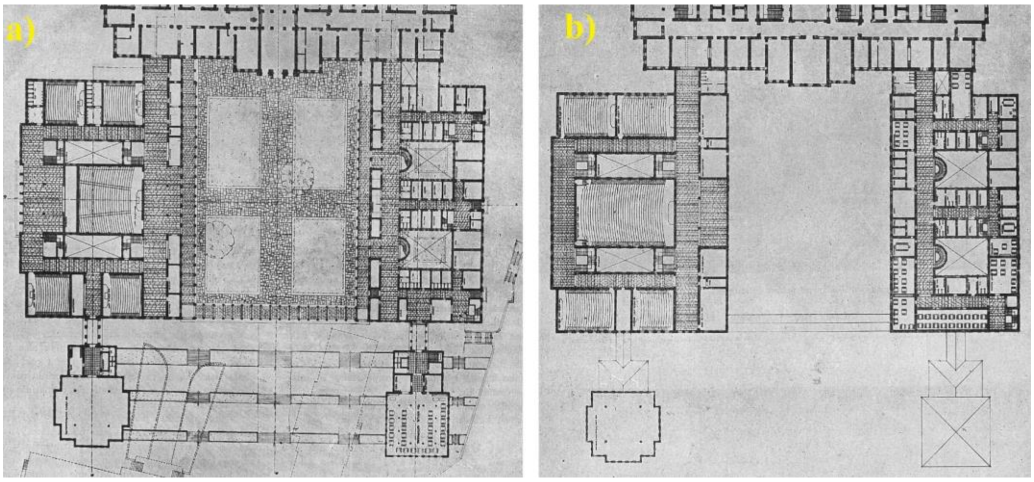

Figure 5. *The project that was selected first in the competition for Istanbul University Faculty of Law and Economics Buildings, the plan drawings submitted at the submission of the competition [12], a) ground-floor plan, b) first-floor plan*

In Figure 6, the site plan and the facade views were given. As can be seen in Figure 6a, it is seen that the area between the Central Rectorate building and the main gate is used as a green area, and no construction is recommended in this area. Since the construction between the main gate and the central rectorate building is not recommended, the perception of large and wide Beyazıt Square has not been harmed. The perception of width is of great importance in the squares where social events take place. In Figure 6b, the facade drawing of the Faculty of Law and Economics buildings submitted to the competition project was given and the historical rectorate building was shown in the facade drawing. The proposed new Faculty of Law and Economics buildings were designed to have a lower building height than the historical rectorate building, and It was not desired to damage the perception of the historical rectorate building.

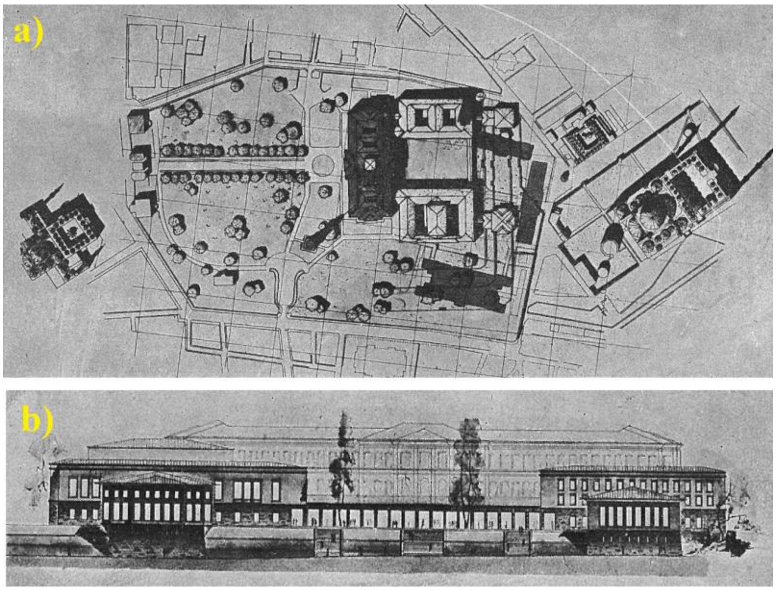

Figure 6. *The project that was selected first in the competition for Istanbul University Faculty of Law and Economics Buildings, the drawings submitted at the delivery of the competition, a) site plan, b) the facade view including the rectorate building [12]*

To describe in detail the development of the buildings belonging to the Faculty of Law and Economics on the Beyazıt campus, Figure 7 shows photographs according to historical chronology. The historical aerial photograph, which is predicted to be in 1918 and was given in Figure 7a, shows Beyazıt Square, Beyazıt campus, and the main central building. The aerial photograph, which is predicted to belong 1952, was given in Figure 7b and it is understood that the building blocks of the Faculty of Law and Economics were completed integrated with the historical rectorate building. In the picture given in Figure 7c, which is predicted to belong to after 1952, it is seen that the historical building known as Sarıkışla has been demolished and removed. Thus, the field of view of the buildings belonging to the Faculty of Law and Economics buildings was expanded and the view of the historical Süleymaniye Mosque from the buildings was provided. In summary, it is understood that a large courtyard was left between the historical rectorate building and the new building blocks during the design process, and the garden in the courtyard and the newly built blocks were intended to visually see the Süleymaniye Mosque.

Figure 7. *The situation of Istanbul University Faculty of Law and Economics Buildings in historical chronology, a) The photo of 1918 (before the buildings of the Faculty of Law and Economics were built) [13], b) The photo of 1952 (Sarıkışla building was located) [14], c) The photo after the Sarıkışla building was demolished [15]*

It is understood from the plan organization in Figure-5 that the main lecture hall was used for educational purposes in the original period when it was first designed. Today, the function of its original period has not been changed and there is no remarkable change in the main lecture hall. It is known that improvements were made within the scope of simple repairs in the lecture hall up to now. The facade of the historical building has been improved in line with the restoration project approved by the conservation board. As part of the facade improvements, the windows in the main lecture hall were improved, the interior was painted and the side facades next to the lecture hall were painted. Today, interior improvement works are carried out in the building in line with the projects approved by the conservation board. The main parameters, which are thought to be necessary to protect the lecture hall, are the necessity of preserving the original interior volume, preserving the original window elevations, and preserving the interior room height. In addition, it was intended to preserve the gypsum ornaments, which are considered to be original period features. Moreover, surface movements considered to be original period properties based on window arrangement were aimed to conserve in the project suggestion. The issues, which are necessary to be protected in the main lecture hall and taken into account in the acoustic project, were clarified in detail in sections 2 and 3.

2. THE PROPERTIES OF MAIN LECTURE HALL

The main lecture hall is located within the building used by the law school. The area of the main lecture hall is approximately 680 m^2. The volume of the main lecture hall is approximately 6920 m^3. The main lecture hall has a total student capacity of 1053. In Figure 6b (in the facade view presented in the competition project), it is understood that the region closest to the height of the rectorate building and having the highest eaves height is the region where the main lecture hall is located. In the first design decisions, it was desired for the main lecture hall to be prestigious and to have a rich interior with a large volume. In the process of change and transformation of Istanbul University, the richness of the interior must be preserved, since the main lecture hall has an important place and is one of the symbols of Istanbul

University. Due to its capacity of 1053 people, it is the largest lecture hall in the Beyazıt campus of Istanbul University. Due to all its features, it is usually chosen as news venue in the television news of the central exams held by the ÖSYM (measurement, selection, and placement center). Many people in our country know the main lecture hall in the central campus of Istanbul University Beyazıt from television news, and the main lecture hall has an important place in the country's memory. Due to the fact that the main lecture hall has an important place in the historical development of Istanbul University on the Beyazıt central campus and its place in the country's memory, the basic design decisions of its original period should be preserved.

The original period features of historical buildings should be preserved and improved according to current regulations and requirements. Due to having the large interior volume of the main lecture hall, auditory comfort conditions should be improved. Medha et al. [16] recommend that the volume per person in speech rooms should be less than 5 m^3. However, even when the main lecture hall is full, the volume per person is above 5 m^3. In this research, interior acoustic improvement suggestions were presented without reducing the original interior space and without giving damage to the design decisions of the original period.

The interior features of the current situation were given in Figure 8. It is understood that the gypsum board suspended ceiling is painted and its reflectivity at high frequencies is high. It has been observed that there are windows on the upper elevations of three of the four separate wall surfaces of the lecture hall. There are no windows only on the upper level of the wall surface of the stage area, but it is seen that the external window system is continued by designing the wall system suitable for the dimensions of the windows. The paint was applied on the plaster on the window sills and window-side surface movements. Just below the window, there is a gypsum ornaments, which is thought to belong to the original period. It is seen that reflective wood panel coverings and regional sound absorbing panels are positioned under the gypsum ornaments on the walls. It is understood that PVC floor covering is applied due to the easy cleaning. In general, it is observed that the reflectivity rate of the materials used in the main lecture hall is high.

Figure 8. *Main lecture hall interior photos*

3. ACOUSTIC ANALYSIS AND IMPROVEMENT SUGGESTIONS

Reducing the room volume can increase the auditory comfort conditions of speech functions and improve speech intelligibility. It is also understood that the main lecture hall is more than the recommended room volume for speech functions. However, reducing the volume in the main lecture hall will reduce the richness of the interior. In the restoration project approved by the conservation board, it was observed that the rich interior features were preserved and the current volume was not reduced. In addition, reducing the volume of the space will result in the inability to benefit from the windows on the upper levels and the inability to illuminate the space naturally. For these reasons, acoustic interior improvement suggestions were presented in this study without reducing the space volume.

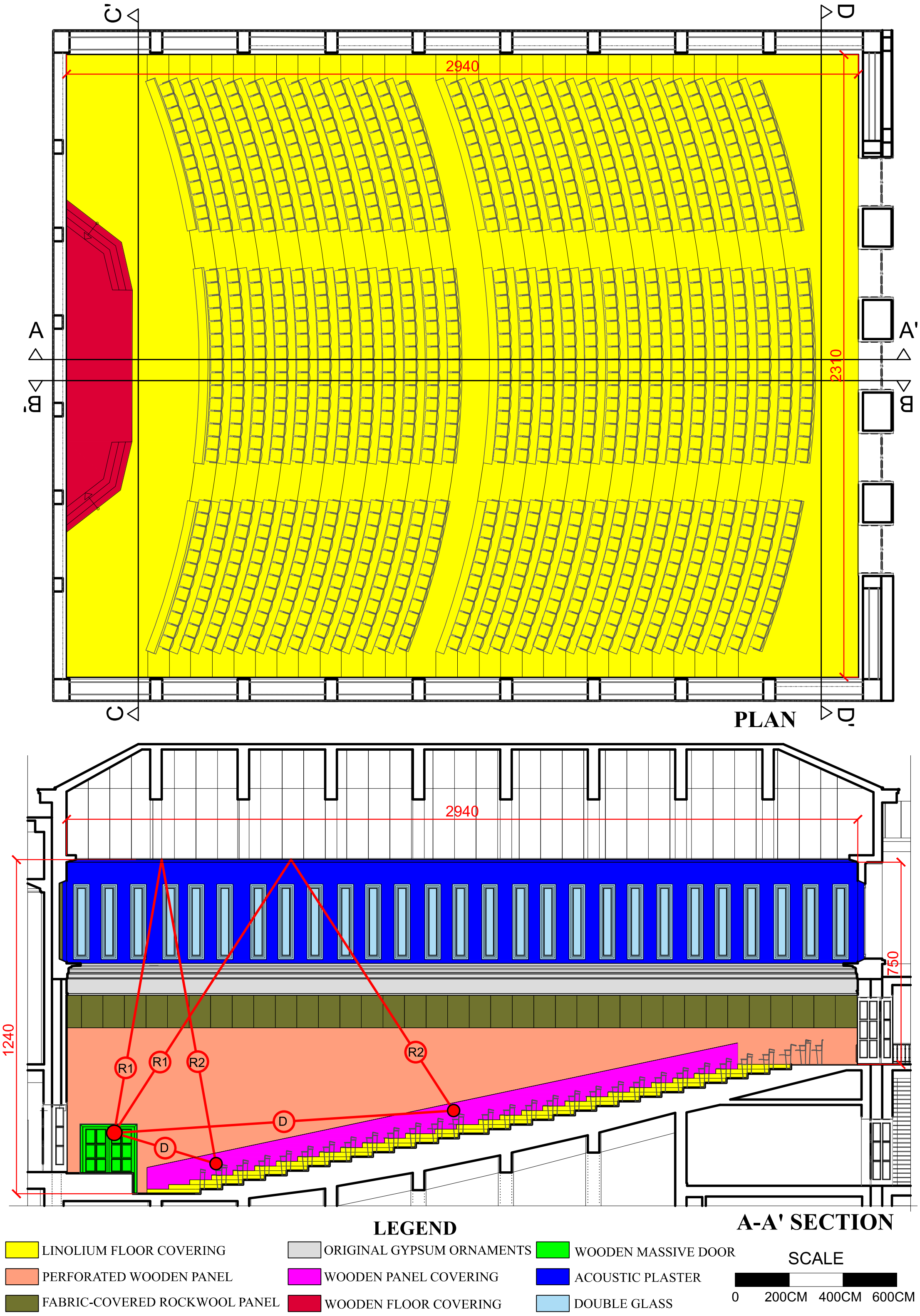

Figure 9. *Acoustic coating project of the main lecture hall, Plan and A-A' section*

It has been foreseen that the high ceiling height, which causes the space volume to be excessive, may cause delayed reflections and the necessary reflection analyzes have been made. Delayed reflections of 30 milliseconds from reflective surfaces can adversely affect auditory comfort [17,18,19]. The formula used in delayed reflections was given in Equation-1. In addition, the analysis of delayed reflections was shown in section A-A' given in Figure 9. It has been calculated that the ceiling reflection of the first 13 rows of students in the A-A' section reaches the receiver after 30 milliseconds. It has been taken into account that hanging the reflective panels in the space may damage the visual perception in the space, disrupt the perception of the large volume of the interior, and decrease the richness of the interior obtained in the lecture hall. Hence, the design decision of the original period can be affected negatively with using hanging the reflective panels in the main lecture hall. In addition, it is seen in the pictures given in Figure-8 that the loudspeaker system is used in the space, there are sound reinforcement systems for the audience in the back rows, and lessons are carried out with the speaker system. For all the reasons stated, it was recommended to use a ceiling surface that has high sound absorption properties. To avoid delayed reflections given in Figure 9 A-A' section, it was suggested to use a perforated acoustic gypsum panel sound-absorbing coating on the ceiling surface. In terms of the integrity of the ceiling covering, it was aimed to be a single material and to be plain as in its original period. The choice of the surface with high sound absorption performance can also be useful in adjusting the reverberation time.

$$ITDG = \frac{(R1+R2)-D}{0,344} \tag{1}$$

ITDG= initial time delay gap (30 ≥ ITDG)
R1= distance between source and reflective panel (meter)
R2= distance between reflector panel and receiver (meter)
D= direct distance between receiver and source (meter)

The reverberation time values of the halls used for speech affect the auditory comfort conditions. It is essential to keep the reverberation time under control in order to ensure the intelligibility of speech. The optimum values of the reverberation time of the halls used for speaking purposes are detailed in the DIN 18041 standard [20,21,22]. It has been explained that the optimum reverberation time is calculated depending on which indoor function type and interior feature [20,21]. In accordance with the DIN18041 standard, the optimum reverberation time can be calculated by using Equation-2 in the main lecture hall where lessons are carried out with the loudspeaker system [21,23,24]. Since it is recommended that the volume of speech rooms should be less than 5000 m^3, the DIN standard is generally used up to 5000 m^3 indoor volume. However, in the acoustic project proposal, it was not recommended to reduce the indoor volume, and the optimum reverberation time was calculated according to the interior volume being approximately 6918, respecting the design decisions of the original period. Using Equation-2, the optimum reverberation time of the main lecture hall was calculated to be approximately 1.059 seconds.

$$T_{TARGET} = [0,32 \text{ x } \log[V]-0,17] \text{ s} \tag{2}$$

V= room volume (m^3)

In the DIN 18041 standard, the recommended maximum reverberation time level and the recommended minimum reverberation time level are detailed in line with the optimum reverberation time (T_{TARGET}). The recommended maximum reverberation time level and the recommended minimum reverberation time level were given in Figure 10, according to the optimum reverberation time level and the frequencies [21,22]. In accordance with the optimum reverberation time calculated according to Equation 2 and the interval values specified in Figure 10, the required minimum and maximum reverberation time values that should be in the main lecture hall were calculated. Calculated values were presented in Table 1.

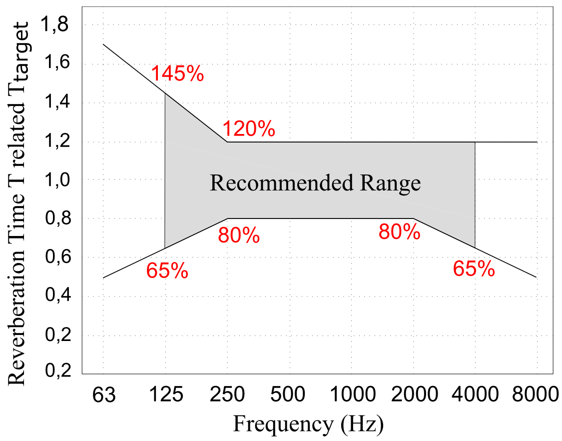

Figure 10. *The interval region of the reverberation time according to the DIN 18041 standard [20,21,22]*

Table 1. *In accordance with the DIN 18041 standard, the minimum and maximum reverberation time values which the main lecture hall should be satisfied*

Reverberation time values	Frequency (Hz)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Required maximum reverberation time	1,54	1,27	1,27	1,27	1,27	1,27
Required minimum reverberation time	0,69	0,85	0,85	0,85	0,85	0,85

To increase the intelligibility level of speech, the reverberation time should be kept under control [1]. It was aimed to keep the reverberation time under control without reducing room volume value in the main lecture hall. The formula for the reverberation time was presented in Equation 3 [18,25,26]. In Equation 3, when the room volume is increased without changing the total absorption value, the reverberation time increases. If the total absorption value is increased without changing the room volume value, the reverberation time decreases. Calculation of total absorption was given in Equation 4 [27,28]. Due to the large volume of the main lecture hall and the highly reflective surface ratio, the total absorption ratio in the room should be increased. If the total absorption value in the main lecture hall is increased, the reverberation time interval defined in Table 1 can be reached without reducing the volume of the main lecture hall.

$$\mathrm{RT} = 0.161\ \frac{\mathrm{V}}{\sum\mathrm{A}} \tag{3}$$

RT= reverberation time of a room (sec.)
V= volume of room (m^3)
∑A= total absorption in the room (Eq. 4) (metric sabins). ∑A includes absorption provided by room boundaries, audience, furnishings, air, etc.

$$\sum\mathrm{A} = \left((\alpha_1\ .S_1 + \alpha_2\ .S_2 + \ldots + \alpha_n\ .S_n) + x.V\right) \tag{4}$$

α_1, α_2, α_n = sound absorption coefficients (For different surface based on material properties)
S_1, S_2, S_n = respectively different room surfaces
x = air absorption coefficient

In order to increase the total absorption in the main lecture hall, surfaces having reflective surface characteristics were reduced as much as possible and surface types, which have high sound absorption performance, were selected. The acoustic coating project of the main lecture hall was presented in Figure 9 and Figure 11. It was recommended to remove the PVC flooring and replace it with a linoleum flooring layer. It was aimed to reduce the impact sound by proposing an elastic linoleum floor covering. In the acoustic coating project (Figure 9 and Figure 11) A-A', B-B', and C-C' sections, it was seen that the wood coating regions are defined. With the suggestion of reflective wood coating, it was desired to increase the level of sound energy at the receiver points without causing delayed reflections. All wall surfaces, except for the reflective wood coatings, windows, doors, and the original gypsum ornaments, have an absorptive character. It was understood that gypsum ornaments belonging to the original period were preserved in the A-A' section given in Figure 9 and the B-B', C-C', D-D' sections given in Figure 11. Sound absorption performance is very low on wall surfaces where paint applications are carried out. However, it was predicted that gypsum ornaments were one of the design decisions of the original period. It was estimated that the gypsum ornaments belong to the original period and it was not recommended to remove the gypsum ornaments. In addition, it was observed that the original gypsum ornaments were preserved in the restoration project approved by the conservation board and it was suggested to be protected by improvement.

The coating feature of the walls has been changed in order to increase the overall absorbency in the main lecture hall. Except for the original gypsum ornaments, reflective wood coatings, glass surfaces, and wooden doors on the walls, all of the wall surfaces were covered with materials having high sound absorption performance. It was recommended to use perforated wood panels with high sound absorption performance and fabric-covered panels up to the original gypsum ornaments level. In sections A-A', B-B', C-C,' and D-D', the positions of perforated wood panels, which have high sound absorption performance, and fabric-covered rock wool panels were shown (Figure 9 and Figure 11).

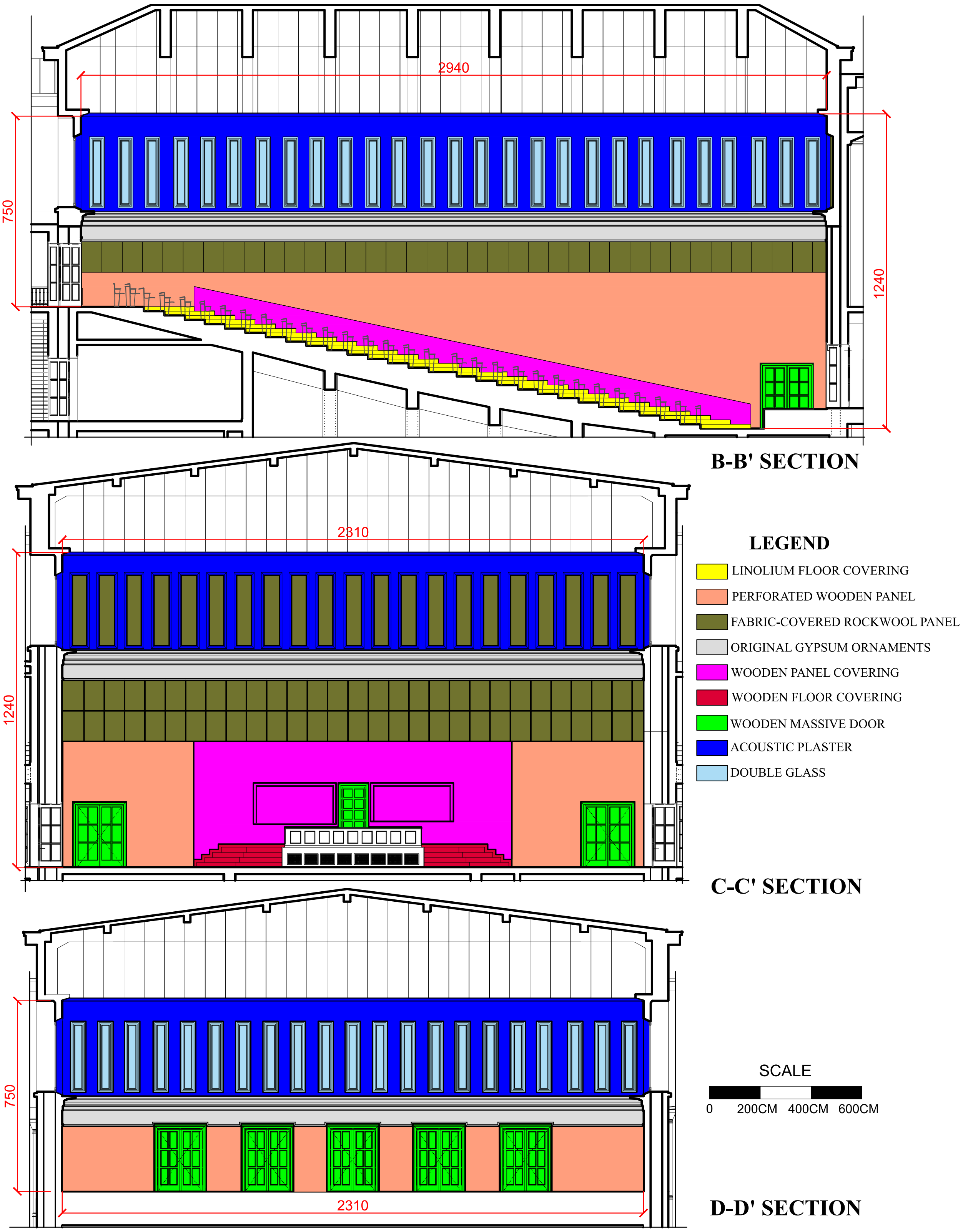

Figure 11. *Acoustic coating project of the main lecture hall, B-B', C-C' and D-D' sections*

It was recommended to use an acoustic plaster coating on surfaces above the original gypsum ornaments. It was foreseen that it will be difficult to cover the small-sized wall movements (window teeth) formed on the sides of the windows with sound-absorbing acoustic panels. It is foreseen that it will be difficult to cover the small-sized wall movements (window teeth) that occur on the window sides with sound-absorbing acoustic panels. Moreover, it was suggested to apply acoustic plaster on the wall surfaces upper levels in order to achieve a similar visual effect of the original period. On the wall surface in C-C' section (Figure 11), on the upper elevation wall surfaces where the window teeth are continued, regional fabric-covered rock wool panel applications were suggested in order to emphasize the surface movement of the original period.

It was recommended to use perforated gypsum board covering, which has high sound absorption performance, on the ceiling surface. In general, the total absorption value of the main lecture hall was increased. After increasing the total absorption value, reverberation time analyzes were carried out. Sound absorption coefficients of the selected surface materials were taken from the literature or material catalogs on the internet. The detailed properties of the coatings used in the main lecture hall reverberation time analysis and the references from which the sound absorption coefficient was taken were given in Table 2. Reverberation time analysis was carried out according to the properties of the materials given in Table 2.

Table 2. *The properties of the coverings and the references which the sound absorption coefficient was obtained*

Type and Properties of Coating	REFERENCE
Linoleum floor covering	Cox& D'Antonio [29]
Perforated wooden panel covering (20 cm depth, distance between holes 16 mm, hole diameter 5 mm, percentage of perforation 7.6%, panel thickness 16 mm, 40 mm thick rock wool with 30 kg/m^3 density in the cavity)	Decustik company catalog [30]
Fabric-covered rock wool panel (50 mm thick, rock wool density 150 kg/m^3)	Yılmaz Demirkale [18]
Original gypsum ornaments (painted plaster surface)	Cox& D'Antonio [29]
Wooden panel (1 cm thick)	Cox& D'Antonio [29]
Wooden floor covering (stage) (on concrete surface)	Cox& D'Antonio [29]
Perforated acoustic gypsum panel (gypsum panel thickness 12.5 mm, hole diameter 8 mm, distance between holes 18 mm, back layer has lining, hole rate 8.7%)	Knauf company catalog [31]
Acoustic plaster	Cox& D'Antonio [29]
Solid wooden door	Cox& D'Antonio [29]
Audience on timber seats (1/m^2)	Cox& D'Antonio [29]
Double glazing (2-3 mm glass and 1 cm space)	Cox& D'Antonio [29]

The reverberation time of the main lecture hall was calculated according to Equation 3 and Equation 4. The results of the reverberation time analysis according to the frequencies were presented in Table 3. In Table 3, the total absorption values calculated according to the frequencies were also given.

Table 3. *Reverberation time results of the main lecture hall*

SURFACE PROPERTIES		**FREQUENCY (HZ)**											
		125 Hz		**250 Hz**		**500 Hz**		**1000 Hz**		**2000 Hz**		**4000 Hz**	
Surface Type	**Area (m^2)**	**α**	**S. α**	**α**	**S. α**	**α**	**S. α**	**α**	**S. α**	**α**	**S. α**	**α**	**S. α**
Linoleum floor covering	276,77	0,02	5,54	0,02	5,54	0,03	8,30	0,04	11,07	0,04	11,07	0,05	13,84
Audience on timber seats	581,26	0,16	93,00	0,24	139,50	0,56	325,51	0,69	401,07	0,81	470,82	0,78	453,38
Wooden floor covering	39,3	0,15	5,90	0,11	4,32	0,10	3,93	0,07	2,75	0,06	2,36	0,07	2,75
Perforated wooden panel	226,4	0,64	144,90	0,76	172,06	0,63	142,63	0,63	142,63	0,35	79,24	0,14	31,70
Fabric-covered rock wool panel	159,63	0,35	55,87	0,70	111,74	0,90	143,67	0,90	143,67	0,95	151,65	0,90	143,67
Wooden panel	87,46	0,28	24,49	0,22	19,24	0,17	14,87	0,09	7,87	0,10	8,75	0,11	9,62
Perforated acoustic gypsum panel	640,01	0,40	256,00	0,45	288,00	0,45	288,00	0,45	288,00	0,45	288,00	0,50	320,01
Painted plaster surface	233,1	0,02	4,66	0,02	4,66	0,02	4,66	0,02	4,66	0,02	4,66	0,02	4,66
Solid wooden door	52,4	0,14	7,34	0,10	5,24	0,06	3,14	0,08	4,19	0,10	5,24	0,10	5,24
Double glazing	126	0,10	12,60	0,07	8,82	0,05	6,30	0,03	3,78	0,02	2,52	0,02	2,52
Acoustic plaster	414,69	0,30	124,41	0,35	145,14	0,50	207,35	0,70	290,28	0,70	290,28	0,70	290,28
Air (Volume- m³)	6918 m^3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	69,18	0,02	138,36
Total Absorption, ∑ A (sabins)			729,16		904,28		1148,36		1299,98		1314,59		1277,67
Calculated Reverberation Time			**1,53**		**1,23**		**0,97**		**0,86**		**0,85**		**0,87**

The reverberation time analysis was not carried out according to the complete filling of 1053 seats. During the on-site investigations, it was understood that it would be rare for 1053 people to use it at the same time.

Considering the general conditions of use, it was predicted that the audience sitting on a wooden seat would be 1 person per square meter, and accordingly, the sound absorption coefficient was taken from the literature and used in the reverberation time analysis (it was not assumed that 2 people sit on average in 1 square meter). The reverberation time results according to the frequencies given in Table 3 and the recommended minimum and maximum reverberation time values according to the frequencies given in Table 1 were compared. Calculated reverberation time results of the main lecture hall according to the frequencies, the recommended minimum reverberation time values, and the recommended maximum reverberation time values were shown in Figure 12. It has been observed that the reverberation time values calculated according to 6 different octave band frequencies are appropriate. According to the DIN 18041 standard, calculated reverberation time values are within the desired range.

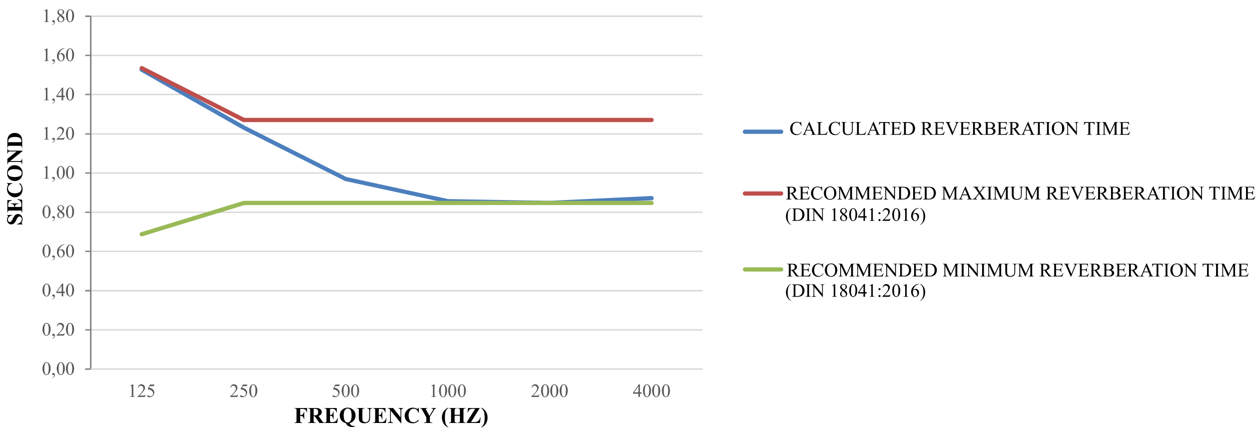

Figure 12. *Reverberation time results of the main lecture hall*

In this study, reverberation time calculation was carried out according to the general calculation method (Eq.3) regardless of the specific listening point, and a comparison of reverberation time calculation and DIN 18041 standard requirements was done according to the general calculation method. The reverberation time calculation for each receiver point is usually carried out in the acoustic computer modeling software. ODEON, CATT, and I-SIMPLIA software can be given as room-acoustic modeling software used in the literature. In the acoustic software, homogeneous propagation of sound can be examined, and the propagation of sound can be analyzed depending on the dimensions of the room. In the room-acoustic software analysis, the shape of the hall, the position, the tilt angle, and the structure of the surfaces/panels are used as important parameters in the calculation method. For example, two different measurement methodologies, which are listed as the image-source method and the ray-tracing method, are generally used in the ODEON program, and analyses are carried out in this direction. It should be known that different calculation methods exist to perform detailed room acoustic analyses, and these methods are used in the room acoustic software.

In the interior design stage, it should be intended to ensure homogeneous propagation of sound. The concentration of sound at certain points can cause acoustic problems. Focusing, echos, flutter echos, whispering galleries, and shadow zones are among the most frequently encountered indoor acoustic problems. Homogeneous propagation of sound can be examined in acoustic simulation programs. In acoustic simulation programs, receiver zones can be defined and acoustic parameters at receiver points can be evaluated. If an acoustic problem is observed in a room, there may be serious value differences between the receiver zones. In this study, the main lecture hall was analyzed in the acoustic simulation program in order to predict if there are acoustic problems and to examine the homogeneous propagation of the sound. It is seen that the I-SIMPA software can be used in acoustic analysis studies in the literature [24,32]. In this study, the I-SIMPA program, which is given as an open-source on the internet, was used and only the distribution of the reverberation time at the receiver points was analyzed. Version 1.3.4 of the I-SIMPA software was used. The main lecture hall was modeled approximately in 3D and the 3D model was transferred to the I-SIMPA software. After the 3D model was transferred to the I-SIMPA software, the coating properties of the surfaces were defined. After the sound absorption coefficient properties of all surfaces were defined in the I-SIMPA software, the interior images were taken from the program. Images obtained from the I-SIMPA program were given in Figure 13.

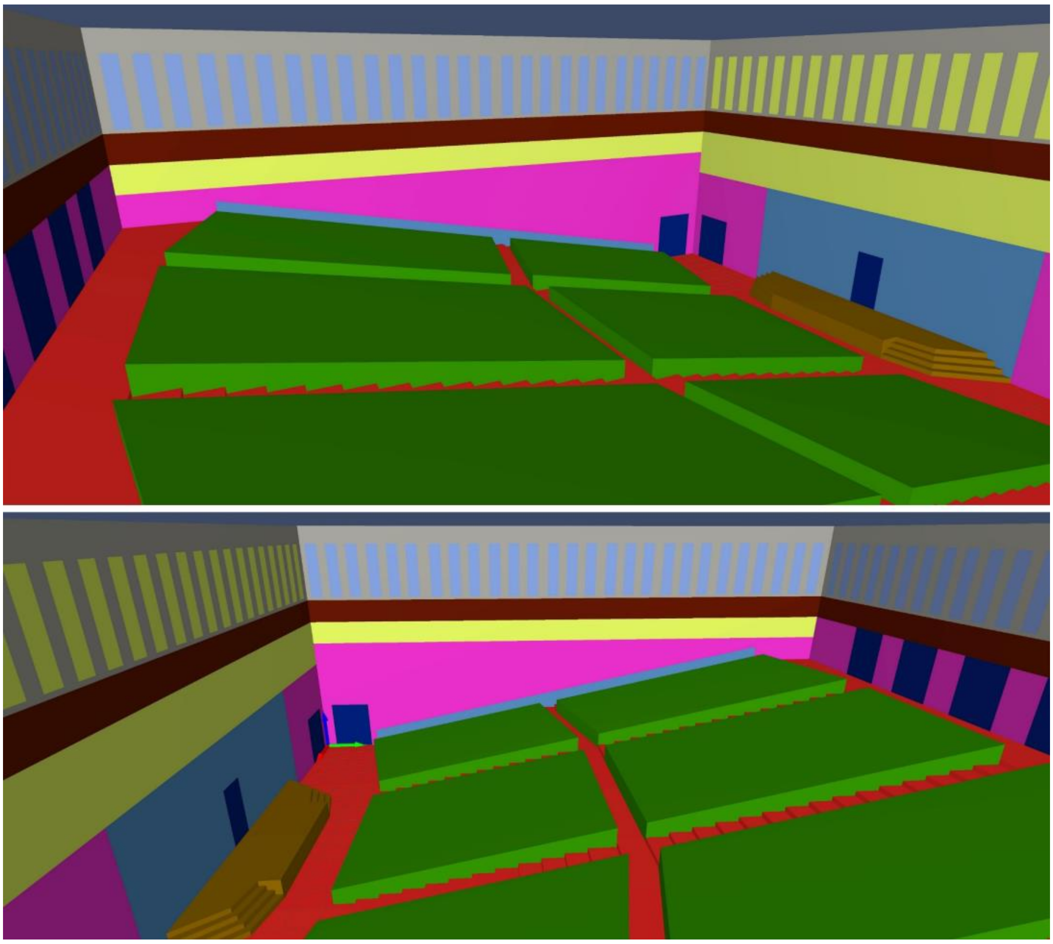

Figure 13. *The model in the I-SIMPA software (after the absorption values were defined)*

The loudspeaker system is used in the main lecture hall and there are loudspeaker sound sources at multiple points. The approximate positions of the loudspeakers were determined in line with the interior visuals of the main lecture hall given in Figure-8, and 10 loudspeaker points were defined in the acoustic simulation software in line with the current loudspeaker positions. In order to analyze the reflections of the loudspeakers on all wall surfaces, the loudspeakers are defined as omnidirectional in the acoustic software. The positions of the 10 loudspeakers defined in the model were shown in Figure 14. The seating areas in the main lecture hall were defined in the I-SIMPA program as a surface receiver and the grid resolution was entered as 0.5. The analysis was carried out by choosing the SPSS calculation method in the program. T_{15} values of the reverberation time at 500 Hz frequency at the receiver points were shown in Figure 14. It was understood that the T_{15} reverberation time values calculated at 500 Hz are approximately between 1.20 seconds and 0.8. It was determined that the results of the computer software reverberation time and the calculated reverberation time results are approximately compatible with each other. It was also understood that there were no significant differences between the reverberation time values at the receiver points. Reverberation time values did not show large changes in certain regions. It was understood that only small changes can be observed depending on the positions of the loudspeakers. By increasing the total absorption value of the room, the homogeneous spread of the sound was increased in general. It was understood from the computer simulation study that there is no significant acoustic problem in the main lecture hall (focus, whispering gallery, shadow zone, flutter echo, etc.).

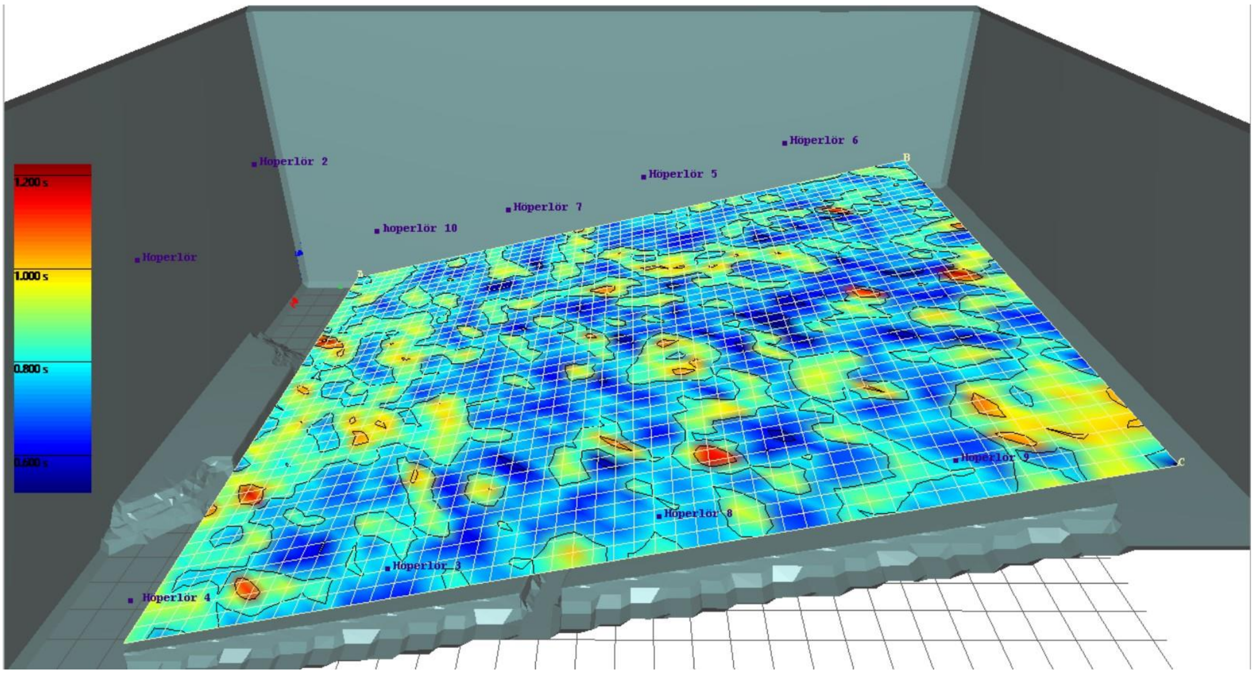

Figure 14. *In the I-SIMPA software, the main lecture hall reverberation time results (T_{15}) at 500 Hz*

The verification of acoustic calculations with sound measurements in the field can be carried out in the literature. Field measurement results and acoustic simulation program results are compared, and if necessary, the acoustic model is calibrated by changing the surface sound absorption values and surface sound scattering values. The results obtained with this method are more accurate and more reliable. However, there must be suitable measurement conditions for the validation of acoustic modeling results with field measurements. To make field measurements, an annual calibrated sound measuring device is required. Field measurement results and software modeling results should be compared to analyze the acoustic project results. In this context, the acoustic improvement applications should be completed in the field to perform field measurements. The suggested acoustic project for the main lecture hall has not been applied in the field. In addition, restoration applications are currently being carried out in the interior of the law faculty building. There are no suitable conditions for sound measurements in the main lecture hall. Due to the reasons stated, sound measurements could not be performed in the field.

With the acoustic improvement proposal, the total absorption value was increased without changing the volume of the main lecture hall, and it was aimed to enhance the auditory comfort conditions. The acoustic improvement proposal was presented in line with the restoration project approved by the conservation board. The total volume of the main lecture hall was not reduced, the positions and numbers of wooden seats were not changed, the dimensions of the stage were not changed, and hanging reflective panels were not recommended on the ceilings in a way that may damage the perception of richness of the interior space. Necessary sensitivity was shown so that the design decisions of its original period were not changed. Considering all these parameters, an acoustic improvement proposal was prepared and it was intended to improve the auditory comfort conditions of the main lecture hall with the proposed project.

4. CONCLUSION

It is necessary to preserve the original period decisions of historical buildings, not to reduce the space volumes of the original period, and to preserve the rich interior features. The reduction of the historical space volume against its original period and the closing of the existing windows due to the lowering of the ceiling level can damage the perception of the rich interior space. The interior volumes of historical buildings should be preserved in harmony with the original period, and intervention decisions in restoration projects should be decided accordingly. At the same time, the requirements of current standards and current needs should be taken into account in the restoration of historical buildings that need to be protected. In this study, the acoustic design of the main lecture hall of the Faculty of Law building on the Beyazıt campus of Istanbul University was detailed. Interventions to be made in the historically registered building to improve auditory comfort conditions were explained.

In the first part, the place of the Faculty of Law and Economics buildings in Istanbul University in the historical development of Istanbul University and its relationship with historical buildings were clarified. In the second part, the characteristics of the main lecture hall in the registered law faculty building were explained and its place in the country's memory was emphasized. In the third chapter, the acoustic improvement decisions of the main lecture hall were explained and the design decisions taken depending on the characteristics of the historical building were detailed. The total absorption rate in the space was increased without changing the volume of the historical lecture hall. With the acoustic improvement project realized in line with the design decisions of the original period of the historical building, the auditory comfort conditions of the main lecture hall were improved. Obtaining the reverberation time interval specified in the DIN 18041 standard was achieved and the intelligibility of speech was increased. The reverberation time values calculated in the computer simulation software were compared and it was stated that there was no significant acoustic problem affecting the homogeneous propagation of the sound in general.

Restoration projects of historical buildings should be prepared in accordance with current standards and restoration projects should be detailed without damaging the original period decisions of the historical building. In this context, there is a need for detailed application examples in the literature. Restoration of historical buildings in accordance with current standards is a very broad field of research. In addition, acoustic problems can be observed frequently in the vault and dome forms used to ensure load-bearing of the masonry construction. It is an important research topic to examine the acoustic problems arising from the vault and dome form used in historical buildings and to offer solutions to acoustic problems depending on the characteristics of the historical building.

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