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Acoustic Evaluation of Trabzon Beşirli Central Tennis Court Multi-Purpose Hall

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Abstract: Today, although acoustic designs for different purposes are not realized in sports halls designed for sports activities, these halls are widely used for various events such as conferences and concerts. In this study; The main activity area in the Beşirli Central Tennis Court building, which was built for sports activities within the scope of the European Youth Games in Trabzon Province, was evaluated in terms of acoustics for different functional uses by computer simulation method. First of all, 3D models were prepared for the current conditions of the main sports event areas according to different audience occupancy rates. Then the models were transferred to the simulation program to evaluate the objective parameters of the sound. After obtaining the objective parameter values of the sound, 3D models of the hall were prepared again with the sound-absorbing mechanisms placed between the existing steel structural system on the ceiling plane of the hall, designed for the realization of sports, music and speech activities in the sports activity areas. The prepared 3D models were transferred to the ODEON V10 program and the simulation process was repeated. As a result of all simulations, the values of the objective parameters of the sound obtained for indoor sports activity areas were compared and evaluated with each other and the accepted optimum value ranges.

Key words: Indoor Sports Hall, Acoustics, ODEON, Objective Parameters of Sound.

Trabzon Beşirli Merkez Tenis Kortu Çok Amaçlı Salonunun Akustik Değerlendirmesi

Öz: Günümüzde sportif faaliyetlere yönelik tasarlanmış spor salonlarında farklı kullanım amaçları için akustik tasarımlar gerçekleştirilmemesine rağmen bu salonlar konferans ve konser gibi çeşitli etkinlikler için yaygın şekilde kullanılmaktadır. Bu çalışmada; Trabzon İli, Avrupa Gençlik Oyunları kapsamında sportif etkinlikler için inşa edilen Beşirli Merkez Tenis Kortu binasındaki ana etkinlik alanı bilgisayar simülasyon yöntemi ile farklı fonksiyonel kullanımlar için akustik açısından değerlendirilmiştir. Öncelikle ana spor etkinlik alanlarının mevcut durumları için farklı seyirci doluluk oranlarına göre 3D modelleri hazırlanmıştır. Daha sonra modeller sesin nesnel parametrelerinin değerlendirilmesi için simülasyon programına aktarılmıştır. Sesin nesnel parametre değerleri elde edildikten sonra spor etkinlik alanlarında spor, müzik ve konuşma faaliyetlerinin gerçekleştirilmesine yönelik tasarlanan, salonun tavan düzlemindeki mevcut taşıyıcı elemanların arasına yerleştirilen ses yutucu özellikteki mekanizmalar ile yeniden salona ait 3D modeller hazırlanmıştır. Hazırlanan 3D modeller ODEON V10 programına aktarılarak simülasyon işlemi tekrarlanmıştır. Tüm simülasyonlar sonucunda kapalı spor etkinlik alanları için elde edilen sesin nesnel parametrelerine ilişkin değerler birbirleri ve kabul edilen optimum değer aralıkları ile karşılaştırılmış ve değerlendirilmiştir.

Anahtar kelimeler: Kapalı Spor Salonu, Akustik, ODEON, Sesin Nesnel Parametreleri.

1. Introduction

Today, venues designed for sports activities, from Olympic stadiums to city-scale sports halls, are also widely used for different events such as congresses, conferences and concerts [1]. Such venues have large volume and high audience capacities that allow the specified activities to be held. When these spaces used for sports and multi-purpose activities are evaluated in general, it is seen that they are not suitable for the perception of sound under optimum conditions.

In the construction of sports halls, materials such as concrete, steel, glass, etc. that form hard and smooth/smooth surfaces are used. Although these materials meet the needs in terms of structure, they negatively affect the intelligibility of sound due to their low sound absorption properties. The high resonance environment, which is caused by the large volume of these halls, the use of materials with low sound absorption on their surfaces and the fact that they usually have a small number of spectators, causes the communication in these spaces to be difficult and tiring [2]. These unfavorable acoustic conditions prevent the activities from being carried out in healthy conditions and the salons from being used efficiently [3]. The purpose of the acoustic design of the spaces is to provide auditory comfort depending on the functions. In this context, acoustic arrangements should be made during the design phase depending on the functions of the spaces. This can be achieved either by volumetric change or material change on the surfaces in the spaces whose design has been completed or in the spaces whose

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application has been completed. This can be achieved either by volumetric change or material change on the surfaces in the spaces whose design has been completed or in the spaces whose application has been completed [3,4].

Within the scope of the study, literature studies including acoustic examinations of the spaces used for different functions were examined. In the study titled "Improving the Acoustic Qualities of Type Sports Halls for Multipurpose Uses", it was aimed to determine the acoustic performance of these halls since the type sports halls organized by the Ministry of National Education are also used in activities with different functions. Within the scope of the study, the objective parameters of the sound obtained at medium frequencies with the Odeon Combined 8.5 simulation program were examined [1]. Within the scope of his study titled "Investigation of Acoustic Performance in Multipurpose Use of Sports Halls through Material and Design Variables", Tekin designed a sports hall with a volume of 34,000m^3 and a capacity of 3,468 people by using the gymnasium designs in the literature. Separate design scenarios were developed for classical music and amplified music activities of the designed hall and models were prepared. The objective parameter values of the variations prepared according to music types and sports activities were obtained with the Odeon program and compared with each other [5]. In his study titled "Evaluation of Volume Acoustics of Antalya Glass Pyramid by Computer Simulation Method", Balcı aimed to investigate the acoustic performance of Antalya Glass Pyramid with 7,000m² glass curtain wall. Although the venue is designed for multi-purpose use such as speaking (congress) and music (concert), improvement suggestions have been developed by determining from the acoustic parameters obtained that the volume does not have the acoustic competence to support multi-purpose uses [6]. Şimşek (2020) examined and evaluated the 421-person multipurpose hall of Anadolu University, where concerts, conferences, theaters and cinema events can be held, in his study titled "Interchangeable Acoustic Design in Multipurpose Halls: The Case of Cinema Anatolian Multipurpose Hall". The acoustic objective parameters of the current condition of the hall were obtained with the Odeon simulation program and compared with the optimum values in the literature [7]. In his study titled "The Acoustic Characteristics of the Bazaar Mosque in Trabzon, Turkey", Kavraz examined the acoustic properties of the Bazaar Mosque in Trabzon with the computer simulation method (Odeon). Objective parameter values for the scenarios designed according to the current status of the mosque, the status of its walls covered with wood and different mosque occupancy rates were obtained and examined with the Odeon program. The acoustic performance of the mosque was evaluated according to the objective parameters RT, D50, EDT, LF and C80 [8]. Aktı (2014), "Acoustics in Multi-Purpose Halls with Apartment Plan and Dome Finish Examining Performance in the Simulation Program Through Design Variables", if the same hall is used for music and speech activities, he presented hall plan type suggestions in order to provide optimum acoustic conditions for both functions. EDT, T30, C80, D50, Ts, LF80, G and STI parameters were evaluated during music and speech activities in the hall for the prepared proposal plan type [9]. Demirel (2018) "Acoustic Design of Sivas Cultural Center Multi-Purpose Hall" analyzed and evaluated the acoustic improvement scenarios in order to provide acoustic conditions for different functions such as conferences, concerts, operas/theaters in the same volume. Within the scope of the study, T30, EDT, STI, SPL, D50 parameters were examined [10].

2. Material and Method

The aim of the study is to evaluate the acoustic conditions of the main sports event venue of Beşirli Central Tennis Court building in the city of Trabzon in line with the suggestions made in the current and ceiling plane. The quantitative values of the objective parameters of the sound in which the evaluations were performed were obtained through the Odeon Combined Version 10.1 computer program. As a result of the analyzes carried out for the current situation within the scope of the study, first of all, suggestions were made to improve the acoustic conditions of the hall, and then these suggestions were evaluated in terms of acoustics. In the suggestions made, the current function of the hall, the three-dimensional visual perceptions of the spaces and the steel structural system in the roof plane were taken into account. Considering the floor heights between the current steel structural system of the sports hall, prismatic mechanisms with covers are designed, the inner surfaces of which can be hung on the ceiling surfaces in a way that does not adversely affect the field of view of the audience, and the outer surfaces are covered with sound-reflective materials. Scenarios have been created for cases where the mechanism covers are 90^o open, 45^o open, closed and the mechanisms are without a cover, and cases where the audience area of the sports hall is empty and half full. For the scenarios created, measurements were made in the simulation program and the objective parameters of the sound for the hall were obtained and evaluated. While the sound absorbing surface area increases when the covers of the prismatic mechanisms are opened, the sound reflecting surface area increases when they are closed. 3D models of the scenarios designed according to the cover movements were created in the Sketchup 2022 program and transferred to the Odeon Combined Version 10.1

program and the objective parameter values of the sound were obtained. The contribution of the arrangements to the improvement of the acoustic conditions of the hall was analyzed by comparing them with the optimum values in the literature. Within the scope of the study, the basic evaluation criteria used acoustically in the sports hall are Reverberation Time (T30), Early Decay Time (EDT), Definition (D50), Clarity (C80), Early Lateral Fraction (LF80) and Speech Transmission Index (STI).

In the examined sports hall, both sports activities and different activities with speech or music content are organized. While music and speech events are organized from the 8 m x 15 m stage area, which can be dismantled and installed on the tennis court at Beşirli Merkez Tennis Court, music plays and speeches are held during sports activities. The contributions of the arrangements to improve the acoustic conditions of the hall were analyzed by comparing them with the optimum values in the literature.

2.1. Beşirli Tennis Complex

Tennis complex was built by the Ministry of Youth and Sports for the European Youth Olympic Games (EYOF) in the Ortahisar district of Trabzon in 2011. The complex, which consists of 1 open central court, 3 closed courts, 12 open courts and 1 children's court, was the largest sports complex in Turkey at the time of its construction [11]. Due to the need for a sports hall in the city in the process, the Central Tennis Court was closed with a steel roof in 2018 and transformed into a multi-purpose sports hall without losing its main function, the tennis court [12]. The multi-purpose sports hall with a size of 42x27 meters, a closed area of 7,760 m^2 and a capacity of 3500 people is designed for the organization of international and local competitions. The hall is suitable for handball, volleyball, tennis competitions [12]. In order to carry out multi-purpose activities in the existing hall within the scope of the study, an 8x15 m dimensions and 0,30 m high, removable wooden stage was added to the hall (Figure 1).

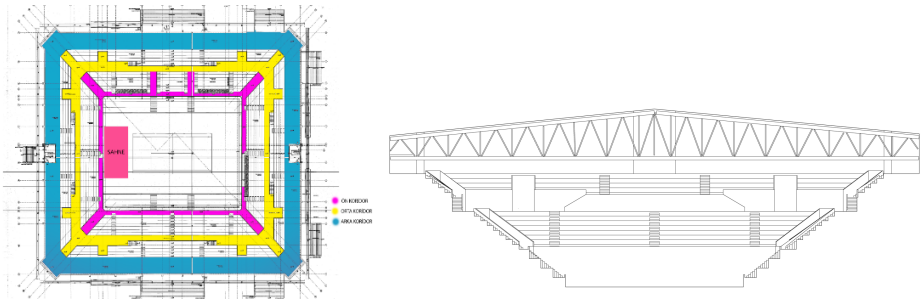

Figure 1. Spectator area and stage layout and section of Beşirli Central Tennis Court [13]

Depending on the occupancy rates, two different scenarios were designed for the hall. These scenarios, which are created according to the occupancy rates of the hall, are situations where the audience seating areas are empty and the audience seating areas are %50 full. For the situation where the hall is half full, the middle corridor separating the audience areas is taken as reference. Spectator areas between the playing field and the central corridor were considered as full, while the spectator areas between the central corridor and the rear corridor were considered as empty.

2.2. Acceptances for applications on the ceiling surface

In order to optimize the high reverberation time, prismatic mechanisms with openable and closed covers, whose inner surfaces are sound-absorbing and whose outer surfaces are covered with sound-reflective material, have been placed between the existing steel structural system on the ceiling surfaces of the hall. The proposed prismatic mechanisms are placed perpendicular to the long facades of the hall (Figure 2). The outer surfaces of the mechanisms are made of 30 mm thick MDF coating and the MDF coatings are mounted to each other with screws. The inner surfaces of the mechanisms whose outer surfaces are formed are covered with double layer of rock wool, which is a sound-absorbing material. The rock wool sheets used are each 70 mm and 80 mm thick. The faces of the rock wool sheets were covered with vinyl to protect them from dust and dirt (Figure 2).

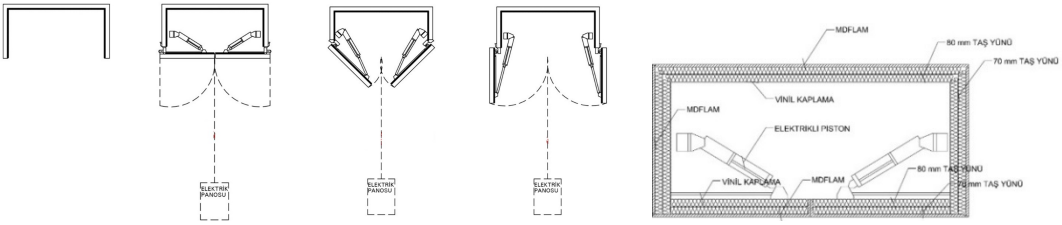

Figure 2. Cover movements of prismatic mechanisms and material detail of mechanisms

2.3. Acceptances for mechanisms mounted on the roof surface on the tennis court

The tennis court, which is evaluated in terms of the auditory perception of the sound, has an area of 3.682 m² and its floor height varies from 4 m to 18.86 m. The distance between the prismatic mechanisms of 2.6x2.6x1.5 m. dimensions placed between the steel structural system on the ceiling surface is 0.2 m. Figure 3 shows the sections of the scenarios where the prismatic mechanism covers placed on the ceiling surface of the tennis court are 90° and 45° open, the covers are completely closed and without a cover (Figure 3).

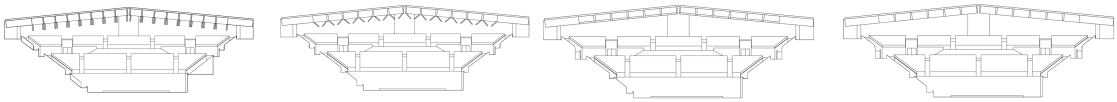

Figure 3. Situations where the covers are 90° open, 45° open, closed and without covers

2.4. Acceptance of Surface Materials

Material assignments were made by selecting materials from the material library of the simulation program (Odeon Combined Vesion 10.1) for new 3D models arranged in line with the status and acoustic recommendations in sports structures [14]. Materials not available in the Odeon material library were added to the material list by conducting a scientific literature search (Table 1). The sound absorption coefficients of the surfaces of the prismatic mechanisms placed on the ceiling surface in the hall are given in Table 2.

Table 1. Sound absorption coefficients of Beşirli Tennis Court surface materials

Surface	Material	Material Code (Odeon)	Sound Absorption Coefficients							
			63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Walls	Plaster+Paint	4002	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
Window	Double Glazing	10004	0,15	0,15	0,05	0,03	0,03	0,02	0,02	0,02
Door	Iron Door	[15]	0,05	0,05	0,05	0,05	0,06	0,04	0,02	0,02
Parapet	Marble Parapet	2001	0,01	0,01	0,01	0,01	0,01	0,02	0,02	0,02
Spectators area	Epoxy Floor Coating	6000	0,02	0,02	0,02	0,03	0,04	0,04	0,05	0,05
Stage	Wooden Stage	3004	0,15	0,15	0,11	0,10	0,07	0,06	0,07	0,07
Roof	Steel Roof	[15]	0,05	0,05	0,05	0,05	0,06	0,04	0,02	0,02
Spectator Chair	Plastic Seat	[16]	0,10	0,06	0,10	0,10	0,20	0,30	0,20	0,20
Vip Spectator Chair	Fabric Seat	11006	0,44	0,44	0,6	0,77	0,89	0,82	0,70	0,70
Audience-1	Plastic seat + Spectator	11009	0,51	0,51	0,64	0,75	0,80	0,82	0,83	0,83
Audience-2	Fabric Seat Spectator	11007	0,72	0,72	0,80	0,86	0,89	0,9	0,9	0,9
Field	Epoxy Floor Coating	6000	0,02	0,02	0,02	0,03	0,04	0,04	0,05	0,05

Table 2. Sound retention coefficients of the surfaces of prismatic mechanisms placed on the ceiling surface as an acoustic improvement proposal

Surface	Material	Material Code (Odeon)	Sound Absorption Coefficients							
			63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Sound Absorber	Rock wool+ Vinyl	[17]	0,57	0,57	0,79	0,77	0,9	0,71	0,47	0,47
Sound reflective	MDF	3063	0,42	0,42	0,21	0,10	0,08	0,06	0,06	0,06

Audio source locations in the hall; The audio source has been selected as omnidirectional, which ensures that the sound is distributed equally in all directions. The sound sources in the hall are placed on the stage and 150 cm above the ground plane.

2.5. Accepted ranges of optimum values for the objective parameters of sound

As a result of the acoustic simulations of the models belonging to the examined sports hall in the ODEON v10 program, the values of the objective parameters of the sound were obtained. Among these objective parameters, numerical values of Reverberation Time (T30), Early Decay Time (EDT), Definition (D50), Clarity (C80), Early Lateral Fraction (LF80) and Sound Transmission Index (STI) parameters were evaluated within the scope of this study. In the hall: 1. Parameter evaluated during sports activities: T30, 2. Parameters evaluated during musical activities: T30, EDT, C80, LF80 3. Parameters evaluated during speaking activities: T30, EDT, D50, STI, C80. If gyms are used for sports activities: For the optimum value range of the Reverberation Time (T30), the optimum tinnitus times recommended for sports halls in the BB93 standard are taken as a basis. According to the standard, the average T30 values obtained in the 500 Hz, 1000 Hz and 2000 Hz octave bands of sports halls larger than 530 m² should be 2 seconds The value range of %10 below and above the T30 value obtained according to the Standard is taken as the optimum range [18]. Accordingly, the optimum value range is T30 $1.8 < T30 < 2.2$. The optimum T30 in music activities was obtained through the graph suggested by Knudsen and Harris [19]. The optimum EDT value was considered as %10 higher than the T30 value [18]. The optimum LF80 value was taken as > 0.25, recommended by Odeon [14]. The optimum C80, on the other hand, was considered within the range of -4 dB to +4 dB [20] (Table 3). For speech activities, the optimum T30 value was obtained from the graph by Knudsen and Harris [19]. For EDT, the optimum value is considered as EDT < Tmid [21]. Regarding D50, the optimum level is within the range of 0.30 to 0.70 [22]. For C80, the optimum level is within the range of -2 dB to +2 dB [23]. As for STI, the values recommended by Houtgast et al. [24] have been taken into account (Table 4).

Table 3. Optimum Value Ranges of Objective Parameters Evaluated for the Use of the Beşirli Tennis Court Sports Facility for Music Activities

Scenarios	T30 [19]	EDT [21]	C80 [20]	LF80 [14]
Current Status	1,60<T30<1,95 $T30_{(ave.)}$: 1,78	1,75<EDT<2,14 EDT:1,95	-4dB<C80 <4dB	LF80>0,25

Table 4. Beşirli Tennis Court sports facility's optimum value ranges of parameters evaluated for speech activities:

Scenarios	T30 [19]	EDT [21]	D50 [22]	STI [24]	C80 [23]
Current Status	0,99<T30<1,21 $T30_{(ave.)}$: 1,1	EDT<1,1	0,3<D50<0,7	0,00 – 0,30 'bad', 0,30 – 0,45 'weak', 0,45 – 0,60 'moderate', 0,60 – 0,75 'good' 0,75-1,00 ‘perfect’	-2<C80<+2

3. Findings and Discussion

In this section, the results of the objective parameters T30 (Reverberation Time), EDT (Early Decay Time), D50 (Clarity), C80 (Definition), LF80 (Early Lateral Fraction), and STI (Speech Transmission Index) obtained using the ODEON V10 simulation program were evaluated. The results of the objective acoustic parameters for the current state of the examined sports facility and the adjustments made for the proposed acoustic improvements were compared with each other and with the optimum values.

3.1. Analysis of T30 values

The average T30 values obtained when the spectator area is %50 full for the Central Tennis Court of Beşirli are given in Figure 4. When the audience area is %50 full, T30 values for the current state of the hall increase up to 125 Hz at lower frequencies, while decreasing with frequency increase at frequencies above 125 Hz. For the current state, the average T30 value was obtained as 3.95 seconds in the mid-frequency range designated for sports activities, while it was measured as 4.52 seconds in the mid-frequency range specified for speech and music activities (Figure 4). These values are well above the optimum level ranges accepted for sports, music and speech activities. The average T30 values obtained for the cases where the covers of the prismatic mechanisms placed between the steel structural system on the ceiling surface of the sports hall were open at 90° and 45°, closed, and without covers, show an increase from low frequencies to mid-frequencies and a decrease from mid-frequencies to high frequencies. The average T30 values obtained at medium frequencies for sports activities are 1.64 sec when the prismatic mechanism covers are open at 90°, 2.01 sec when the prismatic mechanism covers are open at 45°, and 3.08 sec when the prismatic mechanism covers are closed at 90°. In cases where prismatic mechanisms are capless, the T30 value at medium frequencies is 1.98 sec. The mean T30 values obtained at medium frequencies for speech and music activities are 1.72 sec. when the prismatic mechanism covers are open at 90°, 2.13 sec. when the prismatic mechanism covers are open at 45°, and 3.3 sec. when the prismatic mechanism covers are closed. When prismatic mechanisms are capless, the T30 value obtained at medium frequencies is 2.1 sec. During sports activities in the hall, the average T30 values obtained for the situation where the prismatic mechanism covers are open at 45° and the mechanisms are capless are within the accepted optimum values range. While the average T30 value obtained for the situation where the prismatic mechanism covers are open at 90° during music activities in the hall is in the range of optimum values, the numerical data obtained from all scenarios for speech activities remain well above the optimum value range.

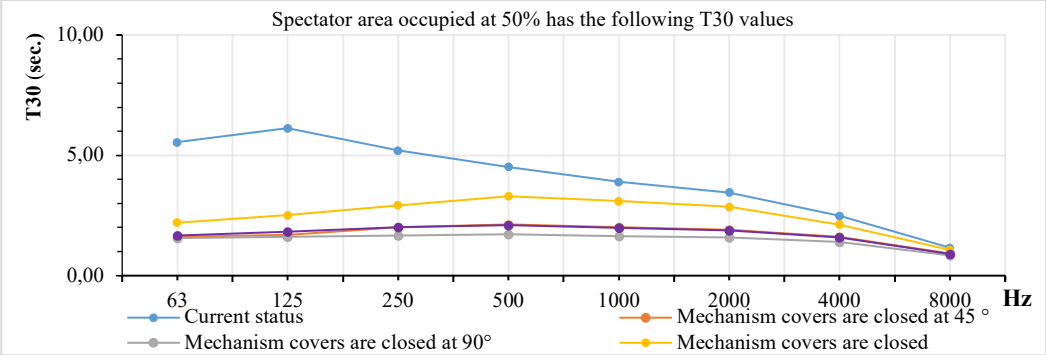

Figure 4. Beşirli Central Tennis Court with the spectator area occupied at %50 has the following T30 values

When the T30 values of the current situation in the sports hall and the situations where prismatic mechanisms are placed on the ceiling surface are compared, it is seen that there is a decrease due to the increase in the sound absorption coefficients of the materials in the new system, especially in the lower and middle frequencies, compared to the current situation.

3.2. Analyses of EDT values

The average EDT values obtained when the audience area is %50 full for the Central Tennis Court of Beşirli are given in Figure 5. When the audience area is %50 full, it is seen that EDT values for the current state of the hall increase up to 125 Hz at lower frequencies, while it decreases with frequency increase at frequencies above 125 Hz. The mean EDT value for the current situation was obtained as 4.35 sec. in the mid-frequency region

determined for speech and music activities (Figure 5). These values are well above the optimum level ranges accepted for music and speech activities. The average EDT values obtained in cases where the covers of the prismatic mechanisms placed between the steel structural system on the ceiling surface of the sports hall are 90° and 45° open, the covers are closed and the prismatic mechanisms are without covers increase from lower frequencies to middle frequencies, while decreasing from middle frequencies to higher frequencies. The mean EDT values obtained at medium frequencies for music and speech activities are 1.53 sec. when the prismatic mechanism covers are open at 90°, 2.01 sec. when the prismatic mechanism covers are open at 45°, and 3.21 sec. when the prismatic mechanism covers are closed. In cases where prismatic mechanisms are capless, the EDT value at medium frequencies is 1.82 sec.

In the hall: The average EDT values obtained when the prismatic mechanism covers are open at 45° and the mechanisms are capless during music activities are within the accepted optimum value range. During speech activities, the mean EDT values obtained when the covers of the prismatic mechanisms placed between the steel structural system on the ceiling surface are 90° and 45° open, the covers are closed, and the prismatic mechanisms are without a cover are well above the accepted optimum value range. When the EDT values of the current situation in the sports hall and the situations where prismatic mechanisms are placed on the ceiling surface are compared, it is seen that there is a decrease especially in the lower and middle frequencies compared to the current situation.

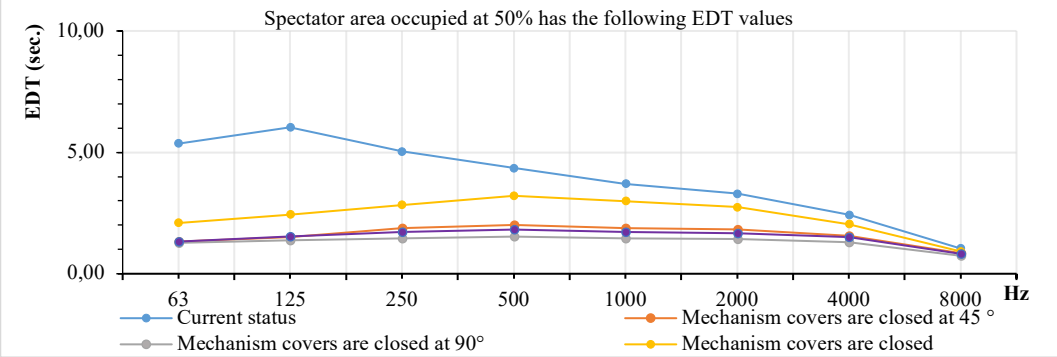

Figure 5. Beşirli Central Tennis Court with the spectator area occupied at %50 has the following EDT values

3.3. Analysis of STI values

The threshold values (X50) of the cumulative distribution of the STI values obtained when the audience area is %50 full for the Central Tennis Court of Beşirli are given in Figure 6. The STI value ranges accepted during speaking activities for the sports hall are given in Table 4. When the audience area is 50% full, the STI value obtained for the current condition of the hall is 0.41; this value is at the 'weak' level at the specified intervals. While the average STI value of the prismatic mechanisms placed between the steel structural system on the ceiling surface of the sports hall was 0.6 when the covers were open at 90°, this value was 0.53 when the covers were open at 45° and 0.48 when the covers were closed. The STI value obtained when the prismatic mechanisms are capless is 0.57 (Figure 6).

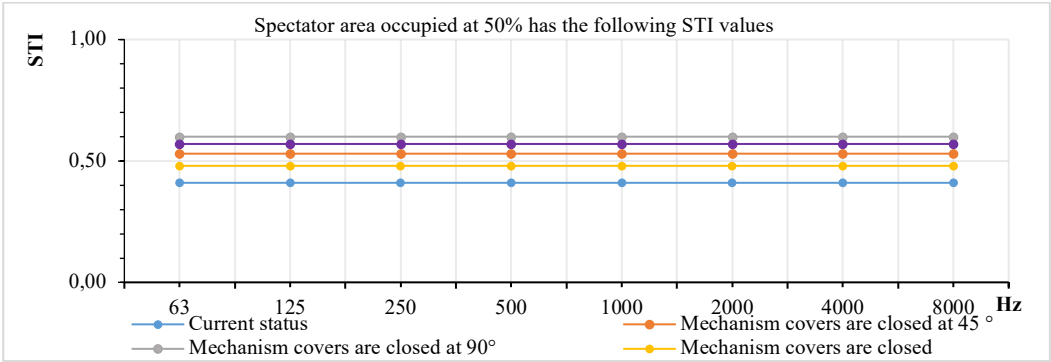

Figure 6. Beşirli Central Tennis Court with the spectator area occupied at %50 has the following STI values

The STI value was found to be 'moderate' in cases where the mechanism covers were 90° and 45° open, the covers were closed, and the prismatic mechanisms were capless.

3.4. Analysis of D50 Values

The average D50 values obtained when the spectator area is %50 full for the Central Tennis Court of Beşirli are given in Figure 7. The optimum D50 value accepted at medium frequencies during speaking activities for the sports hall was determined as $0.3 \leq x \leq 0.7$ [22]. When the audience area is %50 full, it is seen that the D50 values obtained for the current state of the tennis court decrease up to 125 Hz at lower frequencies and increase with the frequency increase at frequencies above 125 Hz. The mean D50 value was obtained as 0.29 in the mid-frequency region for the current situation (Figure 7). This value is below the accepted optimum level.

In cases where the covers of the prismatic mechanisms placed between the steel structural system on the ceiling surface of the sports hall are 90° and 45° open, the covers are closed and the prismatic mechanisms are capless, the average D50 values obtained decrease from lower frequencies up to 500 Hz but they increase from 500 Hz up to 8000 Hz. At medium frequencies, the mean D50 values are 0.56 when the covers of the prismatic mechanisms are open by 90°, 0.43 when they are open by 45°, and 0.36 when they are closed. In the case of prismatic mechanisms without caps, the D50 value is obtained as 0.50 at medium frequencies.

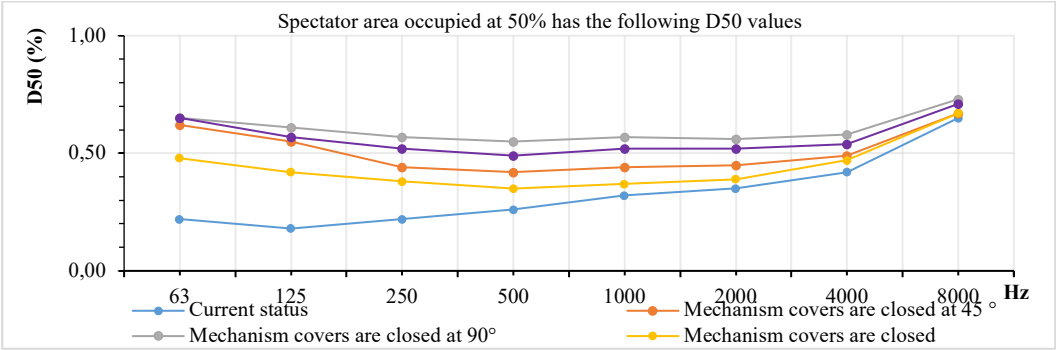

Figure 7. Beşirli Central Tennis Court with the spectator area occupied at %50 has the following D50 values

The average D50 values obtained in cases where the covers of the prismatic mechanisms placed between the steel structural system on the ceiling surface of the sports hall are 90° and 45° open, the covers are closed and the prismatic mechanisms are without a cover are within the accepted optimum value range.

3.5. Analysis of C80 values

The average C80 values obtained when the spectator area is %50 full for the Beşirli Central Tennis Court are given in Figure 8. When the audience area is %50 full, it is seen that the average C80 value obtained during music and speech activities decreases up to 125 Hz from lower frequencies and increases with frequency increase at frequencies above 125 Hz. The mean C80 value was obtained as -2.21 dB in the mid-frequency region for the current situation (Figure 8). While this value is within the accepted optimum level range for music activities, it is below the accepted optimum level range for speech activities. In cases where the covers of the prismatic mechanisms placed between the steel structural system on the ceiling surface of the sports hall are 90° and 45° open, the covers are closed and the prismatic mechanisms are capless, the average C80 values obtained decrease from lower frequencies up to 500 Hz but they increase from 500 Hz up to 8000 Hz. Average C80 values at medium frequencies were obtained as 3.58 dB when the covers of prismatic mechanisms were open at 90°, 1.04 dB when they were open at 45°, and -0.92 dB when they were closed. When the prismatic mechanisms were capless, the C80 value was obtained as 2.3 dB at medium frequencies.

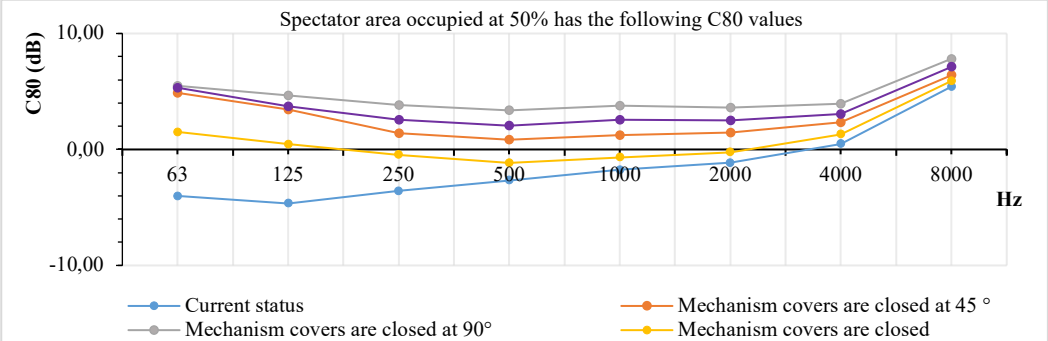

Figure 8. Beşirli Central Tennis Court with the spectator area occupied at %50 has the following C80 values

During musical activities in the hall, the average C80 value obtained for cases where the covers of the prismatic mechanisms are 45° open, 90° open, the covers are closed and the mechanisms are without covers is within the accepted optimum value range. The average C80 value obtained for situations where the covers of the prismatic mechanisms are open by 45° and the covers are closed during speech activities in the hall is within the accepted optimum value range.

3.6. Analysis of LF80 values

The average LF80 values obtained when the audience area is %50 full for the Central Tennis Court of Beşirli are given in Figure 9. The average optimum LF80 value at medium frequencies during musical activities for the sports hall was accepted in the range of LF80 >0.25 [14]. When the audience area is %50 full, the average LF80 value obtained at medium frequencies during musical activities decreases from lower frequencies to higher frequencies. The mean LF80 value was obtained as 0.24 in the mid-frequency region for the current situation (Figure 9). This value is below the accepted optimum level. While the average LF80 values obtained in cases where the covers of the prismatic mechanisms placed between the steel structural system on the ceiling surface of the sports hall are 90° open and the covers are closed remain constant up to 125 Hz at lower frequencies, they decrease in the range of 125 Hz- 250 Hz, remain constant in the range of 250 Hz-4000 Hz and tend to decrease towards frequencies above 4000 Hz. The average LF80 values obtained when the covers of prismatic mechanisms are open by 45° remain constant from lower frequencies to 2000Hz, decreasing from 2000Hz to higher frequencies. The average LF80 values obtained when prismatic mechanisms are capless decrease up to 125 Hz at lower frequencies, remain constant in the 125 Hz-2000 Hz range, and tend to decrease with frequency increase at frequencies above 2000 Hz. At medium frequencies, the mean LF80 values were 0.25 when the covers of the prismatic mechanisms were open at 90°, 0.25 when they were open at 45°, and 0.23 when they were closed. In the case where the prismatic mechanisms were capless, the LF80 value was obtained as 0.24 at medium frequencies.

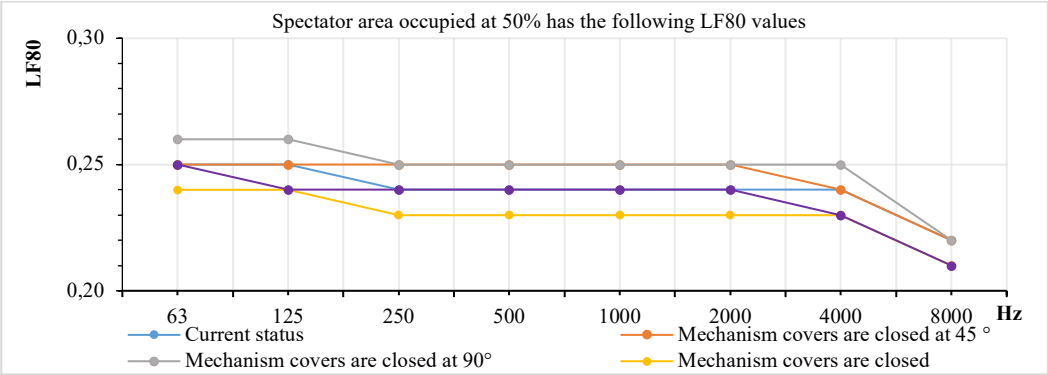

Figure 9. Beşirli Central Tennis Court with the spectator area occupied at %50 has the following LF80 values

The average LF80 value obtained for cases where the covers of the prismatic mechanisms are open by 45° and open by 90° during musical activities in the hall is within the accepted optimum value range.

4. Results

Within the scope of this study, the indoor sports activity area of Beşirli Central Tennis Court, which was built in Trabzon for the European Youth Games, was evaluated acoustically by computer simulation method during sports, music and speech activities. The obtained values were compared with the optimum value ranges. In this context, the current acoustic performance of indoor sports event audience areas in cases where they are %50 full was examined. As a result of the examinations, it was determined that the sports activity area was insufficient according to the optimum acoustic comfort conditions. Then, acoustic solution suggestions were prepared by designing retractable mechanisms that do not affect the field of view of the audience.

The T30 values obtained at medium frequencies for the current conditions of the Beşirli Central Tennis Court activity area are higher than the accepted optimum value. This situation causes the sound in the activity areas to reverberate for a long time, thus reducing the intelligibility of the speech. When the general T30 average for the current situation of the Beşirli Central Tennis Court event area was examined, it remained well above the optimum value ranges determined for music, speech and sports activities. According to the scenarios designed according to the cover movements and audience occupancy rates of the mechanisms placed on the ceiling surface of the tennis court, if sports activities were carried out in the hall, it was obtained in the optimum T30 value range when the mechanism covers were 45° open and the mechanism was uncovered. The T30 values obtained from all designed scenarios remained well above the optimum value range determined when speaking activities were carried out. When the general EDT average for the current situation of the Beşirli Central Tennis Court activity area was examined, it remained well above the optimum value ranges determined for music and speech activities. In case of musical activities in the sports hall, EDT values were not in the optimum range when the mechanism covers were open to 45^0 and the mechanisms were without covers. The EDT values obtained from all designed scenarios remained well above the determined optimum value range in case of speech activities. When the overall D50 average for the current status of the Beşirli Central Tennis Court activity area was examined, it remained below the optimum value range determined during the speaking activities. When musical activities are performed in the sports hall, D50 values are obtained in the optimum range when the mechanism covers are open at 45^0, when the mechanism covers are open at 90^0, when the mechanisms are not covered and when the mechanism covers are closed. When the overall STI average for the current status of the Beşirli Central Tennis Court activity area is examined, the mean STI obtained is at the 'moderate' level. When speaking activities were carried out in the sports hall, STI values were obtained at medium levels when the mechanism covers were open at 90^0, when the mechanism covers were open at 45^0, when the mechanisms were not covered, and when the mechanism covers were closed. When the general C80 average for the current status of the Beşirli Central Tennis Court activity area is examined, the values obtained are above the optimum value range determined during the speaking activities. In case of performing music activities, the situation where the mechanism covers are 90^0 open, the mechanism covers are 45^0 open, the mechanisms are capless, and the mechanism covers are closed is within the optimum C80 value range. When the overall LF80 average for the current status of the Beşirli Central Tennis Court activity area was examined, the values obtained remained below the optimum value range determined during music activities. When musical activities were performed in the gym, optimum LF80 values were obtained when the mechanism covers were open at 450 and the mechanism covers were open at 900.

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