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ScienceDirect

Energy Procedia 78 (2015) 31 – 36

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Sound and architecture – mutual influence

Joanna Jablonska[a]*, Elzbieta Trocka-Leszczynska[a], Romuald Tarczewski[a]

[a]*Faculty of Architecture Wroclaw University of Technology, B. Prusa 53/55, Wroclaw 50-317, Poland*

Abstract

Sound exists in architecture and architecture exists in sound. The process of how the two have influenced each other can be observed throughout history and has brought us the most surprising outcomes. The article presents research results on the interconnection of sound and space, in the aspect of their intertwining influence in introducing physical changes in interiors and transformations in music. The objective was to present and scientifically describe a process in which both buildings and sound effect each other, inspiring new solutions, forming innovative structures and becoming both factors and subjects of their constant interaction. This correlation was investigated within a broad timeframe of European history, from the distant past – ancient Greece and Rome – to the recent future – a "vineyard" configuration of Berlin Philharmonic Hall. Several research methods were used, ranging from case and literature studies aimed at data gathering, to comparative and graphical analysis, discussion, and finally, the synthesis and critical analysis in the concluding part.

A great example of the discussed phenomenon is the development of religious chant resulting from a long reverberation time in sacral buildings, creation of the polychoral technique connected to the architectural arraignment of St Mark's Church in Venice or the popularization of the "shoebox" configuration for music halls, as a consequence of wooden structural system's limitations. Let us have a closer look at the process of mutual influences between architectural space and inner sound.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

*Keywords:*architectural acoustics; sound in space; space for sound; music in architecture;

* Joanna Jablonska. Tel.: +48-71-320-63-79; fax: +48-71- 320-64-60.
E-mail address: joanna.jablonska@pwr.edu.pl

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.110

1. Introduction

Long before the advent of modern day acoustics – prior to when, in the second half of the twentieth century, architectural acoustics was established – architecture and sound co-influenced one another in inspiring musical forms and original interior design solutions. Builders and composers, architects and performers, have all adjusted their work based on their experience in order to achieve the best possible spatial and sound effects. The design evolution is clearly visible in the analysis of the development of musical performance facilities. Subsequent transformations, manifested mainly in continuous changes set to improve sound effects in a closed cubature within a particular geometry, involve not only architectural solutions, but also musical forms, as the latter were adapted to fit the architectural environment they were performed in.

The described phenomenon of mutual interconnection between the physical space which is marked by a vivid presence in time, and the ephemeral and elusive sound, is the main inspiration behind this article. In the paper, the authors present results from long-term research on the correlations between architecture and sound.

1.1. Methodology and research aims

The main research aim was to present mutual correlations between architecture and sound. It was especially crucial to present space as well as musical forms as agents of change. However, achieving this goal requires analyzing the historical development of musical facilities, i.e. theatres, churches and music halls, and their adaptation to different kinds of musical performances. The research scope comprises of facilities built in Europe from antiquity, through the Middle Ages, Renaissance (churches, theatres), Baroque (operas), the classicists period (Wagner), to the nineteenth and twentieth century concert halls, and, finally, contemporary, both “shoebox” and central, i.e. “vineyard”, configuration spatial layouts. A common feature for all of the selected examples is their purpose to provide space for performing music, regardless of their character (sacral, cultural or entertainment). As the scope of the research in the article is very broad, only the most representative examples are presented alongside general conclusions based on a synthesis of the gathered data.

The research was conducted on two levels. On the one hand, literature studies in the field of architecture, acoustics and architectural acoustics, including a critical analysis of source texts and a graphical analysis of iconographic materials, were conducted and paired with case studies, visiting facilities and expert interviews, supplemented by visual materials. Additionally, in the discussion and conclusion part of the text, a synthesis method, including a comparative synthesis, was used.

2. Discussion

2.1. Antiquity

The first theatres in the ancient Greece from between 550 and 500 BC [1] were of a temporary character, gradually enriched with architectural elements (fig. 1 a). Initially, the following elements were constructed: a stone platform, *orchestra* (from Greek) with a 20-40 m diameter [2] surrounded by wooden and stone benches, as well as an alter or a temple [3]. Those, together with the surrounding background, used to create the basis for a theatrical building. Although, in the described facility, the acoustic scheme was rather simple (direct sound was amplified by, firstly, reflecting off the floor and, later, the theatrical building [4]), already then zones with worse sound reception were noticed. These were the side parts of the auditorium, reduced after 330BC, e.g. in Priene (Turkey) [1].

Solutions from ancient Rome can be perceived as a continuation and development of the previously discussed forms. Mistakes marked in sound quality during that time (i.e. creating the hyposkenion through deepening and raising the proskenion, as well as locating the most prominent guests in the area of the stage floor), significantly decreased the role of the already mentioned first sound reflection. Having said that, it needs to be noted that a steeply rising auditorium [3] has greatly improved the direct sound propagation. Moreover, Shankland’s research on Roman theatres (fig. 1 b) proved that in such objects the power of sound in speech articulation was reaching 80% [4]. Despite the inability to perform appropriate calculations, in Roman theatres, optimal acoustics was of greater importance than visibility. This is further described by Vitruvius, who, in his works, clearly states that a theatre has

good acoustics, when *dissonances* or *resonances* are not present, while the words are heard clearly and in a pure tone [4]. The famous author also stresses the fact that in order for the sound to possess appropriate characteristics, the area where the theater is built should be chosen wisely. Considering the latter, we may suspect that the ancient constructors were aware of the role of the auditorium angle and sound reflection of the floor [1], [4].

2.2. Middle Ages

The decline of the Roman Empire paired with the expansion of Christianity have brought a loss of interest in the ancient theatre in favor of the development of choral music, performed during religious gatherings in houses, caves and catacombs [2]. Since 380 AD, when Christianity was officially recognized as the state religion of Rome, sacred architecture has been on the rise. According to Broniewski [2], the first churches, built in the first half of the fourth century, were elongated halls with one apse and an elevated floor. An evolution to more complex spatial forms with side naves and a transept was an effect of the intense development of religion in the second half of the fourth century. Due to their large capacity and the closed spatial environment they provided, the church buildings facilitated multiple side reflections of sound waves as well as reverberation. Moreover, as the reverberation time was significantly prolonged, musical pieces from the time were based on a choral (e.g. Gregorian chant) [5]. Thus, music was adapted to acoustic characteristics of the interior.

Another interesting phenomenon in the described period was connected with the emergence of chivalry and knighthood, more specifically, knightly songs and ballads performed in palace halls. In such interiors of a relatively small cubature, usually furnished with drapes, the reverberation time was short, and thus enabled understanding of individual words. Furthermore, other decorations and reliefs facilitated acoustic wave scattering. Later, the form of a palace hall will be copied in the modern shoebox shaped halls solutions.

2.3. Renaissance, Baroque, Classicism

In the Renaissance period, churches continued to play a significant role, providing room for music to be performed. One of the most notorious examples is the St. Mark's Basilica in Venice, which served as an example for the development of polychoral technology. "Polychoral technique (also known as polychoral style) is a composing technique developed at the turn of the sixteenth and seventeenth century and based on a choir (also accompanied by musical instruments) divided into groups. Each of those was placed in a different part of the church. The groups, usually 2 or 3, performed the song alternately" [5, p. 700]. The unique shape of the St. Mark's Basilica facilitated an emergence of a characteristic sound, thus inspiring the advent of a new musical form.

The interest in theatre reemerged at the time of Renaissance (i.e. in Italy, around the sixteenth century). Yet, the first attempts to install roofs in antique buildings, e.g. Teatro Olympico (second half of the sixteenth century) were rather unsuccessful, due to an elongated reverberation time and an inadequate ratio of width and length of the floor plan. The issue was further complicated by the "relief stage" – fitted with long narrow corridors. It was not until the creation of Teatro Farnese, where the floor plan is of an elongated rectangle shape, that one may find an effort to install acoustic corrections to the interior. Unfortunately, the introduction of a stage portal, a frame dividing the stage from the auditorium, undermined the chance for a satisfactory sound propagation. The discussed problem became even more serious with the introduction of an orchestra pit, firstly inaugurated in Teatro San Carlo in Naples in 1737, as well as with the development of a classical opera theatre (fig. 1 c), favored in the Baroque period. The floor plan of the latter, with an acoustically unfavorable U-or-horseshoe-shaped auditorium, facilitated a creation of an "uneven" sound field. Moreover, rows of balconies created an additional area of concentration for sound waves, as well as a significant number of late sound reflection. However, the latter was slightly alleviated by sculptural decorations, which scattered sound [2], [4], [6].

2.4. Wagner's Theatre, halls in the nineteenth and twentieth century

Other changes in architectural acoustics were elicited by the composer Richard Wagner, who, together with architect Otto Bruckwald, wanted to create the best possible space for his music. This lead to the opening of the Festspielhaus in 1876 in Bayreuth (fig. 1 d) [4]. Deprived of balconies, the interior had a rectangular layout and an

increased, in comparison to Renaissance and Baroque theatres, cubature. Smooth walls and ceiling, complemented by only one regal gallery with a full balustrade and columns located close to the sides. This arrangement provided an impeccable audibility for Wagner's compositions [1], [4], [6].

During that time also the so called "shoebox" recital halls were gaining popularity (fig. 2 a). George Izenour, an American scholar [7], speculated that such a layout was a result of constructional factors, as, historically, buildings were covered with wooden ceiling spanning usually up to 27 m, due to the load-bearing capacity of beams [7]. The system of long, narrow and tall rectangular rooms with the following proportions 1:2:2, provided fine acoustics [4]. Thus, it is possible that good acoustics of the discussed interiors contributed to the popularization of a musical form called a concert. Dedicated to this specific musical form, larger "shoebox" – shaped concert halls were being built starting from the Altes Gewandhaus in Leipzig in 1780 (firstly for an audience of 400 and later 600 people), continuing with the Musikvereinsaal in Vienna (1870), St Andrews in Glasgow (1877), Concertgebouw in Amsterdam (1888), and finally the Symphony Hall in Boston (1900). The latter became a long-lasting model for future endeavors [6]. However, the evolution of the "shoebox" style, complemented by new discoveries in the field of modern acoustics, including the works of Wallace Clement Sabine, Leo Beranek, Richard Bolt, Robert Newmana and many others, did not put an end to the development of concert halls, as well as to the mutual influences between architecture and acoustics.

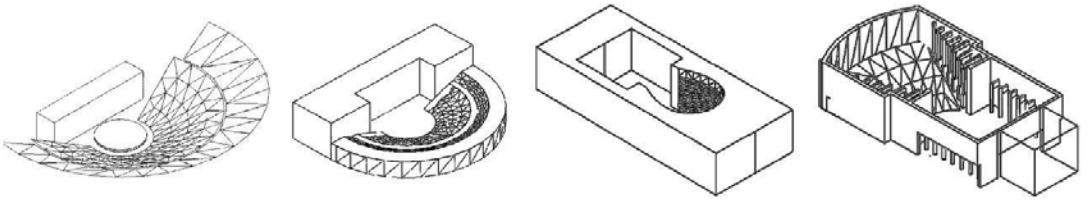

Fig. 1. Concert hall development stages: (a) Ancient Greek theatre; (b) Ancient Roman theatre; (c) Opera; (d) Wagner theatre

2.5. Vineyard configuration – a special case of a musician's, architect's and acoustician's intuition

The dynamic development of both music and acoustics in the second half of the nineteenth century resulted in the need of enlarging the existing concert halls. Yet, a growth in cubature in the shoebox, fan or horseshoe – shaped layouts posed a threat of an overly prolonged reverberation time as well as of an echo. This, in the second half of the twentieth century, prompted the creation of an innovative solution, willingly applied, also today, in larger concert halls with an auditorium for over 1800 people [8].

The Berliner Philhamonie, opened in 1963, absolutely groundbreaking in terms of architectural acoustics, was designed by Hans Scharoun who thoroughly consulted his project with an acoustician, Lothar Cremer. The idea behind the design was to create an architectural facility from inside out (i.e. from the concert hall to the outer façade). The winning hall outlay plan was selected in a competition in 1956. Unfortunately, the construction process was halted due to controversies surrounding the project. It was not until Herbet von Krajan – the conductor of the Berlin Philharmonic and a renowned musician – intervened that the project was resumed. The hall was centrally laid out and included balconies were the auditorium was located. This arrangement was called the vineyard configuration (fig. 2 b) [9], [4]. It needs to be noted that at the time, intense research on sound was taking place; Richard Bolt and Robert Newman were working on the issue from the 1960's, while Rusell Johnson and Harold Marshall from the 1970's.

The term "central terraced layout" comes from English-language source texts and is a paraphrase of the "vineyard terraces" expression. According to text sources [10], [11], [4], the discussed expression is a reference to the way in which the hall is built, as the terraced auditorium resembles a vineyard, while individual audience members are seated on platforms – the so called terraces. Moreover, in literature one encounters other expressions, such as i.e. "vineyard terraces", "vineyard", "vineyard style", "central-terraced layout" [10], [11], [4]. "Terraced central system is a concert hall layout plan with the stage located centrally (geometrical center, sometimes asymmetrical placement), surrounded by the auditorium from all sides. Audience seats in such types of configurations are grouped and placed on terraces, which are piled up in the direction of the crown of the

auditorium. Walls in-between the terraces (the so called terrace fronts) serve as additional planes facilitating diverse acoustic wave reflection, proper sound mixing (directly with the sound from the first side reflection) and creation of intense higher sound reflections. In a cross section, auditorium seats on the terrace are piled up in accordance with proper visibility in the direction of the auditorium crown. The ceilings in central layouts with terraces are usually of the baldachin or tent variety. In comparison to other halls, in this type it is possible to gather a larger audience [8, p. 8].

The discussed layout, through various transformations – usage of curves in designating certain elements of the interior, moving the stage more centrally, changing the layout from central to elongated (similar to shoebox style halls) – is being developed until this day. Judging by the popularity of this solution in designing world-class interiors, it may become the concert hall style of the future. Amazingly, we owe this to the intuition of those innovators who did not possess adequate tools to verify their predictions.

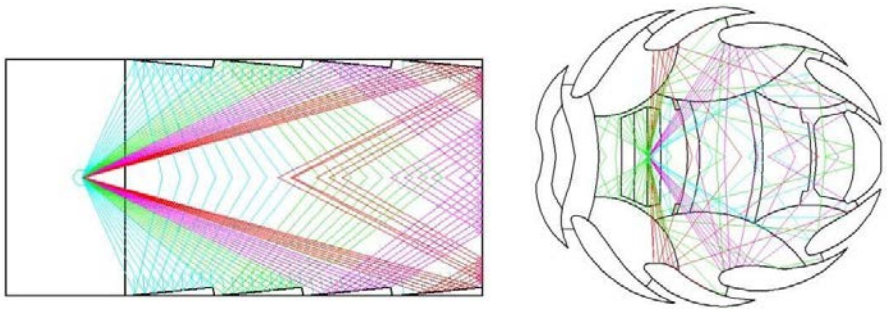

Fig. 2. Transformation of lateral reflection distribution according to the concert hall interior shape: (a) shoebox; (b) vineyard.

For the contemporary „vienyards" (i.a. Suntory Hall in Tokio, Muza Kawasaki Symphony Hall, Walt Disney Hall in Los Angeles, DR Koncerthuset in Copenhagen, new Philharmonie de Paris) following the discussed style, the crucial aspect in the design process is the usage of proper computer software technology, allowing for forecasting acoustical properties and parameters of the constructed interiors, even those of a very complex geometry.

3. Conclusion

The purpose of examining the relationship between architecture and sound was to determine how physical space affects the intangible sound and vice versa, as well as to present both phenomena as important factors in facilitating transformations. A detailed analysis of the subject resulted in the following table, illustrating the correlation between interacting entities and entities of change together with modifying factors.

Table 1. Architecture and sound as interconnected elements influencing development and transformation.

Interacting entity	Factor	Entity of change
Greek theatre	Refinement of architecture	Sound volume enhancement
Roman theatre	Refinement of architecture	Sound volume enhancement
Medieval churches	Emergence of a new type of interior	Emergence of a new music genre – chant
Medieval palace halls	Development of a new type of architecture	Evolution of songs performed by a soloist
Renaissance churches	Development of interiors with a complex geometry	Development of polychoral
Renaissance theatres	Construction of new solutions based on ancient	Deterioration of sound quality due to subsequent

	theatres	improvements
Baroque theatre/opera/classicistic theatre	Formal refinement of previous theatrical solutions	
Wagner's theatre	Richard Wagner's inspirations	Emergence of the predecessor of the shoebox hall
Popularization of concerts in the nineteenth and twentieth century	Development of previously established interior layouts with good acoustics	Emergence of the classical shoebox hall
Architectural-acoustic idea of a hall designed from inside out	Herberta von Karajan's inspirations	Emergence of the vineyard configuration

The table attempts to present elements that had the strongest impact on the issue, however, in some cases, they may be easily interchangeable. While the table shows that it was the quality of sound in the ancient theatres that caused certain changes in architecture, one could also say that the reduction of sides of the auditorium was introduced in order to limit seats with poorer audibility.

As the authors strove to prove, architecture and sound inextricably coexist and influence each other. Thus, architectural acoustics, as a tool in assisting the creation of optimal conditions for listening to music, should be developed interdisciplinary, in order for the subsequent transformations to produce new, as yet unknown, solutions.

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