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THE ACOUSTICS OF FATRA HOUSE OF ARTS IN ZILINA, SLOVAKIA

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Abstract: In this article, we present a concert hall of The Fatra House of Arts in Zilina Slovakia, describe the hall itself and examine the acoustical quality of the hall. The concert hall primarily serves for symphony, chamber orchestra and soloist but hosts various cultural and social events as well. The hall is being considered as acoustically exquisite space by many professional musicians and conductors all around the world for a long time. However, real measurement of the objective acoustical quality parameters, that could confirm the subjective assessment, has never been carried out. We conducted the acoustic measurements following the ISO 3382 standard, which specifies methods for evaluating room acoustics using impulse response analysis. The measurements were performed using an omnidirectional sound source and an omnidirectional microphone to capture the room's impulse responses at multiple receiver positions. From these responses, we assessed reverberation-based (reverberation time, early decay time), energy-based (clarity), spectral-based (bass ratio, treble ratio), and spatial impression-based (lateral energy fraction) objective criteria. The measured results of these parameters demonstrate a correlation with the recommended values found in specialized literature for chamber orchestra performances, with a reverberation time of 2 s, an early decay time of 1.57 s, a clarity of 0.8 dB, and an initial time delay gap of 12 ms.

Keywords: room acoustics, concert hall, acoustical quality, measurement and evaluation, ISO 3382

1. INTRODUCTION

The acoustics of concert halls are an essential component for performances of various musical genres, especially classical music. In just over a century, acoustics has evolved from a simple measurement of reverberation into a multidisciplinary science which concludes signal processing, architecture and psychoacoustics. Nowadays, the halls have been architecturally modified and assessed by simulations even before their construction. The main key to an acoustically suitable hall is the collaboration between the architect and the acoustician from the beginning of the project [1]. However, we often encounter halls that were built before the possibility of judging by their modern software tools evaluated by new measuring techniques, nevertheless, their subjective evaluations by musicians and listeners achieve high satisfaction [2]. If we want to understand positive subjective evaluations, we must proceed to the experimental measurement of objective acoustic metrics. There are only a few publications that deal with a comprehensive acoustic evaluation of a specific concert venue [3]. Most of them are comparative studies of objective parameters of several concert halls [4], subjective studies [5], or combination of subjective and objective measurements and their comparison [6]. Due to time consuming physical measurements and program occupancy of concert halls, majority of the research deals with acoustic measurement by using simulation software [7-9]. However, this methodology is still subject of discussion about the precision and relationship of simulated results with real acoustic measurement in concert halls [10].

This paper presents results of objective parameters, derived from impulse response measured in chambre concert hall - Fatra House of Arts. Acoustic measurement was done by recommendation from international standard procedure ISO 3382-1:2009 [15]. The main motivation for this study was the positive subjective evaluations of musicians, conductors and public listeners, and the absence of sound field measurements in this cultural stand. Reverberation-based, energy-based, spectral-based and spatial impression-based objective criteria were investigated and evaluated by comparison with the recommended values in specialized literature. In the discussion, there is an effort to connect the measured results with the architectural aspect of the concert hall. The limitation of this study lies in absence of subjective listening tests as well as dummy-head measurement, which may bring new conclusions and more precise results in future work.

The rest of the paper is structured as follows: Next part contains the history of the building and information about its purpose and parameters. Whereas a lot of information about the building was unavailable and unclear, we searched in the historical files of the state archives to find relevant documents. Another section is devoted to the description of the measurement methodology. We will describe the type and specifications of used equipment, excitation signals and software for extraction of objective parameters from impulse response. Subsequently, objective parameters are presented in theoretical detail with their correlation with subjective evaluations and recommended values for chambre orchestra performances. Finally, the results are commented on in the discussion section with related architectural aspects and summarized in the conclusion.

2. BRIEF HISTORY OF FATRA HOUSE OF ARTS

History of The Fatra House of Arts in Zilina Slovakia extends to the beginning of the 20th century. Jan Rufinus Stejskal, native of Moravia living in Slovakia, came with the idea of building a city cultural centre around 1915. Unfortunately, building works were progressing slowly because of several planning changes. During the years 1919-1921, with approval of the town hall of Zilina, Rufinus Stejskal demolished two residential buildings from 17th century and in their place built a movie theatre - The Grand Bio Universum. The final shape of the art nouveau building project has proposed engineer Szekely Illes and the building has had a stage in a large hall, and two galleries (shows in Figure 1). The ground level seated 482 spectators, the first gallery 100 and the second one 146 viewers.

Fig. 1: Exterior view of the Fatra House of Arts

After construction, the first Slovak feature-film premiere, “Janosik,” was held on January 3, 1922. The silent film was accompanied by the military orchestra and the performance met with great success. Since this important event, regular cultural events have been held at the Grand Bio Universum. After the World War II, the building was national-ized and renamed to Fatra movie theatre. During the years 1983 and 1988, the Fatra was reconstructed to meet the needs of the State Chamber Orchestra of Zilina - The Slovak Sinfonietta Zilina abroad - and has become the seat of the orchestra. The State Chamber Orchestra of Zilina - Mozart-type orchestra - was founded with an enormous merit of well-known Slovak composer Jan Cikker in 1974, based on the old Zilina City Symphony Orchestra (1959-1974). Regrettably, during a reconstruction, the original historical inscription “BIO UNIVERSUM” on the upper facade of the original building was heartlessly re-moved. A concert organ was installed in the hall in 1988 and the first festive concert was held on January 4, 1989. Nowadays, The Fatra House of Arts is registered as No. 13729/0 in the Central List of the Memorial Fund in Slovakia [11, 12].

2. 1. Concert Hall

The concert hall has a traditional "shoebox" shape. Design of this rectangular halls with high ceiling are well known for their historic relationship with classical music. Shoebox was typical architectonic approach mainly at the turn of 19th and 20th century of past millennium. Many musicians and composers prefer this type of shape.13 Some of the famous composers created their pieces especially for these halls. Famous halls with this shape such as Vienna musikverein hall are characteristic in their "fullness" of sound and best rated acoustics [14]. Physical dimensions of the Fatra concert hall are 21 m in length, 14.8 m in width and 8 m in height that corresponds to total volume of approximately 2500 m3. Side walls as well as ceiling are covered by generally plaster on masonry. Base floor is made of flat concrete with parquet wood affixed and consists of 13 rows with 244 seats. Tops of the seats and fronts of backrests are 5 cm upholstered with cloth covering while the underseats and the arms are of solid wood. Stage floor of 78 m2 area is raised by 0.68 m over floor and it is made of wooden plank. Side walls and ceiling above the stage are also covered by plaster (shows in Figure 2). Cambered balconies in 1st and 2nd upstairs offer another 149 upholstered seats including honorary lodge that is located opposite to the stage in 1st floor. Front wall is fitted with concert organ built by bohemian brand Rieg-er-Kloss that has 42 registers and 3284 pipes of different types, construction and sizes from few mm to 6 m in length. Concert hall comprises many diffusion elements such as the art nouveau embossed decorations, embrasures, ornate decorations, or sculptures and prismatic sections on flat ceiling. The technical parameters of the hall summarize Table 3. In Figure 3 is a plan view of a concert hall borrowed from the Slovakia State Archives, which was created during reconstruction of building in 1983. On the right side of the Figure 3 there is a stage, on the left side an auditorium marked with crosses.

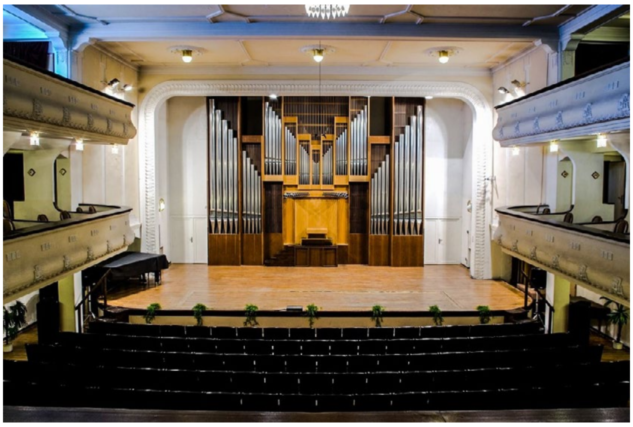

Fig. 2: View of the concert hall stage

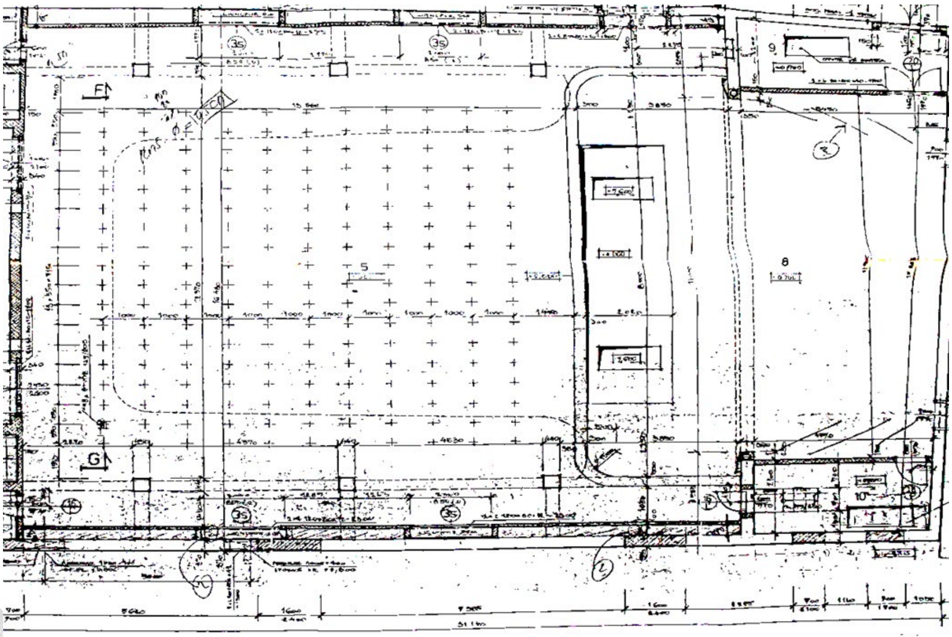

Fig. 3: Plan view of concert hall Fatra (Courtesy of State archive Zilina)

3. MEASUREMENT METHOD, EQUIPMENT AND SET-UP

The measurement was performed according to requirements of the standard ISO 3382-1:2009 [15], and the following measurement equipment are listed in Table 1.

Equipment	Type	Specifications
Loudspeaker	Brüel & Kjær OmniPower™ Type 4292-L	12 loudspeakers (dodecahedral configuration) SPL: 122 dB re 1 pW (100 – 3150 Hz) Nominal impedance: 6 Ω
Amplifier	Brüel & Kjær Power Amplifier Type 2734-A	Maximum output power: 330 W (6 Ω) Total harmonic distortion: 0,1 %
Sound Analyzer	NorSonic Nor140	Microphone: Nor1225 Class 1 Freefield sensitivity: 50 mV/Pa Frequency response: 3.15 Hz to 20 kHz Measurement range: -10 to 137 dB
Microphone	Samson CL8	Type: condenser Polar pattern: omni/figure 8 (switchable) Frequency response: 20 Hz to 20 kHz Sensitivity: -40 dBV/Pa
USB Audio Interface	Brüel & Kjær ZE-0948	Resolution: 8/16 bit Sample frequency: 8/16/32/44.1 or 48 kHz

Tab. 1: Equipment specifications

Fig. 4: In situ measurement

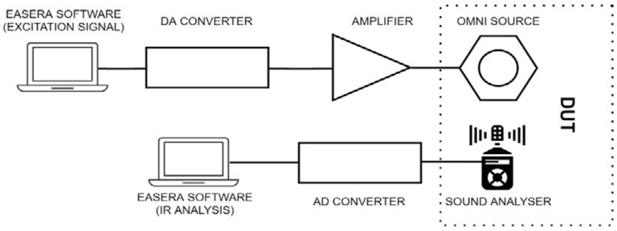

Fig. 5: Generalized block scheme of measurement

First, we examined background noise level (BNL), to make sure that our signal-to-noise ratio (SNR) is sufficient for measurement. We measured value of 45 dB, while our source was able to provide 122 SPL. We decided to set the source to SPL 90 dB, which is sufficient when using smaller interval of sound decay as will be commented in the reverberation section. We utilized software tool EASERA - Electronic and Acoustic System Evaluation and Response Analysis [16] for the measurement and extraction of objective quality parameters. Measuring system was configured as a single channel measurement with 5 times averaging (+1 pre-send). The audio playback and recording were performed at 48 kHz sample rate and 16 bits resolution (32 bits internally in EASERA software). In order to obtain the most relevant measurement results, we utilized 2 different types of excitation signals. We exploited logarithmically swept sine signal (SS) of 5.5 s length with starting and ending frequencies of 20 Hz and 24 kHz respectively. We applied maximum length sequence (MLS) of 18th order corresponding to the same 5.5 s duration as well.

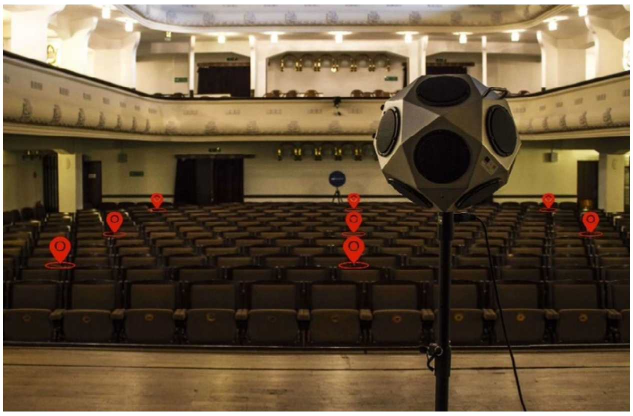

Fig. 6: View of the auditorium with microphone placement positions.

ISO 3382-1 international standard defines the minimum number of microphone positions for a given number of seating positions to 6. However, we have decided to perform the measurement at 9 different positions to get a better overview of the sound field distribution in the auditorium. The analyzer was moved to the third, sixth, and twelfth row of the auditorium (Figure 6). Sound source was constantly placed in the middle of the stage. In every microphone position we performed measurement with both excitation signals. Each of the resulting parameters was averaged from all measurement points in each octave band (125-4000 Hz) as well as for the overall impulse response. For the spatial characteristic's measurement of the auditorium, studio microphone Samson CL8 with figure-of-eight polar pattern characteristic was used in association with the omnidirectional characteristic of the other Samson CL8 microphone since it has a switchable pattern characteristic. It is worth noticing that all measurements were performed in an unoccupied auditorium.

4. SUBJECTIVE AND OBJECTIVE ROOM ACOUSTICS PARAMETERS

4. 1. Theoretical principles

In theory, we consider enclosed space as linear time-invariant system (LTI) [17]. In simplified way, propagation in this system can be expressed as:

$$\boldsymbol{y}(\boldsymbol{t}) = \boldsymbol{h}(\boldsymbol{t}) * \boldsymbol{x}(\boldsymbol{t}) \tag{1}$$

where y(t) is the output of linear system, h(t) is linear transfer function, x(t) is input signal to the system, and * denote convolution operation.

Fig. 6: LTI block scheme.

If sinusoidal swipe signal is used, impulse response derived from excitation of room can be expressed in time domain as:

$$\boldsymbol{h}(\boldsymbol{t}) = \boldsymbol{y}(\boldsymbol{t}) * \boldsymbol{f}(\boldsymbol{t}) \tag{2}$$

where f(t) is swipe function with increasing frequency defined as:

$$\boldsymbol{f}(\boldsymbol{t}) = \mathbf{sin}\,[\mathrm{K}\left(\boldsymbol{e}^{\frac{t}{L}} - \mathbf{1}\right)] \tag{3}$$

where w_start and w_stop are frequency borders and T is duration of signal in s.

$$\boldsymbol{K} = \frac{\boldsymbol{T}_{\boldsymbol{\omega}_{start}}}{\mathbf{ln}\,(\frac{\boldsymbol{\omega}_{stop}}{\boldsymbol{\omega}_{start}})}, \qquad \boldsymbol{L} = \frac{\boldsymbol{T}}{\mathbf{ln}\,(\frac{\boldsymbol{\omega}_{stop}}{\boldsymbol{\omega}_{start}})} \tag{4}$$

4. 2. Reverberance

Wallace Clement Sabine, a pioneer in the area of room acoustics, was one of the first man who noticed the relationship between the reverberance of room and the quality of room acoustics. He was using only simple tools (organ pipes and stopwatch) to measure the reverberation time in the Fogg Art Museum, but he has laid the foundations of the room acoustics and the reverberation time is still the essential criterion to evaluation the acoustics quality of a room. The reverberation time T60 is defined as the time it takes for the sound level in the room to decrease by 60 dB after a continuous sound source has been shut off [17].

The Schroeder backward integration of the impulse response [18], that is implemented as integrated impulse response method in ISO 3382-1, is the mostly used method for determining the slope of sound energy decay. It is defined as follows:

$$E(t) = \int_{t}^{\infty} h^2(\tau)d\tau = \int_{\infty}^{t} h^2(\tau)d(-\tau) = \int_{0}^{\infty} h^2(\tau)d\tau - \int_{0}^{t} h^2(\tau)d\tau \tag{5}$$

where h(t) denotes the measured sound pressure of the impulse response as a function in time [15]. In practice, the evaluation of the reverberation time is limited to a smaller interval of the sound decay curve, from –5dB to –35 dB (or –5dB to –25 dB) below the start value; but still relating to a 60 dB decay. The parameters are referred to as T30 and T20 respectively. Early decay time (EDT), that is represented as the first 10 dB drop of the decay curve, has proved to be more important for the subjective perception of the listener than the classical reverberation time. Longer reverberation emphasizes music but can cause speech to be muddled and unintelligible. For many forms of music, however, reverberance can add an attractive fullness to the sound by bonding adjacent notes together and blending the sounds from the different instruments/voices in an ensemble [19]. Optimal reverberation time strongly depends on volume and the purpose of room. For a chamber orchestra and the space of given volume, optimum values of reverberation time are in the range 1.8 - 2.0 s [20, 21]. For the Fatra concert hall, parameters T30 and T20 acquire ideal value of 2 s. while EDT stated a slightly shorter reverberation time. Table 2 summarize the objective parameters of some of the best rated hall and Table 3 shows chambre halls with comparable dimensions to Fatra House of Arts. Table 4 shows these values supplemented with the rest of measured quality criteria of Fatra House of Arts.

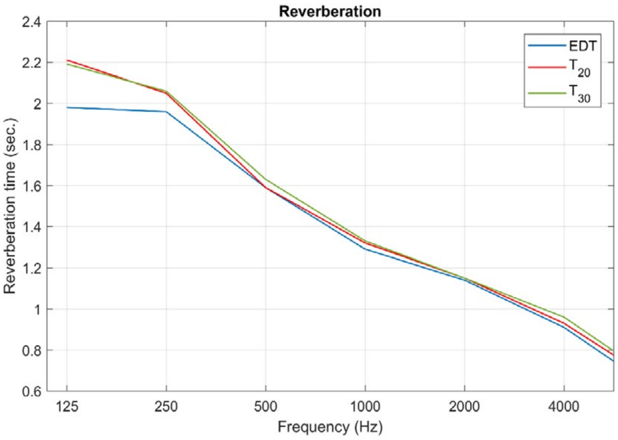

Fig. 7: Octave-based reverberation time for The Fatra House of Arts

4. 3. Clarity

Clarity is related with a definition of music in that manner that listener is able to distinguish sounds in a musical performance. Definition can be discernable in two basic forms - horizontal and vertical. The horizontal one is related with tones played in succession and is determined by musical factors such as tempo, repetition or number of tones in phrase [20]. Horizontal definition is usually defined by acousticians as the ratio expressed in decibels of the strength of the early sound to that of the reverberant sound. The vertical one refers to the degree to which notes that sound simultaneously is heard separately. Vertical definition is primarily predesignated by the composer but can be altered by varying the dynamics of their simultaneous sounds for example. Objectively and mathematically, measure of clarity can be defined as the clarity index that is a ratio of early-to-late sound energy:

$$C_{80} = 10.log\left(\int_{0}^{0.08} h^2(t)dt \Big/ \int_{0.08}^{\infty} h^2(t)dt\right) \tag{6}$$

where upper integration boundary in numerator (lower boundary in denominator respectively) represents 80 ms time interval of room impulse response h(t) (50 ms for speech auditoria). An inappropriate ratio may be manifested by masking the following rhythmic elements in the music, or, conversely, a low reverberation rate with prevailing direct sound.

The ideal value of the clarity index C80 in concert halls ranges between -2 to 2 dB and Fatra House of Arts achieved value of 0.8 dB.

4. 4. Intimacy

Similarly to physical intimacy, "intimacy" in concert halls refers to the feeling of being close to the source of the music. In other words, a hall can have "acoustical intimacy" if sounds seem to originate from nearby surfaces. The degree of musical intimacy in a space corresponds to how soon after the direct sound the first reflection reaches the listener's ears. In the quantitative area, intimacy can be best measured by the initial time-delay gap (ITDG) parameter. This criterion is given by the time difference between arrival of the direct sound and arrival of the first significant reflection at a certain receiver position.

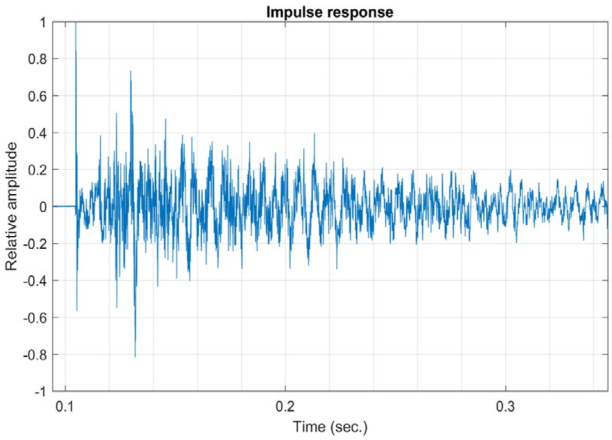

Fig. 8: Example of impulse response of Fatra House of Arts.

Halls with a relatively short ITDG seem to be more intimate while a longer ITDG indicates less intimacy. In smaller halls, enclosing surfaces are closer together, so reflections occur more frequently than in large halls where surfaces are farther apart. Therefore, smaller halls generally have shorter initial time-delay gaps. In best halls, ITDG remains between 12-25 ms. Figure 5 depicts first 250 ms of room impulse response recorded in the Fatra concert hall. One can see that first significant reflection is located at approximately 12 ms time position.

4. 5. Warmth and Brilliance

The term "warmth" in a concert hall is directly related to whether the bass sounds are clearly audible when the full orchestra is playing and is determined by the strength of the bass tones. Its counterpart - brilliance - refers to a bright, clear, ringing sound that is rich in harmonics. Either one of these qualities is desirable in moderation. If a sound field has strongly presented a bass frequency, the hall can be undesirably "dark." With too much brilliance, the sound becomes harsh, brittle, and metallic sounding. Both warmth and brilliance are directly related to the reverberance. In objective measure, there are 2 basic quality parameters - bass ratio (BR) and treble ratio (TR) defined as follows:

In concert halls, BR and TR optimum values range between 0.9-1.5 and 0.7-0.95 respectively. The Fatra House of Arts gains 1.4 and 0.7 for BR and TR respectively.

4. 6. Loudness

The loudness of sound in a hall, is obviously very important although it was over-looked in the auditorium context for many years. The audience needs to be able to hear the complete performance without any straining. Loudness can affect perception of other acoustic qualities as well, such as intimacy and spatial impression - if the loudness is too low, it is possible for audience not to feel that the space is intimate. This is simply the difference in dB between the level of a continuous, calibrated sound source measured in the room and the level the same source generates at 10 m distance in anechoic surroundings [19]. In the objective manner, we can express loudness in a concert hall by the strength factor G. It can also be obtained from impulse response recordings from the ratio between the total energy of the impulse response and the energy of the direct sound with the latter being recorded at a fixed distance (10 m) from the impulsive sound source, according to the following formula:

$$BR = \frac{T_{125\,Hz} + T_{250\,Hz}}{T_{500\,Hz} + T_{1000\,Hz}}, \quad TR = \frac{T_{2000\,Hz} + T_{4000\,Hz}}{T_{500\,Hz} + T_{1000\,Hz}} \quad (7)$$

where h10m(t) represents the impulse response measured with an omnidirectional micro-phone at a 10 m distance from the sound source in a free field. In practice, it is obtained by the difference between the SPL measured at the receiver position and the SPL of the source, adding 31 dB [22]. For a chamber music with an auditorium under 700 seats, the preferred value of G is located between 9 - 13 dB [20]. The Fatra House of Arts has this quantity equal to 13 dB.

4. 7. Spaciousness

Spaciousness or spatial impression is a term that was introduced in the 1970s to refer to a listener's feeling that the sound is arriving from many different directions in contrast to a monophonic impression of all sound reaching the listener through a narrow opening. After the past three decades of research, it is now clear that there are two aspects of spaciousness - Apparent Source Width (ASW) and Listener Envelopment (LEV). ASW is related with the impression that the sound image is wider than the visual. LEV, meanwhile, describes the impression of being inside and surrounded by the reverberant sound field in the room. Both aspects have been found to be dependent on the direction of incidence of the impulse response reflections. When a larger portion of the early reflection energy (up to about 80 ms) arrives from lateral directions, the ASW increases. When the level of the late, lateral reflections is high, strong LEV results. In objective manner, these spatial aspects can be described by the parameters such as early lateral energy fraction JLF [15] or LF [13, 20], relative level of late-arriving lateral sound energy LJ [15] or LG [20], and interaural cross-correlation coefficient (IACC). Early lateral energy fraction is well correlated with the ASW spatial aspect, while late lateral energy relates with the LEV spatial aspect. The lateral components of the impulse response energy can be recorded using a figure-of-eight microphone with the sensitive axis held horizontal and perpendicular to the direction towards the sound source (so that the source lies in the deaf plane of the microphone). For measurement of the JLF, the early part of this lateral sound energy is compared with the energy of the direct sound plus all early reflections picked up by an ordinary omnidirectional microphone:

$$G = 10.log\left(\int_0^\infty h^2(t)dt \middle/ \int_0^\infty h^2_{10\,m}(t)dt\right) \qquad (8)$$

where is the impulse response pressure recorded with a figure-of-eight microphone, whereas h(t) is captured through the omnidirectional microphone. It is of advantage if JLF is within the following range of 0.1 - 0.25 [23, 24]. The Fatra House of Arts gained JLF equal to 0.17.

Table results and comparison with other concert halls

Concert Hall Details	Value	Quality Parameter	Value
volume = 2500 m^3	2500 m^3	T30	2.00 sec
length	21 m	T20	1.99 sec
width	14.8 m	EDT	1.57 sec
height	8 m	C80	0.8 dB
stage area	78 m^2	ITDG	12 ms
number of seats	453	BR - TR	1.4 - 0.7
volume/seat	5.5 m^3	G	13 dB
true seating area	162 m^2	J_{LF}	0.17
true area/seat	0.66 m^2	BNL	45 dB

Tab. 4: Building details and measurement results of Fatra House of Arts concert hall.

Concert Hall	V [m^3]	LF [-]	ITDG [ms]	RT [s]	EDT [s]	G [dB]	C$_{80}$ [dB]
Vienna, Grosser Musikverinsaal	15000	0.17	12	2.0	2.0	4	-1
Boston, Symphony Hall	18750	0.22	15	1.9	1.9	0	0
(Berlin, Konzerthaus (Schauspielhaus	15000	-	25	2	1.9	4	-1
Tokyo Opera City, Concert Hall	18750	-	15	2.0	1.9	4	-1
Buenos Airos, Teatro Colon	21524	-	21	1.6	1.6	1	1

Tab. 2: Objective parameters of world best rated halls [20].

Concert Hall	V [m^3]	LF [-]	ITDG [ms]	RT$_{occ, M}$ [s]	[EDT$_M$ [s	G$_M$ [dB]	C$_{80}$ [dB]
Prague, Martine Hall	2410	-	15	1.76	2.19	12.6	-1.9
Amsterdam, Kleinersaal in Concertgebouw	2190	-	17	1.25	1.49	12.9	1.5
Vienna, Mozartsaal in Konzerthaus	3920	-	20.5	1.49	1.79	10.8	-0.2
Tokyo, Ishibashi memorial Hall	5450	-	19.5	1.70	1.84	10.8	-0.8
Salzburg, Wiennersaal in Mozarteum	1070	-	15	1.25	1.33	14.3	1.7

Tab. 3: Chambre concert halls.29 Occ means occupied; M means averaged mid (500 – 100 Hz).

6. DISCUSSION

Based on the measured results, we can summarize some practical knowledge of the acoustics in Fatra House of Arts and assumptions about the architectural aspects. Main advantage of the measured space is an ideal shape, relatively small size and used materials which bring adequate reverberance and spatial impression. RT (2.0 s) is more comparable to the best halls in Table 2 than to the halls of a similar size, which appear less reverberant as can be seen in Table 3. The reason may be found in the absence of absorbents. The most absorbent material in the hall are the seats or the audience, if occupied. Clarity index in recommended values (0.8 dB) is caused by small dimension of hall, and scattering on side walls, balconies and support columns, thus direct sound is not masked by re-flections of side walls, which contribute to high intelligibility in subjective dimension. We did not examine the objective parameters of the stage acoustics like STearly and STlate, but there is a strong assumption that highly reflexive side walls and ceiling above the stage support fast distribution of sound reflection toward the audience as well as for the musicians themselves.

Based on the findings by Beranek [25] shoebox halls with less than 25 m on width and greater than 15 m on width has great capability to avoid later lateral reflections, and thus not mask the direct sound. Fatra House of Arts with an average width is 14.8 m just above these boundaries. This can explain the great JLF (0.17) measured in the examined hall, which is in ideal range and may result in correlation with subjective ASW. In corporation with ITDG (12 ms) within the recommended values, closer enclosing surfaces in hall may implies feeling of intimacy. The visual aspect of spectators may also contribute to intimacy, as the front row of the auditorium is only about 2 m away from the stage and back row distance does not exceed 40 m as recommended in [25]. Psychoacoustic hypothesis published in and tested in paper [26] claims that appropriate lateral early reflections from parallel side walls in shoebox shape halls enhance dynamic hearing range and thus musical dynamics as well. This can be linked with high subjective rating of warmth, brilliance and listener envelopment, which is also provided by BR and TR (1.4 – 0.7) in Fatra House of Arts concert hall.

At first glance sound strength in Fatra (13 dB) is above the best rated halls in Table 2, but principle presented in paper [27] demonstrates that G should be determined by maximum size of the orchestra. Majority of performance in Fatra Hous of Arts is done by Slovak Sinfonietta, so-called "Mozart type orchestra", which is composed by less than 40 members. For big orchestras there is need to have G around 6 dB, while for smaller orchestras, there is need to increase this parameter. Also, G is next contribution for subjective intimacy and spatial impression. The low-absorption materials used in the hall play an important role in reflection/diffusion [28] and contribute to the high G value in Fatra. Be-sides heavy upholstering seats, most of them are reflexive and diffusion elements, such as convex shaped lower side of the balconies around the auditorium or side walls and ceiling covered by plaster. Also, the design of balconies in concert halls is natural element that prevent generation of flutter echoes, which is frequent problem in halls with parallel sidewalls. We also included the echo criterion function in the EASERA software, which confirmed the absence of this phenomenon.

The last mention is about measuring performed with an empty auditorium. Because of that there is a possibility that RT should be little lower when occupied by audience. Nevertheless, according to findings in Beranek [25], in halls with heavy upholstering on seats there is nearly the same RT without the audience – just about 0,2 s difference. Since RT was averaging over 2 s, even with a reduction of two tenths of a second it is still within ideal limits for chamber music. Heavy upholstering and small RT difference in Fatra House of Arts can also be an advantage during orchestra rehearsals without spectators, because the conductor and the musicians will hear the reverberation during the concert performance.

6. CONCLUSIONS

In this article, we presented a concert hall of The Fatra House of Arts in Zilina Slovakia, a seat of The Slovak Sinfonietta Zilina. We described short history of the building, physical dimensions of the concert hall and the measurement methods and techniques that we utilized in measuring process. We also described parameters that are related with the acoustical quality from both subjective and objective point of view - reverberation-based, energy-based, spectral-based and spatial impression-based criteria. Concert hall of Fatra House of Arts has earned a reputation of an exquisite sounding space be-tween the musicians and conductors from the whole world. Measurement results con-firmed these subjective impressions and showed that the hall is comparable to other world-famous concert venues. Our motivation is also to popularize and present this rare cultural monument with great acoustics to the general public. In the future work, we would like to supplement the results with the dummy-head measurement. Furthermore, we would like to continue to measure the acoustical quality of a concert halls in Slovakia, since any complex study in this area is missing.

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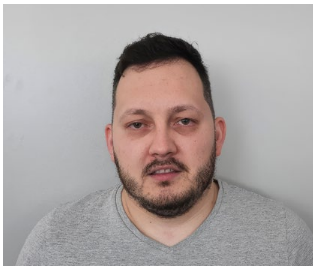

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