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Assessing the Acoustic Comfort Conditions of a Historical Mosque: Pergamon Great Mosque

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Objective acoustical parameters,
Reverberation time.

Abstract: The acoustics of historical mosques are essential cultural heritages that should be protected as carefully as their architectural features. The Pergamon Great Mosque is one of the few large-volume historical worship buildings nearby. Some researchers, especially historians, have studied this mosque. Since the acoustic comfort conditions of the mosque have not yet been studied, the analysis of objective acoustic parameters in the mosque according to ISO 3382 led to the study. The article aims to document its acoustics as an intangible cultural heritage and to analyze the current acoustic conditions of the mosque through background noise levels, T30, D50, C80, STI, and SPLA parameters. When the measurement results are compared with optimum values, it is revealed that the mosque is suitable for music functions. Moreover, the parameter values related to speech are also close to the optimum values. The reason for this situation can be explained by the fact that the renovations have not changed the original physical environment of the mosque. The SPL-A measured at the receiver points are close to each other (except for the women's worship area), and it is thought that the curvilinear forms used on the upper cover and the niches on the walls have a positive effect on the homogeneous distribution.

Tarihi Bir Caminin Akustik Konfor Koşullarının Değerlendirilmesi; Bergama Ulu Cami

Anahtar Kelimeler
Cami akustiği,
Kültürel miras,
Nesnel akustik parametreler,
Yansışım süresi

Özet: Günümüzde tarihi camilerin mimari özellikleri kadar ana ibadet mekânı olarak iç ortam hacimlerinin akustik özellikleri de özenle korunması beklenen önemli bir kültürel miras olarak kabul edilmektedir. Bergama Ulu Cami, bulunduğu bölgedeki az sayıdaki büyük hacimli tarihi ibadet yapılarından biridir. Başta tarihçiler olmak üzere çoğu araştırmacı bu cami üzerinde çalışmalar gerçekleştirdiği ve cami hacminin akustik konfor koşullarını belgeleyen henüz bir çalışma olmadığı tespit edilmiştir. Caminin boyutu, tarihsel önemi ve günümüzde özgün işlevinde hala kullanılır durumda olması yapının akustik özelliklerinin somut olmayan kültürel miras bağlamında belgelenmesine yol açmıştır. Bu çalışma, cami hacminin akustik ortamını belgelemek ve mevcut akustik koşullarını ISO 3382'ye göre objektif akustik parametreler (arka plan gürültü seviyeleri, T30, D50, C80, STI, SPLA) aracılığıyla analiz etmeyi amaçlamaktadır. Ölçüm ile elde edilen ortalama parametre değerleri optimum değerlerle karşılaştırıldığında caminin müzik işlevli ritüeller için uygun koşullarda olduğu görülmektedir. Ayrıca konuşma işlevi ile ilgili parametre değerleri de optimum değerlere yakındır. Bu durum cami için yapılan yenileme çalışmalarının caminin özgün mimarisine ve hacimde kullanılan yapı elemanları özelliklerinde büyük değişikliklere sebep olmamasıyla açıklanabilir. Alıcı noktalarda ölçülen SPL-A'lar birbirine yakın (kadın ibadet alanı hariç) olup, üst örtüde kullanılan eğrisel formlar ve duvarlardaki nişlerin homojen dağılıma olumlu etki yaptığı düşünülmektedir.

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1. Introduction

Mosques are one of the essential building typologies that describe the culture, traditions and history of the region in which they are located. The acoustic properties of historical mosques, considered part of cultural heritage, are also important. The acoustic properties of the historical volume also affect the overall perception of the indoor environment [1].

The idea that acoustics are a cultural heritage, especially in historical worship buildings, has become widespread in recent years [1, 2]. In the literature, many studies investigate the acoustic characteristics of mosques [3, 4, 5] and focus on the relationship between worship building as a 'tangible' cultural heritage and its acoustics as an 'intangible' cultural heritage [6, 7]. An acoustic model of a historical cathedral on the grounds was created in a different study. It did not show the physical traces of the period in which it was built, and even the sound of the cathedral was virtually recreated using "acoustic archaeology". With this work, the sound of the original acoustic environment of the cathedral, which is one of the lost or forgotten intangible cultural heritage values, was restored [8].

From an acoustic point of view, it is seen that the speech function is at the forefront in mosques, but some rituals also have musical requirements. In mosques, giving sermons on Fridays and holidays constitute the speech function, while the hymns sung on some special religious days constitute the musical function. T30, C80, D50, and STI are important objective acoustic parameters to evaluate for sacred buildings, especially mosques, due to the performance of speech and musical rituals. If acoustic problems, such as high background noise levels and long or short reverberation time, occur in mosques, the quality of auditory comfort conditions will be negatively affected. As a result, the consequences of acoustic defects hinder the sense of unity or wholeness that is intended to be created during religious rituals. Therefore, while documenting the acoustic environments of historical mosques, evaluating the environmental conditions in terms of user comfort is important.

When the literature is examined, it is seen that acoustic data can be ignored in conservation studies. Studies in the field of acoustics on Mimar Sinan mosques emphasize the importance of this issue [9, 10, 11]. In Süleymaniye Mosque, it was determined that the closure of the sebus (clay pots) in the dome during repairs caused long reverberation times at low frequencies [10]. In addition, it is thought that the renewal of the plaster applied to the surfaces, which was not in accordance with the original, caused longer reverberation times to be recorded than the original situation [11]. CAHRISMA, one of the leading studies on this subject (Conservation of Acoustic Heritage through Identification and Revitalization of Acoustic Characteristics of Sinan Mosques) Research Project (2000-2003) emphasizes that the acoustics of old buildings are part of cultural heritage. The project aims to identify, revitalize and preserve the visual + acoustic heritage [12]. In another study, it was revealed that acoustic parameters alone are not sufficient in the evaluation of the auditory environment of mosques, and that acoustic parameters should be considered as a whole with the geometric parameters and material properties of mosques. In this context, an acoustic classification is proposed based on the architectural features that are expected to affect the acoustic characters of the main worship spaces of the historical mosques in the Aegean Region [13].

When the researches about the acoustic evaluation of religious buildings are examined, it is seen that church buildings are predominantly the subject of study. There are many studies documenting acoustical features and examining the relationship between the acoustic environment in religious buildings and architectural design [1, 14, 15] In addition to documenting the acoustic properties of churches, the effects of architectural elements and volume formations on acoustics have been studied [16, 17, 18, 19, 20]. Although internationally recognized reference parameter ranges/values have been defined for church buildings, studies are ongoing for mosque-specific assessments.

Bergama, in Turkey, has many cultural heritages, especially worship spaces, which belong to different historical periods. Bergama Great Mosque is the largest mosque structure in Bergama. Today, in addition to being used for religious purposes by a large community, it hosts many visitors throughout the year for touristic purposes. This paper mainly aims to analyze the Bergama Great Mosque as a case, which is architecturally well preserved from past to present, outlining its acoustic characteristics.

2. Material and Method

2.1. Mosque description

As understood from the Arabic inscription of the building, the mosque was built by Bayezid I between 1398 and 1399 [21]. The mosque has a multi-unit basilical scheme. During the Ottoman period, starting from the 15th century, the central plan typology became widespread in mosque architecture, and the construction of mosques with multi-unit basilical plans decreased. According to some sources, it is stated that the Pergamon Great Mosque is the last representative of the multi-unit basilical plan typology [21].

The main worship space, which has a longitudinal rectangular plan, is covered with a top cover using a combination of domes and vaults (Figure 1). The dimensions of the plan are 21.75x 27.85 m, and the height from the floor to the pulley is 11.35m. The volume of the mosque is 6450 m^3. The rectangular plan is divided into three aisles perpendicular to the mihrab wall. The three domes on the mihrab axis have a diameter of approximately 7.5 m. The height of the middle dome (4.95 m) is about 60 cm higher than the others (4.35 m). The side aisles are covered with vaults. The women's mahfil is in the southern part of the mosque and is supported by wooden pillars. It is visually separated from the main prayer hall by perforated wooden surfaces. The mimbar is made of marble, and the preaching platform is made of wood. The mihrab niche was made by using plaster. The frame surrounding the mihrab niche contains many floral motif decorations. The mosque is illuminated by non-wide opening windows (Picture 1).

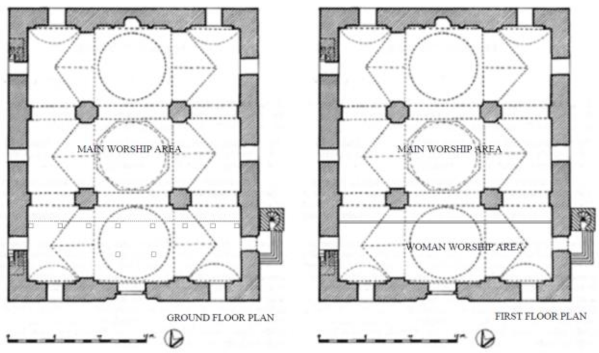


Figure 1. The plan of Bergama Great Mosque [21]

Picture 1. Main worship area and exterior view of the mosque

As a result of the examinations, it is known that the mosque has not received any major intervention except for minor repairs due to earthquakes and other disasters that occurred over time. According to the some researches, the mosque was repaired in 1905 and 1949. Due to the decay of the forged tension irons used in the past to prevent the arches from opening and to connect the building, the irons were removed in the last repair and putrels were put in their place. In 1905, the inscription on the door and the ornaments on the mihrab were uncovered. It is known that the plasters were renewed during the repair works. The minaret, which was demolished in 1949, was reconsidered in 1956 and was demolished and rebuilt during the repairs in 1970-1971. The fountain was also added after 1949. It is stated that the mahfil in the north of the harim was rebuilt during the repairs. Therefore, it is thought that the women's worship area was also used in the earlier periods of the mosque [22]. It can be seen that the original physical environment of the building's interior has been preserved from past to present.

2.2. Field measurement method

Religious rituals take place in mosques where intelligibility of speech and clarity of music are important. The rituals in mosques include the imam's sermon, the reading of the sermon, the hymn recited on important religious days and individual and collective acts of prayer. For this study, the field measurement was based on the prayer ritual and the positions and heights of the imam, and worshipers were adjusted in accordance with this scenario. The prayer ritual can be performed collectively with the congregation or individually. During the congregational ritual, the imam (the source) recites verses and suras from the Qur'an and leads the congregation in prostration, giving commands at regular intervals. Throughout the entire act of prayer, the imam stands facing the mihrab. The congregation performs the ritual, sometimes standing and sometimes sitting on their knees, in accordance with the requirements of the prayer. Objective acoustic parameter values were obtained with the acoustic field measurement performed in the mosque following ISO 3382-1:2010 [23]. Dirac Room Acoustics Software Type 7841 v.6 is used to assess the measured impulse response from receiver points. One preamplifier, one power amplifier, one dodecaedric speaker, one microphone and a microphone tripod were also used in the field measurement. A total of 16 receiver points (R1- R16) were determined for the acoustic measurement. 15 of them are located in the main worship area, and the last one is located in the women's worship area. For each receiver point, the microphone is placed at 0.85 m, considering the ear level of the worshipper sitting on the ground. The front of the mihrab was determined as the omni-power sound source point at the height of 1.50 m, considering the standing Imam position (Figure 2) (Picture 2).

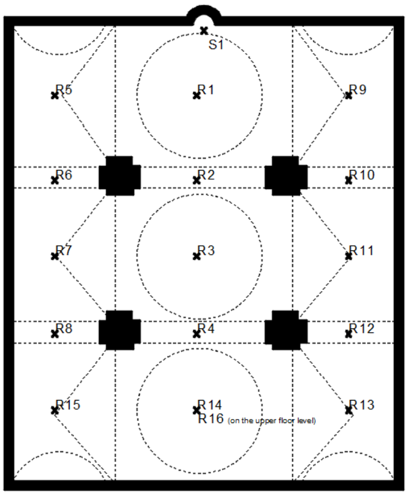


Figure 2. Locations of the sound source and receiver on the plan view of the mosque (S1; Sound source, R1-R16; Receiver points)

Picture 2. The location of R2 and R16

The evaluations between the original condition of the mosque at the time it was built (the historical plastered condition of surfaces such as walls, domes, etc.) and its current condition are not included in the scope of the study. Evaluation studies of both conditions of the mosque are targeted as future studies.

3. Results (T30, C80, D50 and STI Data: Comparison with the Literature)

T30, C80, D50, A-weighted sound levels (SPL-A) and STI are the most definable objective parameters associated with mosques. Related objective acoustical parameters are assessed according to the results of field measurements inside the mosque.

3.1 T30 (s)

Based on reverberation time information, a quick preliminary assessment of the suitability of a space for music or speech can be made. Because of this reason, reverberation time remains one of the most valuable measurable quantities for room acoustics [24]. In this building, the average T30 value in mid frequencies is 2.04 s. The minimum value of the average T30 is 1.91 s at R6, and the maximum is 2.16 sat R7. While T30 average values are obtained close to the recommended ranges for music functions, they were found to be high for speech (Figure 3). It is observed that average T30 values decrease from low to high frequencies. This may have been caused by the fact that carpet, a material with high sound absorption at high frequencies in volume, and a different insulation layer underneath were applied to the floor, one of the mosque's most extensive surfaces.

Creating a warm sound environment for musical rituals is also crucial for mosques. A parameter called bass ratio is used to evaluate the warmth in volumes. This ratio, which is obtained by dividing the T30 values in the low frequencies (125 Hz+ 250 Hz) by the T30 values in the mid frequencies (500Hz+ 1kHz), is expected to be greater than 1.2 according to Egan and is expected to be in the range of 1.1 to 1.45 for volumes with reverberation time between 1.8 and 2.2 s, according to Beranek [25, 26]. According to Long, achieving a rising reverberation time at very low frequencies is difficult due to the weight and thickness of the materials required. High bass reverberation is a beneficial solution for volumes used for unreinforced music but is not necessarily desirable in spaces where the low frequency is provided by loudspeakers [27]. The bass ratio for this mosque is calculated as 2.0, and according to the optimum value suggested by Egan, it can be interpreted that the warmth of the main worship area is suitable for musical religious rituals.

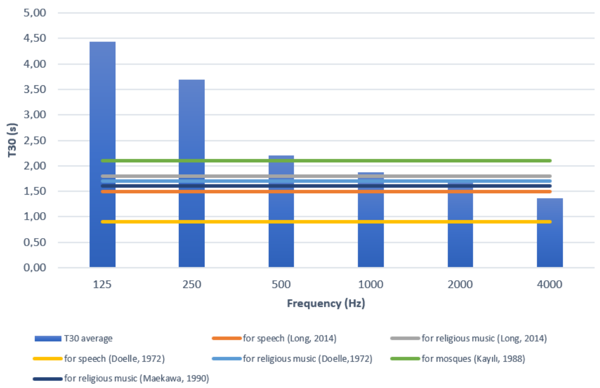


Figure 3. Measured reverberation times in octave bands and the recommended ranges [10, 27, 28, 29]

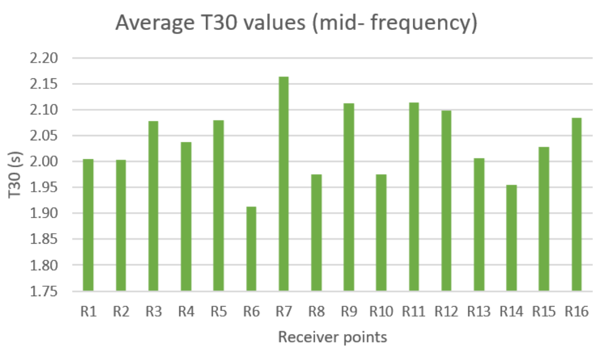


Figure 4. Measured average reverberation times at receiver points (R1-R16)

When the average reverberation time values according to the receiver points are analyzed, it is seen that the lowest T30 values are obtained at the receiver points (R6, R8, R10) under the arches located in the transition sections in the side sections and at point R14 under the women's worship area (Figure 4). It is thought that these differences in values may be due to reasons such as the form of the upper cover of the mosque, the height difference between the middle section and the side sections, and the fact that the transition sections are located behind the columns.

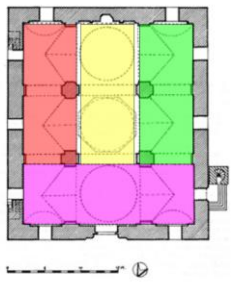


Figure 5. The parts of mosque to evaluate T30 values (■left part, ■center part, ■right part, ■back part)

It is felt that the side sections of the mosque are differentiated from the middle section with the effect of the columns, height differences and the form of the upper cover. In this context, in order to examine the distribution of reverberation time values within the scope of the study, the mosque was divided into 4 main parts: side parts (right / left), middle part (mihrab axis) and back part (women's worship area) (Figure 5).

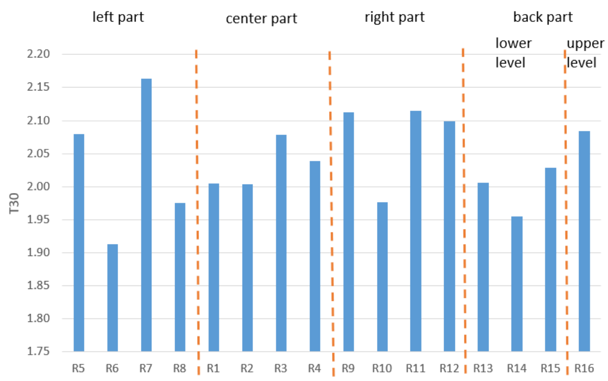


Figure 6. The average T30 values at receiver points

When Figure 6 is examined, it is seen that the T30 value distribution at the receiver points in the center of the mosque is close to each other and more balanced. In the left and right-side sections where the ceiling height decreases, T30 values show a more variable distribution.

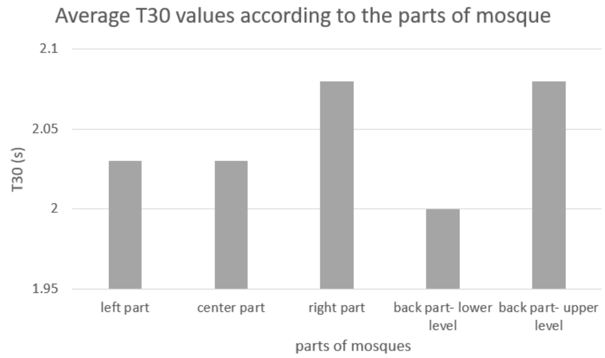


Figure 7. The average T30 values according to the parts of mosque

In Figure 7, the average T30 values for the four main sections of the mosque are calculated and compared with each other. According to the graph, the lowest T30 average was obtained in the back part- lower level, the highest in the right part and back part- upper level as 2.08 s, and the left and the middle parts were obtained at a value of 2.03 s. In general, as a result of obtaining average values close to each other, it can be said that the average T30 values in the parts of the mosque show a balanced distribution.

According to the measurement results, it can be said that the T30 values are high in the right section, but there is no difference that the ear can understand (JND), and in general, the reverberation times are distributed evenly in the main worship area. The use of recessed and protruding surfaces such as niches, domes and vaults on the upper cover and walls, which are common in historical mosques, distorts the mutual flat surfaces. This situation can be explained by the fact that it has a positive effect on the scattering and diffusion of sound and helps the balanced distribution of sound by creating an equivalent sound field at different receiver positions within the volume. T30 values close to each other in the center part (mihrab axis), a more irregular T30 distribution was obtained in the side stages (left and right parts). The reason for this is that the height of the side sections is less than the center section, the dome pulleys in the center section have windows and their surfaces are covered with glass, which has a high reflectivity value, and the receiver points behind the thick-section columns remain in the acoustic shadow areas, so T30 values are generally lower in the side sections than in the center section. The use of marble with high reflectivity value in the pulpit element in the right section can be considered to contribute to the increase in T30 values in that section. Although there is no difference (JND) that can be perceived by the ear between the receiver points R16 in the women's worship area covered with domes and vaults and R13, R14, R15 on the lower level, differences in T30 values were detected. The T30 value at R16 in the area covered with curvilinear elements was higher than the T30 values at the receiver points in the area covered with wood and flat surface on the lower floor. The increase in T30 values can be explained by the fact that curvilinear surfaces (dome/vault) increase the volume, and plastered surfaces are more reflective than wooden surfaces. However, the Just Noticable Difference (JND), which refers to the change that can be perceived by the listener in a sound field, is stated as 5% (0.1 s) for T30 in the literature [5]. According to the recommended JND value for T30, the T30 values obtained at different listener/prayer locations in the Bergama Great Mosque were below the 5% limit. Although there were differences in the T30 values obtained according to the receiver points, it can be said according to these values that the auditory perception did not change at different locations.

3.2 C80 (dB)

In the literature, the allowable C80 limits for listening to music at 500-1000-2000 Hz in the volumes are 1- (-4) dB [30] or 2 and (-4) range [31]. The average C80 for 500 Hz is -2.95 dB, the minimum value is -6.14 in the women's worship area (R16), and the maximum value is 5.37 dB close to mihrab (R1). The average C80 for 1000 Hz is -0.70 dB, while the minimum value is -5.49 at R16, and the maximum value is 4.89 dB at R1. The average C80 for 2000 Hz is -0.26 dB, while the minimum value is -3.94 at R16, and the maximum value is 4.92 dB at R1.

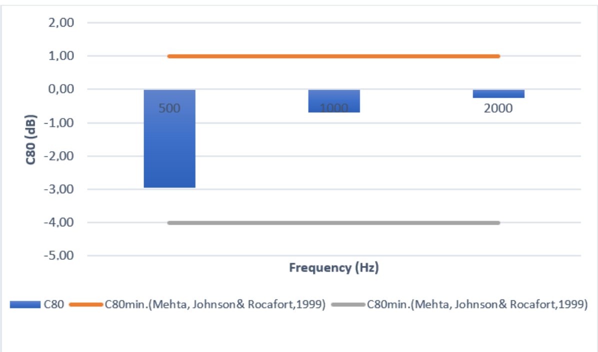


Figure 8. Measured clarity (C80) for 500- 1000- 2000 Hz and the recommended ranges [30]

According to the recommended ranges, the average C80 (clarity) values presented for the mosque in Figure 8 are considered acceptable. The obtained C80 values show that the desired otherworldly feeling in this mosque reaches the users. In the context of the obtained average C80 values, this mosque can be said to be able to give the feeling of being surrounded by music, which correlates with a sensation of "spaciousness".

3.3 D50 (%)

Definition (D50) is an objective acoustic parameter related to speech, and higher D50 values are desired for better speech intelligibility in the volumes. The optimal range for D50 should be between 30% and 70% according to ISO3382-1 and greater than 20% for music and speech functions according to Templeton. [23, 32]. When the recommended values and measurement results are compared, the averages are close to the lower limit but within the optimum range (Figure 9).

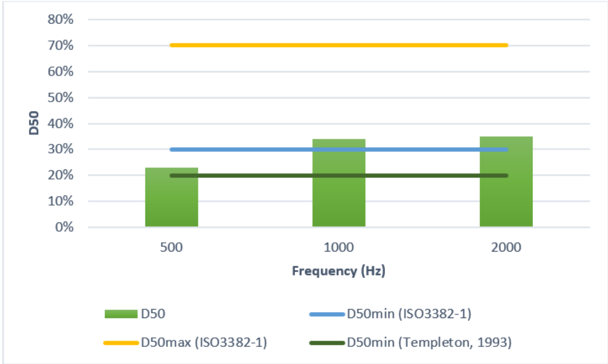


Figure 9. Measured definition (D50) for 500- 1000- 2000 Hz and the recommended ranges [23, 32]

3.4 STI

Mosques have rituals related to speech functions, such as Friday's sermon on the minbar and giving information to the prayers on the pulpit. In these rituals, speech intelligibility is expected to be good. STI is an important objective acoustical parameter to assess speech intelligibility in the volumes.

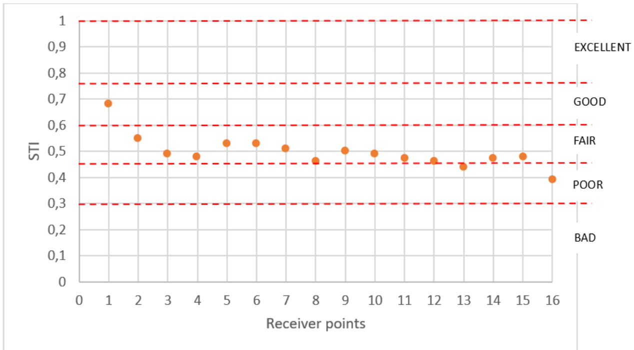


Figure 10. Average of STI values on the receiver points (R1-R16)

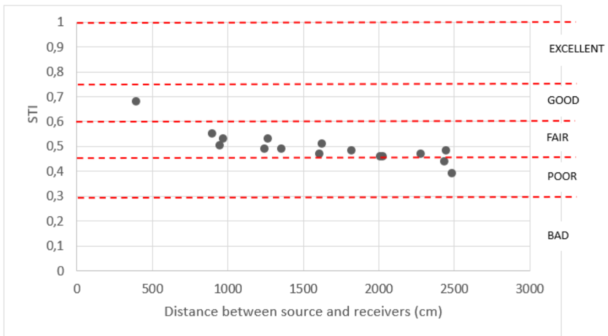


Figure 11. Average of STI values according to the distance to S1

In this mosque, the average STI value is measured as 0.5, which means the speech intelligibility is considered as fair. The minimum STI value in the mosque is 0.39 at the woman worship area (R16) while the maximum STI value is 0.68 at R1 in the front of mihrab (Figure 10). STI values decrease in each corridor due to increasing distance to the source (Figure 11).

3.5 SPL-A (dBA)

Sound pressure level is the most widely used indicator of acoustic wave power and is related to the human perception of loudness [27]. This study aimed to evaluate the distribution in the main place of worship by measuring the sound pressure levels at the receiver points. The difference of SPL-A values measured at the receiver points should not exceed 10 dBA to have a balanced pressure distribution within the volume.

The SPL-A values at receiver points and their distance to the sound source are reported in Table 1. It shows the SPL-A values decrease with distance from the sound source in the main worship area. It is also observed that SPL-A values decrease at the receiver points located in the acoustic shadow area behind the columns and under the arches. The average SPL-A for this mosque is 72.0 dBA. The minimum value in the mosque is 68 dBA, and maximum value is 78.6 dBA. The difference in SPLA between minimum and maximum value is 10.6 dBA more than 10 dBA. This means that the sound pressure level within the volume is not homogeneous, and different perceptions may occur depending on the position of the prayer.

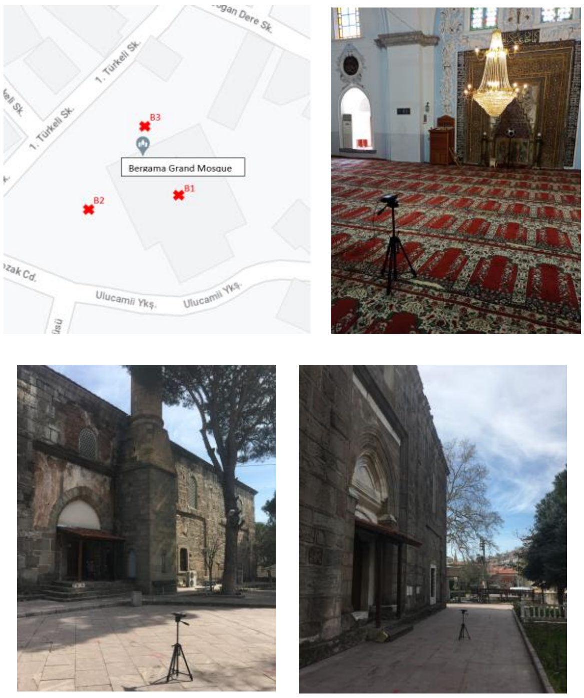
Table 1. The distance of each receiver points from the sound source position (S1)

	R1	R2	R3	R4	R5	R6	R7	R8
Distance from S1 (m)	3.9	9	13.6	18.2	9.8	12.7	16.2	20.3
SPLA (DBA)	78.6	74.7	72.6	71.5	74.6	73.6	72.2	70.4
	R9	**R10**	**R11**	**R12**	**R13**	**R14**	**R15**	**R16**
Distance from S1 (m)	9.5	12.5	16.1	20.2	24.4	22.8	24.5	24.9
SPLA (DBA)	72.7	73.5	71.3	70.2	69	69.9	69.1	68

3.6 Background Noise Level

Background noise level is mainly related to environmental noise factors around the building and the sound of mechanical equipment within the volume. For an activity in an enclosed volume to be easily understood, the background noise in the volume is expected to be below a certain limit. In the list of basic requirements determined by Doelle (1972) for the design of speech rooms, the statement that background noise levels should be low enough not to interfere with the listening environment is included. It is recommended that the highest noise levels be 25-30 dBA (NC15-20 in terms of noise criterion) for volumes with speech and/or music activities [4, 28]. Knudsen and Harris emphasized in their book that religious buildings need insulation from outside noise. They added the noise inside doesn't exceed 30 dB for religious buildings [33].

Background noise is related to environmental noise factors that will reach inside through the walls of the building and noise factors inside the volume (mechanical equipment, human noise, etc.). In historical mosques, the sound insulation properties of building elements such as wall thicknesses, roofs, properties of windows and doors show positive features in the absorption of environmental noise into the interior volume. It is also important to consider the sound insulation properties of these building elements in repair works of historical mosques. Therefore, A-weighted sound levels (LAeq) were measured at 3 locations (two on the courtyard, one in the building) for this mosque using the Bruel &Kjaer sound level meter type 2250. (Picture 3) Internal and external measurements were made to understand the acoustic conditions around the mosque and to reveal the effect of the building envelope on the difference between the sound level inside and outside of the mosque. The background noise levels for inside and outside of the mosque are listed. (Table 2)



Picture 3. The locations of background noise level measurement points (B1, B2, B3)

Table 2. The results of background noise level measurements from inside and outside

	B1 (in the mosque)	B2 (on the courtyard)	B3 (on the courtyard)
Background Noise Levels (Dba)	24.1 dBA	47.9 dBA	48.7 dBA

According to the results, the mosque's background noise level was 24.1 dBA, within the optimum range. The noise levels measured in the courtyard (B2 and B3) are very close and 47.9 dBA, 48.7 dBA were obtained, respectively. The difference between inside and outside is approximately 24 dBA. The measured values are within the appropriate range because the mosque is located far from the city center, surrounded by vehicle/pedestrian roads and low-rise residential buildings. In this mosque, design solutions such as wall thickness, window openings that are not too large, garden walls, trees, and building materials also help the interior have suitable background noise conditions.

4. Discussion and Conclusion

Bergama Great Mosque is a significant cultural heritage that needs to be protected, as it is a mosque that has remained almost unchanged in terms of architecture from the past to the present and represents the Ottoman period architecture when it was built. In this context, in addition to preserving the architectural features of the mosque as a tangible cultural heritage, documenting the acoustic environments of this building is also important in terms of intangible cultural heritage. Therefore, in the present study, the acoustic properties of the Bergama Great Mosque were documented by field measurement and the results were evaluated by comparing them with the values recommended in the literature. Parameters T30, C80, D50, STI, SPLA, and Background noise levels were measured according to ISO 3382, and the average values per octave band are described in the tables.

The average T30 value in mid frequencies is obtained as 2.04 s, which shows the volume is suitable for the musical version of the Holy Quran. The average C80 for 500-1000-2000 Hz is -1.3 dB, which is within the acceptable range for both speech and music. The values of D50 vary between 23% and 35%, which are close to the lower recommended limit within the optimum range. The lowest STI values were obtained in areas where sound-receiver distances were over approximately 20 m due to lack of direct sound. Mosques usually have separate prayer areas for men and women, divided by perforated wooden surfaces or curtains. In the mosque in this study, the women's gallery is located on the upper floor and is separated from the main worship space by using wooden perforated surfaces and curtains. Therefore, the lowest STI and SPLA values were obtained in R16, which is located in this area.

Evaluations demonstrate that the interior of the mosque is suitable for rituals with music. When the volume for speech purposes is evaluated, the reverberation time values obtained are higher than the desired range, although they are not far from the recommended values. However, to create the desired aural environment by the user during speech-function rituals, arrangements are needed to increase the absorbing surfaces and reduce the reverberation time to the desired range. After adjustments for the speech function, if the volume remains dry for the musical rituals, sound reinforcement systems (existing in the current situation) can be arranged to satisfy the users desired lively environment. On the other hand, in this study, the reverberation time was measured when the mosque was empty. A high T30 value has been obtained for the speech function. When the mosque is occupied, it is expected that the reverberation time will decrease and approach the recommended values, thanks to the sound absorptions of the users.

This study supports the documentation of the acoustic conditions of historical religious structures as intangible cultural heritage. Bergama Great Mosque, with its history of approximately 625 years, is one of Turkey's most important sacred buildings that has survived until today. It is aimed to document the aural environment of this mosque, which has been found to have well-preserved architectural form and volume characteristics, as a cultural heritage and to bring it into the literature. It is thought that the surfaces in the interior volume of the mosque, which have not undergone major changes in terms of architecture, have been renewed using up-to-date materials through maintenance and repair works. Since the carpet and plaster coverings of these surfaces are large surfaces, the mosque can be re-evaluated by applying the plaster and carpet absorbencies of the period when the mosque was built to these surfaces through acoustic simulation for the future of the study.

Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" are not carried out.

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