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THE ACOUSTIC FEATURES AND MUSIC-CULTURAL CONTEXTS OF CONCERT AND THEATRE HALLS IN SLOVAKIA – ZICHY PALACE, THE SLOVAK NATIONAL THEATRE

[a)]Pavol Brezina, [b)]Alena Čierna, [c)]Michal Jarabica, [d)] Peter Zaťko

[a-c)] *Constantine the Philosopher University in Nitra*
[d)] *A&Z Acoustics s.r.o.*

***Abstract**: This study deals with spatial-acoustic research on two buildings in Bratislava, built in two different historical periods, with a significantly different primary function in terms of the musical life of the town. The Opera and Ballet Hall of the Slovak National Theatre is a relatively new building with a relatively short concert history. The concert life of the Concert Hall of Zichy Palace dates back to the 18th century and has an extremely rich concert history. The present study is devoted to describing the historical and cultural contexts, while also investigating their acoustic properties. The subject of the acoustical research is the description of the basic parameters – reverberation time T, clarity C80, interaural correlation coefficient IACC and spoken speech intelligibility measure STI.*

***Keywords:** field acoustics, concert halls, cultural heritage*

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1. INTRODUCTION

Every phase in the development of a human society is characterized by a specific material and spiritual culture that reflects its maturity level. Settlements give one of the most significant testimonies about the desires, ideals, and even the technical capacities and social needs, of the society. These reflect not only the mutual links between the social classes and strata, the state of knowledge, science, the development of industry, and technological advancements, but also the state of the spiritual sphere of the society, including its morals, philosophy, and arts.

The matter of building towns and their subsequent development and rebuilding in accordance with the new social and cultural requirements is extremely complex. Uncovering the history of buildings from the architectural aspect in terms of spatial and acoustic design, and from the aspect of their utilization in musical life, represents a well known research area in the world [1,2,3]. In Slovakia, this issue was addressed sporadically. At the same time, concert life in various historical periods has always been very closely linked to the space that determined the sound ideal of the performed music. The laws of spatial sound reflection and sound absorption were known already to ancient architects and their successors. With their acoustic features, the Romanesque basilicas, the Gothic and the Baroque cathedrals, the opera theatres, and the aristocratic residences had a direct influence on the development of musical thinking throughout the history of European music [4,5,6]. To a great extent, vocal and, later, instrumental music were influenced by the way the sound was produced by the musical instruments and by the quality of their material, as well as by reverberation time and the extent of the interaction of disturbing sound reflections and the distribution of the sound energy in concert halls. During historical development, a relationship has gradually developed from empirical experience between sound and space, which directly determined the architectural disposition of the halls meant for live concert music.

The acoustic properties of concert venues have been the subject of worldwide research for many decades. In Slovakia, a research team from the Constantine the Philosopher University in Nitra started to deal with this phenomenon and in their studies they present acoustic research of historical spaces as a form of intangible cultural heritage [7, 8]. Also in the case of the objects presented in this study – The Opera and Ballet Hall of the Slovak National Theatre and Concert Hall of Zichy Palace, it is the preservation of extremely valuable data obtained by field research. The aim of such research is not only to preserve the real measured acoustic parameters and acoustic models, but also to carry out extremely valuable historical-architectural research. It is hoped that, in addition to the real-world use of the research results in musical and performance practice as a guide for musicians and conductors, the findings can also serve other areas of research.

1.1 The Slovak National Theatre

From the architectural aspect, the new building of SNT may appear as a timeless one even today. It consists as if of two buildings connected with a central staircase, with a wing for the drama ensemble on the one side, and an opera and ballet wing on the other side. Regular geometric shapes appear in both the exterior and the interior of the building, and are enhanced also by the division of its layout along a central vertical axis. [9,10] Four theatre premises are accessible to the audience: the Opera and Ballet Hall with a capacity of eight hundred and sixty-two seats, the Drama Hall with six hundred and forty-nine seats, the Studio with a hundred and sixty seats, and the Blue Salon with eighty seats.

The Opera and Ballet Hall is situated in the right section of the building and its designers drew on the typology of historical buildings of opera halls in the form of a classic frontal theatre, with the possibility to enlarge the hall at its stage area. The

proportions of the hall resulted from a compromise between the requirements for musical and for dramatic performance. This compromise also reflects in the orchestra pit, which is partially covered from the side of the stage to enable a closer contact between the performers and the audience. This design partly discriminates against the orchestra players, to whom the sound comes back. The orchestra pit of SNT, with an area of 136 m^2, is the largest of its kind in Slovakia.

The auditorium has a so-called peephole shape (with a length of about twenty-seven metres and width about thirty metres), with decreasing elevation (from twelve to three and a half metres). The ceiling of the auditorium consists of hanging, convexly curved, relatively heavy slats of wooden boards. Along its sides, towards the stage, there are similarly curved heavy sheet metal slats, with further acoustic resonators behind them, and the main wall is covered with acoustically perforated travertine. The rear, concavely curved wall is covered with travertine of a very thick structure, to create a diffuse reflection surface. The seats in the auditorium are covered with standard absorbent fabric foam.

The auditorium (Fig. 1) provides extra spatial possibilities – the stage area is a rectangle of 25 x 20.8 metres, which can be extended at all sides (by 17.5 metres along its lateral sides and by 15.2 metres along its rear side). The rigging loft reaches a height of 30.7 metres from the auditorium floor and there is an over thirteen-metre-deep technological area under the wooden floor.

Fig. 1: The Slovak National Theatre (author Peter Zaťko)

1.2 The Concert Hall of Zichy Palace

In the 1780s, at the time when Zichy Palace was built, Bratislava was the second largest town in Hungary, and it was the political, economic, ecclesiastical, and cultural centre of the country. As a coronation town during the reign of Maria Theresa, Bratislava was the seat of the Hungarian governor, the Hungarian government, the central Hungarian authorities, the religious orders, numerous royal officials, and noble families. Its booming commerce and crafts attracted people of various professions, scientists, and artists, to the town. The high standard of musical life was maintained and regulated by church officials and the high nobility throughout the eighteenth century. [11,12]

The noble family of the Zichys made a name for themselves mainly by their excellent military skills, for which they became the guardians of the Hungarian crown. By time, the military career advancement in the family changed to more peaceful professions. From military achievements, it was a straight path to a bright career in politics or high positions in the Catholic Church. However, even music was not distant to this ancient family (the first reference to whom dates back to 1260). As the extant records reveal, Zichy Palace housed musical productions – solo and chamber concerts – just like other noble salons in Bratislava. The intensive cultivation of music by the nobility is documented by several articles in the *Preßbuger Zeitung* newspaper. Music was also cultivated by Count Johann Nepomuk Zichy (1777 – 1830), who employed the German composer Heinrich Marschner (1795 – 1861) as a music teacher from 1817 to 1821. As the records reveal, several evenings of music were held in Zichy Palace in the winter months of 1816/1817, where, besides Marschner and other musicians, the fourteen-year-old countess Francisca Zichy (the daughter of Johann Nepomuk Zichy and the pupil of Marschner) performed, too. [13]

After the last renovation of Zichy Palace (1980 – 1989), music also returned to its premises. Its Concert Hall houses concerts by domestic and foreign performers – the Slovak Chamber Orchestra of Bohdan Warchal, Peter Michalica (violin), Pietro Massa (piano, Italy), Klára Havlíková (piano), Miroslav Dvorský (tenor), cycles of generational concerts, the Paganini of Pressburg violin competition, and concerts of primary schools of arts in Bratislava.

Fig. 2: The Concert Hall of Zichy Palace (author Peter Zaťko)

2. METHODOLOGY

The measurement methodology of the acoustics of the halls was primarily based on the requirements set by the STN EN ISO 3382-1 [14] and the STN EN 60268-16 [15] standards. Today, the Opera and Ballet Hall of the Slovak National Theatre and the Concert Hall of Zichy Palace serve for cultural and concert activities. In both halls, the measurements were conducted using the following devices:

- Norsonic Nor276 omnidirectional sound source,
- Yamaha HS50 nearfield active monitor (to create an acoustic model of the space),
- Roland Quad Capture sound card,
- Audix TM1 Plus calibrated measurement microphone,
- Behringer ECM8000 measurement microphones (to create an acoustic model of the space),

- Soundman John artificial head with Soundman OKM II calibrated microphones,
- ARTA measurement software,
- AudioEase Altiverb 7 convolution reverb plug-in.

Research at Opera and Ballet Hall of the Slovak National Theatre was held on 3rd of July 2021 and at Concert Hall of Zichy Palace at 31st of March 2022.

2.1 The Opera and Ballet Hall of the Slovak National Theatre

Sound Source Positions

Measured hall can be considered to be symmetric. For this reason, we placed the omnidirectional sound source at a height of 1.5 metres in the central position of the stage (Fig. 3). The measurements were conducted in the halls without an audience.

Microphone Positions

We chose thirty-one microphone positions M in the **Opera and Ballet Hall of the Slovak National Theatre** (Fig. 3). The microphone was placed at the height of a seated listener, at 1.2 metres above the floor. For higher precision, three subsequent averaged measurements were conducted in each position. To measure the inter-aural cross-correlation coefficient (IACC), we placed the artificial measurement head to identical positions.

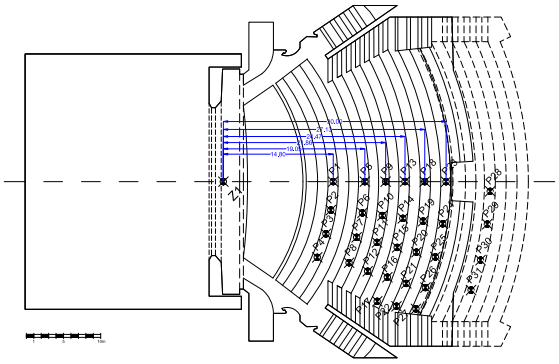


Fig. 3: Floor plan of The Opera and Ballet Hall of the Slovak National Theatre with sound source position (Z), microphone positions (P) and their distances

2.2 The Concert Hall of Zichy Palace

Sound Source Positions

Measured halls can be considered to be symmetric. For this reason, we placed the omnidirectional sound source at a height of 1.5 metres in the central position of the stage (Fig. 4). The measurements were conducted in the halls without an audience.

Microphone Positions

We eight positions P in the Concert Hall of Zichy Palace (Fig. 4). The microphone was placed at the height of a seated listener, at 1.2 metres above the floor. For higher precision, three subsequent averaged measurements were conducted in each position. To measure the inter-aural cross-correlation coefficient (IACC), we placed the artificial measurement head to identical positions.

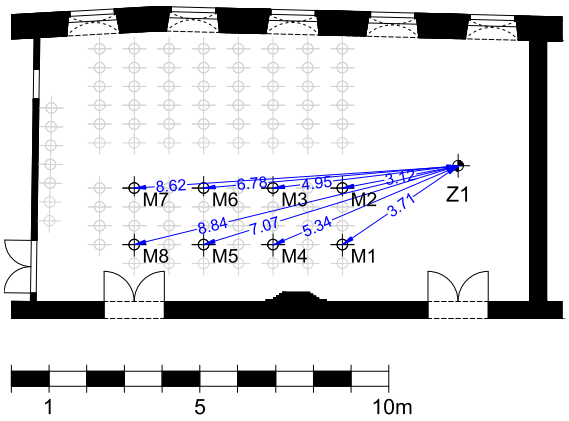


Fig.4: Floor plan of the Concert Hall of Zichy Palace with sound source position (Z), microphone positions (M) and their distances

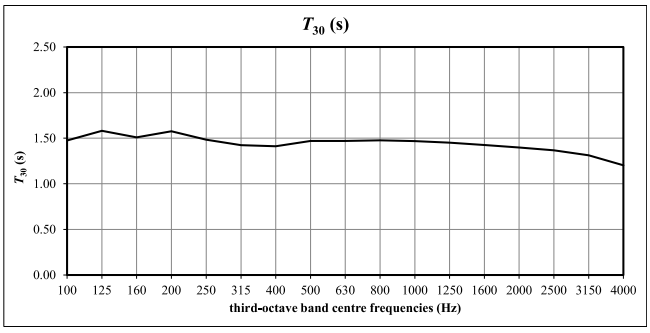
2.3 The Scanning Methodology of the Acoustics of the Halls

The acoustics of the halls were scanned and reproduced with Altiverb 7 convolution reverb processor according to the methodology provided by its manufacturer, AudioEase. The reproduction of the acoustics of the halls is helpful for the post-production adjustment of monophonic sound signals (e.g. speech, singing, solo instrument).

3. RESEARCH RESULTS

3.1 The Opera and Ballet Hall of the Slovak National Theatre

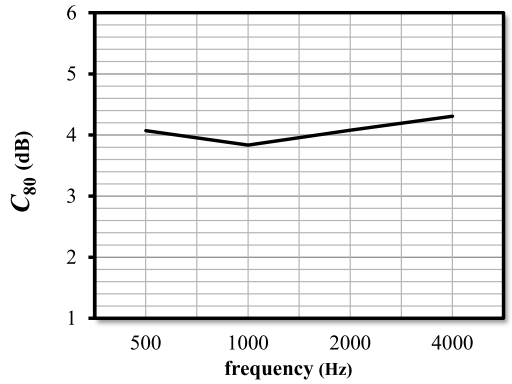
According to Leo Beranek [16], the generally recommended reverberation time for opera performances is approximately 1.3 to 1.8 seconds. From 250 Hz onwards, the reverberation time curve is extremely balanced and moves around 1.4 seconds (Graph 1). From the given course of the reverberation time, we may conclude that the hall is balanced in terms of frequency and provides full-fledged sound transmission as well as intelligibility to solo instruments, singers, and various chamber ensembles.



Graph 1: Reverb time T_{30} (s) in third-octave band centre frequencies (Hz) for The Opera and Ballet Hall of the Slovak National Theatre

The course of the clarity index curve suggests that the hall is highly suitable for the opera repertoire, where the intelligibility of each component of the musical performance plays a crucial role. According to the current categorization of the C_{80} parameter [17], the values measured in the Opera and Ballet Hall of the Slovak National Theatre fall into the band of concert

halls suitable for the performance of orchestral music, whose character requires each musical part to be intelligible and clear (Graph 2).



Graph 2: Clarity C_{80} graph for The Opera and Ballet Hall of the Slovak National Theatre

According to the categorization of the respective Hidaka methodology [18], the IACCE3 mean value at 0.53 ranks it among good to excellent halls (Tab.1). The ***IACCE$_3$ = 0.53 value*** may be considered to be in the mid-band of the quality categorization of concert halls. The limit values for the average to good band are 0.54 – 0.55. In this case, the mean values of the IACCE3 parameter are significantly helped by the ascending floor that may cause a quick dampening of the lateral reflections towards the audience. This may manifest in the inequality of the distribution of part of the sound energy in the various parts of the auditorium. The slope of the auditorium, however, is designed according to the visibility curve, as this is one of the basic requirements in designing an auditorium of this type. In this case, the slope of the auditorium is natural. This layout of the hall also improves acoustic perception in the auditorium. Since the floor slopes upward, it does not mask the direct sound from the stage.

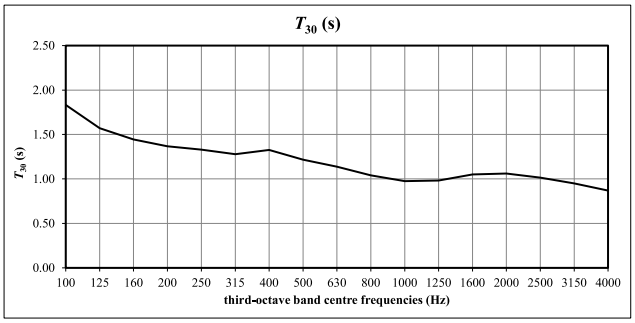
octave band centre frequencies (Hz)	125	250	500	1000	2000	4000
$IACC_E$	0.96	0.87	0.53	0.51	0.55	0.47
$IACC_{E3} = 0.52$						

Tab. 1: IACC values for The Opera and Ballet Hall of the Slovak National Theatre

Despite the fact that the Opera and Ballet Hall of the Slovak National Theatre has not been ranked among historical halls, the research in this hall was motivated primarily by a need to define its acoustic features for conductors and dramaturges, who may then adjust the repertoire of the various seasons to a certain extent according to the described characteristics. In conclusion, the objective acoustic parameters that describe the features of indoor halls make this hall in principle suitable for the productions it is meant for.

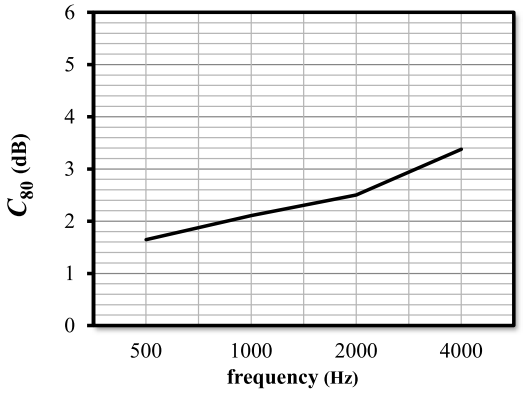
3.2 The Concert Hall of Zichy Palace

With an area of 90.09 m^2, the Concert Hall of Zichy Palace may be regarded as a highly chamber-like concert space. The reverberation time curve, which is balanced in its entire course and moves in the range of 0.87 to 1.83 seconds, also corresponds to this. With respect to an optimal assessment of reverberation time, Beranek [18] recommends the mean reverberation value to move in the range of 1.9 to 2.1 seconds. The failure to meet this requirement does not disqualify the respective hall, but it should be noted that the minimum reverberation times have a significant impact on the intelligibility and clarity of musical performances. For this reason, the hall is suitable mainly for solo instruments or small ensembles. At the same time, the presence of a grand piano predestines it for organizing piano recitals. The quality of the sound of the musical instruments is maintained in the hall thanks to a balanced reverberation time throughout the entire frequency spectrum (Graph 3).



Graph 3: Reverb time T_{30} (s) in third-octave band centre frequencies (Hz) for the Concert Hall of Zichy Palace

At all the frequencies of the octave band, the C80 clarity index distinctively moves in positive values (Graph 4) and, according to the current categorization [17], this makes the hall suitable for solo instruments even of percussive character; moreover, musical performances will be intelligible even in faster tempos. The measured values of the C80 parameter are an important indicator also of the suitability of the Concert Hall of Zichy Palace for chamber concerts of smaller ensembles.



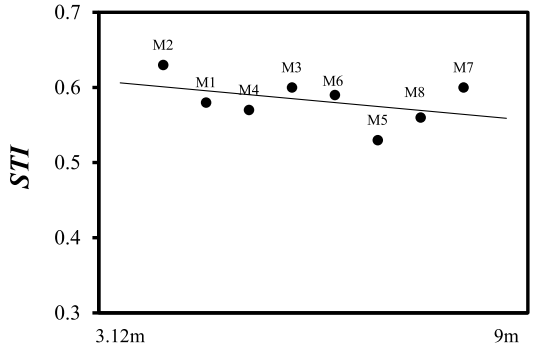
Graph 4: Clarity C_{80} graph for the Concert Hall of Zichy Palace

The value of the IACCE inter-aural cross-correlation coefficient is 0.19 (Tab.2) and, according to the categorization by Hidaka's methodology [18], this represents an excellent concert hall. We should not forget, however, that it is a relatively small area, whose capacity is not comparable to large concert halls. The value of the correlation coefficient is more like illustrative in this case.

octave band centre frequencies (Hz)	125	250	500	1000	2000	4000
$IACC_E$	0.91	0.80	0.18	0.18	0.22	0.18
$IACC_{E3} = 0.19$						

Tab. 2: IACC values for the Concert Hall of Zichy Palace

Thanks to its area and volume, the Concert Hall of Zichy Palace can be used also for verbal presentations. In all measurement positions throughout the hall, the STI speech intelligibility values were balanced. Based on the measured values, the hall has an average to satisfactory level of subjective intelligibility assessment. This renders sound reinforcement unnecessary in the case of solo speech.



Graph 5: STI index values and positions for the Concert Hall of Zichy Palace. Microphone positions M were placed according to Fig. 4.

4: DISCUSSION

The acoustic research carried out is based on several renowned studies that have been published in the international professional community over the past decades [1,2,3]. Compared to these studies, however, it aims to describe more rigorously how given acoustic parameters affect the realization of musical productions. Since the present article is also concerned with concert venues, the intention is to describe the research results in a way that is also understandable to musicians, dramaturgs or conductors. The main pitfall of the conducted research is the delimitation of the investigated acoustic parameters. The latter currently includes only the basic ones. This is mainly because of the financial requirements for the appropriate technical equipment that would allow, for example, measurements of the sound strength parameter G. Another problem of current field acoustic research in concert venues is the absence of an internationally accepted uniform methodology for the placement of sound sources and microphones. The research team therefore relied primarily on the methodology developed by the Takenaka Institute [18].

5. CONCLUSION

The Opera and Ballet Hall of The Slovak National Theatre and The Concert Hall of Zichy Palace are extremely different in terms of construction, dimensions and partly also function. However, it is possible to compare the two venues in terms of the quality of acoustic properties in relation to acoustic treatments. Based on the presented research data, it can be concluded that the acoustic design of the Opera House provides ideal acoustic properties for a specific type of orchestral performances – both opera and ballet. If the much smaller space of The Concert Hall of Zichy Palace had at least basic acoustic solutions, it would have been possible to achieve better reverberation balance, especially in the bass frequencies, which are crucial for the quality of musical-sound interpretation. Although the concert history of The Concert Hall of Zichy Palace is extremely rich and dates back to the 18th century, the venue has not yet undergone a major acoustic renovation. The Slovak National Theatre, a much younger building, has undergone several acoustic modifications during its existence. From the point of view of intangible cultural heritage, the measurements in both spaces are extremely important and in the case of The Concert Hall of Zichy Palace can serve as a starting point for the eventual reconstruction of the acoustic solutions.

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