The restoration of the Theatre of Arts Academy in Tirana – Acoustic analysis and design of the new Orchestra pit

Simone Secchi[a]* | Veronica Amodeo[a] | Fabio Capanni[a] | Riccardo Renzi[a] | Lamberto Tronchin[b]

[a] Dipartimento di Architettura, Università degli Studi di Firenze
[b] Dipartimento di Architettura, Università degli Studi di Bologna
* Corresponding author: simone.secchi@unifi.it

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The origin of the Theatre of Arts Academy of Tirana dates back to the early 20th Century, based on the design of the Italian architect Gherardo Bosio. It was almost abandoned in the last 20 years and only recently a complete renovation has been undertaken, including the extension of the Orchestra pit.
Measurements were carried out at different points in the stalls, in the gallery and in the lodges, using both balloon bursting and sine sweep convolution technique. The results of the measurements achieved in each of the areas with the two different techniques were compared with each other and with the reference values given by literature.
According to the measurements, the Theatre appears to be rather *dull*, but is nevertheless listed as one of the best theatres in Albania.
We used acoustic measurements (monaural and binaural IRs) to calibrate the 3D simulation model and to elaborate the new acoustic design of the Theatre, the most important part of which concerns the reopening of the Orchestra pit, which had been closed and unused for the past decades.
The paper briefly reports the history of the Theatre and the most important outcomes of measurements and simulations.
Keywords: theatre, orchestra pit, reverberation time, acoustic design

Il restauro del Teatro dell'Accademia delle Arti a Tirana – Analisi acustiche e progetto della nuova fossa d'orchestra
Il Teatro dell'Accademia delle Arti di Tirana è stato realizzato all'inizio del XX secolo su progetto dell'architetto fiorentino Gherardo Bosio. Solo recentemente è stato avviato un ampio intervento di restauro dell'edificio in abbandono da 20 anni, che ha incluso la riapertura e l'ampliamento della fossa d'orchestra.
Sono state effettuate delle misurazioni sia con la tecnica dello scoppio del palloncino che con quella della convoluzione della *sine sweep* in diversi punti della platea, della galleria e dei palchi ed i relativi risultati sono stati confrontati tra loro e con i valori di riferimento forniti dalla letteratura.
In base alle misurazioni, il teatro appare piuttosto *sordo* ma è comunque annoverato tra i migliori teatri di tutta l'Albania.
Le misurazioni acustiche (IR monoaurali e binaurali) sono state poi utilizzate per calibrare il modello di simulazione 3D e per elaborare il nuovo progetto acustico del teatro, la cui parte più importante riguarda la riapertura della fossa dell'orchestra, che era rimasta chiusa e inutilizzata negli ultimi decenni.
L'articolo riporta brevemente la storia del teatro e i risultati più importanti delle misurazioni e delle simulazioni.
Parole chiave: teatri, fossa d'orchestra, tempo di riverberazione, progetto acustico

1 | Introduction

This paper is an extended version of the one presented at the international Symposium "The Acoustics of Ancient Theatres", held in Verona 6-8 July 2022 [1].

The Theatre of the University of Arts of Tirana has been recently involved in a project for the restoration and renovation that has been carried out by the Department of Architecture of the University of Florence in collaboration with the engineering study Atelier4 of Tirana [2-5]. The supporter of the study was Trans Adriatic Pipeline, TAP, with the agreement of the Ministry of Culture of Albania.

The Theatre is considered by the Albanian Ministry of Culture the one with the best acoustic quality in the whole Albania and therefore the restoration project required a special effort in the acoustic characterization and design.

In this paper we show some of the acoustical investigations performed on the different areas of the Theatre (gallery, stalls and lateral lodges), in order to ensure optimal room acoustics after the restoration works.

2 | The concert hall at the University of Tirana

2.1 | About the history of the Theatre

The origin of the Opera Dopolavoro Albanese in Tirana dates back to the period between 1939 and 1943. During these years, the city underwent a building and territorial transformation that changed Tirana's landscape from the small original city, with a predominantly residential layout, into an urban complex that better reflected the image of a capital city. As part of this political, social and urban planning project that affected the whole of Albania, some Italian architects, mainly from Florence, guided by Gherardo Bosio, were called to contribute actively to the transformation of the city of Tirana.

The Theatre, designed by Bosio and developed by collaborators after his suddenly death, reflects that language of classical matrix, made of regular geometries, rhythmic repetitions, and functional expressions, which belong to the Italian architecture of Rationalism and that constantly characterize the work of the author (see Figures 1 and 2).

Fig. 1 – Photo of the time during the Theatre construction works (AEGB - archivio eredi Gherardo Bosio - Firenze)
Foto d'epoca durante i lavori di costruzione del Teatro (AEGB Firenze)

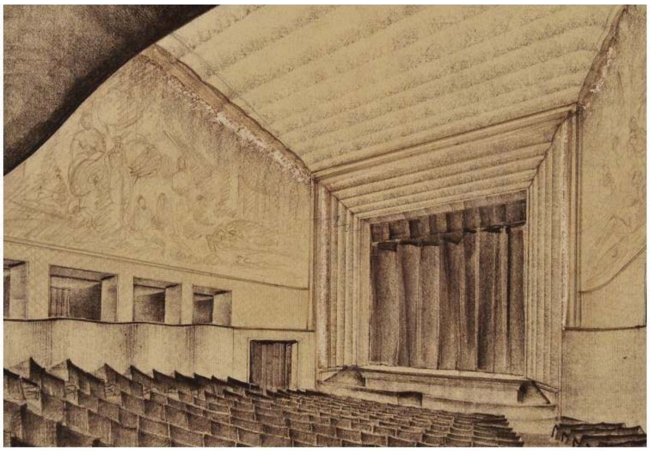

Fig. 2 – Gherardo Bosio, 1939-40. Original design of the Theatre Hall interiors (AEGB Firenze)
Gherardo Bosio, 1939-40. Progetto originario dell'interno della sala del Teatro (AEGB Firenze)

Even though the settlement of the city has changed over time, as well as the surrounding area of the Theatre, where now one can find many other architectures close to the building which have lost the original linguistic strength, the Opera Dopolavoro Albanese, within which the Concert Hall of the University of Arts is located, and the other architecture and boulevards of the same years are still a fundamental part of the historical identity of the city of Tirana. In fact, the building is currently considered as part of the Historical Heritage of Monumental Axis of Tirana: it's located in the historic center of the city, within a national importance area, declared protected since 2017, as architectural, cultural, heritage of 20^{th} Century (see Figure 3).

Fig. 3 – Aerial photo: bottom left, in red, the Theatre in its current; the right side, the new stadium in Tirana
Fotografia aerea: in basso, evidenziato in rosso, il Teatro allo stato attuale; a destra, il nuovo stadio di Tirana

2.2 | About the Theatre

In the functional plan, it is possible to divide the Theatre into four parts corresponding to different development activities (see Figure 4): the hall, the stage and the stage tower, the Orchestra pit and the technical rooms at the lowest level.

The hall of the Theatre has a volume of about 5000 m^3 and is characterized by the presence of the stalls surmounted by the gallery, both flanked by an order of double lodges. Both stalls and gallery have a similar number of seats.

The stalls have a carpeted floor and a suspended ceiling that completely encloses a glazed roof, provided by the original design of the Theatre but partially realized. The original armchairs have been partly removed and replaced with different models.

The Orchestra pit was closed during the last decades with a light iron structure and wooden paving built to expand the stage. This space is lined with dark wood, the same used also in the other parts of the Theatre.

The scenic tower is composed of superimposed orders service and technical rooms.

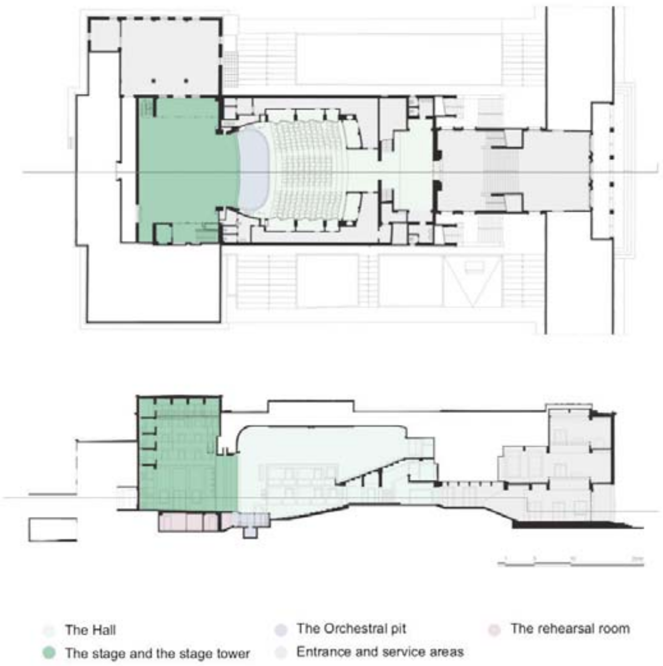

Fig. 4 – Plan and section of the Theatre at the current state
Pianta e sezione del Teatro allo stato attuale

According to the literature [6] considering the volume of the hall, the optimal reverberation time should be between 1.3 s (for operas and theatrical performances) and 2.4 s (for classical music).

2.3 | The aims of restoration project

The main aim of the Department of Architecture of the University of Florence feasibility study was to define a restoration and refurbishment of the Theatre such as to identify, bring to light and protect the constructive and language characteristics of Bosio's project, and at the same time to guarantee an optimal and safe use of the building, in terms of technological and legislative adaptation, usability and accessibility, minimizing as much as possible the alteration of the original identity of the Theatre (see Figures 5 and 6).

The main specifications for the acoustic project of the restoration of the Theatre concern the reduction and restoration of armchairs, the replacement of curtains and the restoration and enlargement of the Orchestra pit. To achieve this increase of the size of the pit, the floor plan was significantly modified from its original dimensions. It was also foreseen the installation of a mobile platform to allow the height of the Orchestra pit to be varied, according to the needs of the performances.

Fig. 5 – Interior photo showing the Theatre Hall at the current state
Foto interna che mostra la sala del Teatro allo stato attuale

Fig. 6 – Interior rendering showing the restoration design of the Theatre Hall
Rendering interno che mostra il progetto di restauro della sala del Teatro

Moreover, a new rehearsal room was designed under the stage (see Figure 4).

3 | Measurement procedure

The impulse response measurements were carried out in the Theatre in February 2020.

Due to the operational requirements of travelling to Albania, only lightweight and easily transportable instrumentation was used for measurements. In particular, the signal was acquired with a 1/2-inch diffuse field microphone and recorded in a 4-channel digital recorder Zoom H4n model. In addition, two Sennheiser in ear microphones were used for binaural measurements.

The results of the measurements were then processed with the software Audacity for windows with the Aurora plug in for Audacity.

Two different types of fixed sound sources were used:

- the Theatre's loudspeakers, with a "sine sweep" audio signal generated by the PC and reproduced by the Theatre's amplification system. In this case, the measurement was then convolved by means of the plugin "Aurora" for Audacity® into a corresponding impulse response [7] and the position of the two loudspeakers was that envisaged by the Theatre (frontal, lateral to the stage, figure 7, S2 a and b);
- an impulse source consisting of the bursting of balloons with a diameter of 40-45 cm; the balloons were all sequentially burst from the stage at the position shown in figure 7 (S1).
- Care was taken to maintain a random and non-symmetrical distribution of microphone positions during the measurements (see Figure 7). Measurement positions R10-R12, not shown in figure 7, were placed in the gallery and in the lateral lodges.

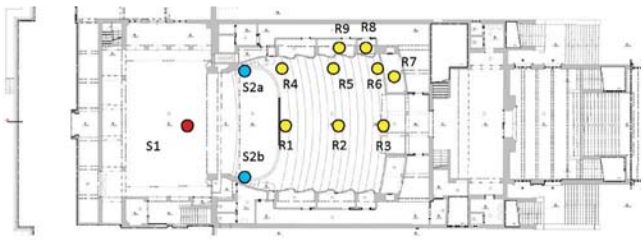

Fig. 7 – Source and measurement positions in the stalls (R1 – R6), in the central stage (R7) and in the lower side lodges (R8 and R9); S1 = position of the impulse source; S2a,b = positions of the two loudspeakers

Posizioni delle sorgenti e dei punti di misura nella platea (R1 – R6), nel palco centrale (R7) e nei palchi laterali inferiori (R8 e R9); S1 = posizione della sorgente impulsiva; S2a,b = posizioni dei due altoparlanti

4 | Measurement results

We obtained the impulse responses in the different positions and in both omnidirectional monaural and binaural modes, using the two measurement methods described (balloons and sine sweep), then we analyzed the following parameters:

- Reverberation time T_{30};
- Clarity C_{50};
- Clarity C_{80};
- Barycentric instant ts;
- Early Decay Time EDT;
- Sound Strength G.

Moreover, Speech Transmission Index measurements were also carried out.

The results referred to the 12 measuring points of T_{30} and C_{80}, measured with the sine sweep technique and the omnidirectional microphone, are shown in Figures 8 and 9.

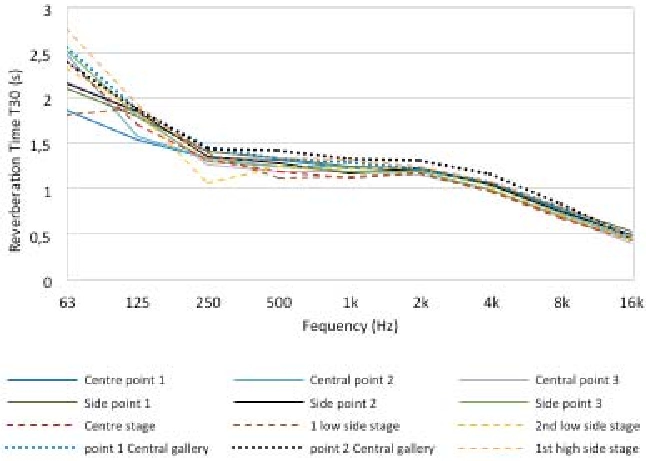

Fig. 8 – Reverberation time T30, in octave frequency bands in the 12 measurement positions

Tempo di riverberazione T30, in bande di ottava nei 12 punti di misura

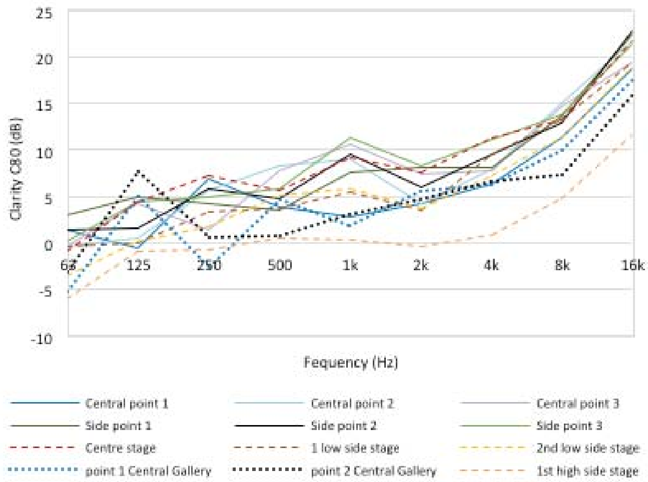

Fig. 9 – Clarity C80, in octave frequency bands in the 12 measurement positions

Chiarezza C80, in bande di ottava nei 12 punti di misura

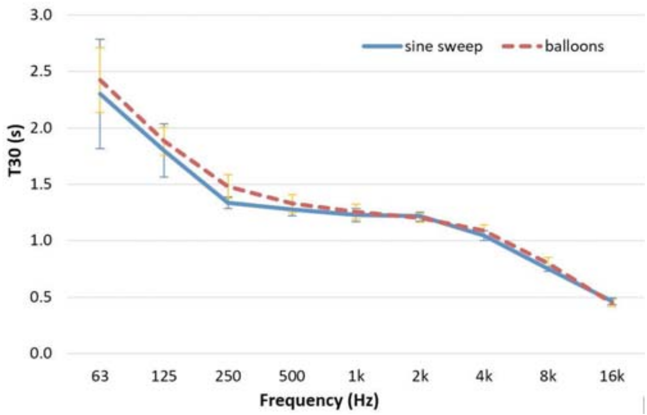

Fig. 10 – Comparison of averages of Reverberation Time (T30) results with the two measurement techniques adopted (error bars are given by ± standard deviation)

Confronto tra i valori medi delle misure di Tempo di Riverbero (T30) ottenuti con le due tecniche di misura (le barre di errore sono date da ± la deviazione standard delle misure)

Figure 10 shows a comparison between the average values of the reverberation time in the 12 measuring points obtained with the two techniques.

A good repeatability of the measurement results obtained with the two signal techniques can be observed. Moreover, the average values of T_{30} obtained at the different locations are quite repeatable and therefore "stable". Figure 11 shows the values of the average T_{30} in the stalls, gallery and lodges positions.

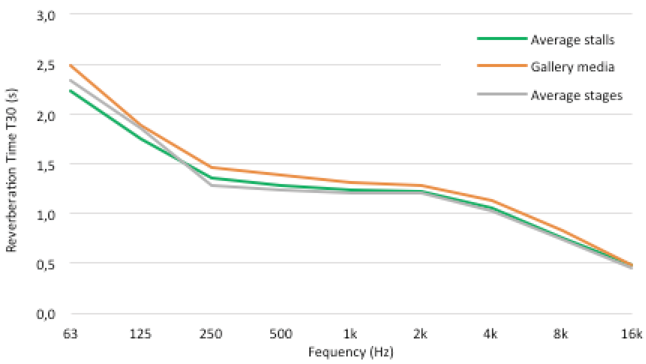

Fig. 11 – Average values of Reverberation Time (T_{30}) in the stalls, gallery and lodges

Valori medi del Tempo di Riverbero (T30) misurato nella galleria, nella platea e nei palchi

Considering the Theatre's volume of approximately 5000 m³ and referring to the value assumed by the reverberation time at 500 Hz it can be said to have a rather "dry" acoustics, i.e. it has a low reverberation that is well suited to theatrical performances and listening to speech.

With regard to listening to music, for which a greater contribution of reverberation is normally required, the Theatre is probably a little "dull" at high frequencies, i.e. it has a slightly too low reverberation time.

5 | Main indications of the restoration project

The most relevant acoustic changes connected with the restoration project of the Theatre were:

- restoration and reopening of the Orchestra pit;
- reduction of seats in the stalls by about 35%;
- reduction of seats in the gallery by about 30%;
- refurbishment of all plants and of all interior finishes (plasters, stuccos, etc.);
- elimination of the carpets of the gallery;
- elimination of the curtains of the lodges.

The main aim of the restoration project was the conservation of the actual acoustics of the Theatre. At this purpose, in agreement with the design team, the main acoustics issues of the project were:

- the design of the new Orchestra pit;
- the design of the new rehearsal open space under the stage;
- the selection of the new armchairs;
- the selection of the new curtains.

The new armchairs have been designed on the base of the Bosio's original model. New armchairs, produced in Spain by Euro Seating, have a weighted sound absorption coefficient of 0.70 (MH).

In order to maintain an acoustic response similar to the current one in the lodges, where the curtains will be removed, it was also necessary to insert sound-absorbing panels on the lateral walls inside them.

Figure 12 shows the comparison of the average value of T_{30} according to the measurements and simulations.

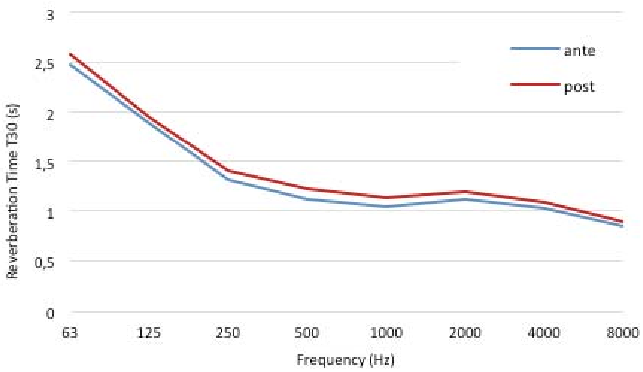

Fig. 12 – Comparison of average of Reverberation Time (T30) results before and after the Theatre Hall restoration project (simulations)

Confronto tra i valori medi del Tempo di Riverberazione (T30) prima e dopo gli interventi di restauro della sala del Teatro (ottenuti dalle simulazioni)

Anyway, the main acoustic design efforts concerned the renovation of the Orchestra pit.

5.1 | Orchestra pit requirements

The main characteristic of an Orchestra pit is the high sound level due to the early reflections which causes a low reverberation sensation compared to the rest of the Theatre; indeed, the sound level due to the early reflections must not exceed a certain range, beyond which it can cause a masking of the reverberated sound [8].

The main problem with the Orchestra pit is usually finding excessive sound levels in some places compared to others; another problem is resonance, especially at low frequencies [9], which can be solved by inserting bass-traps. Moreover, it is important to consider the different combinations of pit floor levels, the material with which it is covered, whether diffusing, reflecting or absorbing, and how this is applied and directed, so as to optimize the acoustics within the Orchestra pit and at the same time, balance its transmission to the hall and stage. Lowering the floor of the pit and adding absorbent material, in fact, changes the relationship between the early energy of the sound and the energy of the late reflections: in particular, by lowering the floor, the late reflections are higher; by inserting absorbent material, the early ones are higher [10] and the sound level decreases; however, this could increase the difficulty of listening between the musicians and the conductor [11, 12].

A way to have a better sound transmission from the pit to the audience [13] could be to insert reflectors above the pit; instead, a way to better transmit the sound from the pit to the audience could be to modify the height of the parapet surrounding the pit [14].

A widely used solution that theoretically helps to create a more diffuse sound field and improve the overall conditions are diffuser panels.

Although reverberation time is the primary reference for providing an indication of the acoustic qualities of an environment, it does not fully translate the subjective experience of the audience, the musician playing in the pit, or the conductor. To indicate this subjective experience, parameters such as Early Decay Time (EDT), Late Support (STlate) and Sound Strength (G) are used [15] to describe the impression of reverberation. Anyway, this is an attempt to parameterize what is in any case a subjective experience, which can be influenced by many factors, including the listening judgement of the musician, choir or conductor.

5.2 | Orchestra pit restauration

Considering the above indications and the architectural and historical constraints of the Theatre, the following indications emerged from the analysis of the measurement results and from the simulations: the side wall and the floor of the Orchestra pit must be lined in wood, as previously; moreover, it was necessary to apply sound-absorbing material in the ceiling of the covered part of the pit.

Therefore, an acoustic system consisting of panels that can take three different configurations was designed, so that the acoustic response within the orchestral pit can be modified according to the requirements of conductor and musicians.

The panels consist of a 100 cm thick layer of polyester fiber with a density of 40 kg/m^3 and flow resistivity of about 5,000 Pas/m^2, an air gap 10 mm thick and a rigid wood panel 15 mm thick, which can be replaced with another one with holes with diameter of 10 mm and distance of 100 or 50 mm (or a panel with half surface with holes spaced 50 mm and half surface with holes spaced 100 mm to broaden the spectrum of sound absorption – Figure 13).

Each panel, placed in the rear wall and/or in the ceiling of the Orchestra pit (see Figures 14), is independently adaptable, this allows to choose the configuration of the panels, according to the number and distribution of musicians and to the needs of the conductor and orchestral players, varying the acoustic response of the orchestra pit in frequency.

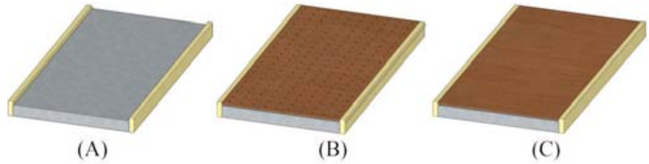

Fig. 13 – Acoustic system with three different possible configurations: (A) high frequency sound absorbing panel (not covered by the wood panel); (B): low frequency sound absorbing panel (covered by the drilled wood panel); (C): sound reflecting panel (when covered by the smooth wood panel)
Sistema acustico con tre diverse configurazioni: (A): pannello assorbente alle alte frequenze (in fibra poliestere non coperta dal pannello in legno); (B): pannello assorbente alle basse frequenze (coperto con il pannello in legno forato); (C): pannello riflettente (coperto con un pannello in legno liscio)

Three possible panel configurations are shown in the figure 13:

(A) the panel is not covered with any wood layer, making an high frequency sound absorber;
(B) the panel has a perforated wood cover, making a low frequency sound absorber;
(C) the panel has a smooth rigid wood cover, making a reflecting surface.

The sound absorption coefficient of these panels has been calculated according to the Allard and Champoux model for rigid panels [16, 17]. The flow resistivity of the polyester fiber has been calculated according to the Garai and Pompoli model [18].

Moreover, since the simulations carried out by means of a finite element model showed that stationary waves may occur at low frequencies, mainly because of the parallelism between the two opposite walls of the pit, the doors of the back wall were retracted so to create a sound spreading surface (see Figure 14).

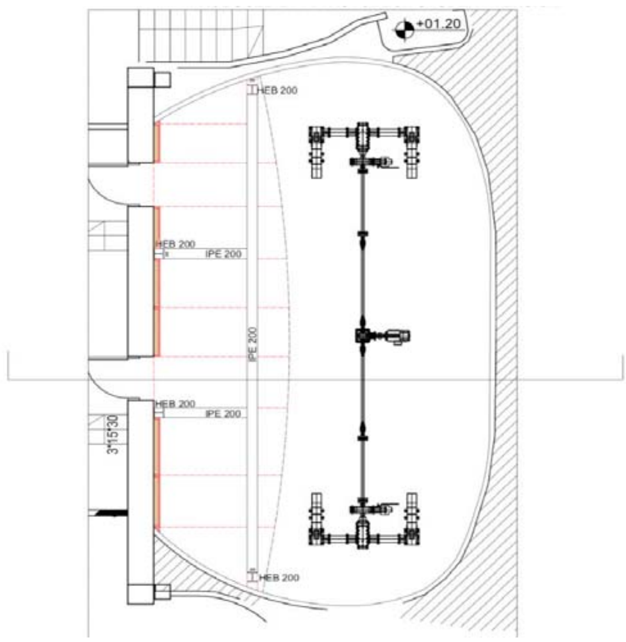

Fig. 14 – Orchestra pit plant showing the position of the variable acoustic panels (in red)
Pianta della fossa d'Orchestra che mostra la posizione dei pannelli ad acustica variabile (in rosso)

The parapet, that separates the Orchestra pit from the stalls, has a very important acoustic function, to reflect the sound rays coming from the stage and the pit. For this reason, it was tilted 7° toward the stalls to better reflect sound toward the stage (see Figure 15).

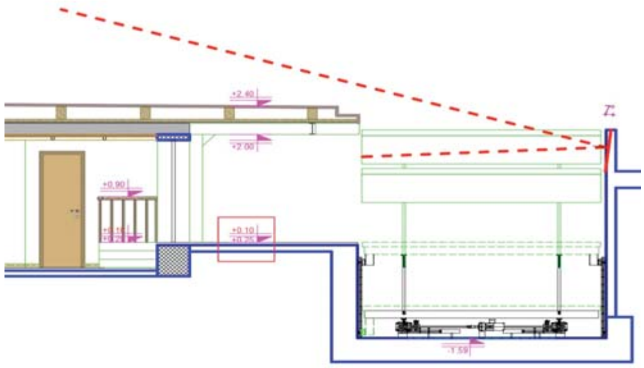

Fig. 15 – Orchestra pit parapet design to improve the propagation of sound from the Orchestra pit toward the stage and vice versa

Progetto del parapetto della fossa d'orchestra per migliorare la propagazione del suono dalla fossa d'orchestra verso il palcoscenico e viceversa

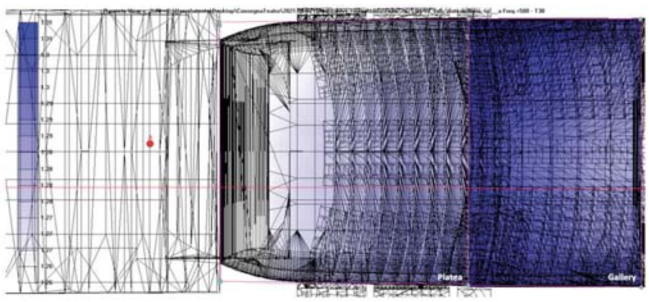

Fig. 16 – Ramsete® software simulation – Reverberation Time (T30) at 500 Hz at the stalls level and at gallery level (raised Orchestra pit configuration)

Simulazione del software Ramsete® – Tempo di riverbero (T30) a 500 Hz simulato al livello della platea e della galleria (con la fossa d'Orchestra coperta)

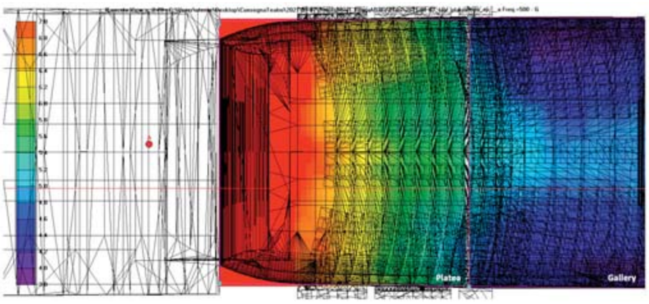

Fig. 17 – Ramsete® software simulation – Sound Strength (G) at 500 Hz at the stalls and at the gallery level (raised Orchestra pit configuration)

Simulazione del software Ramsete® – Forza (G) a 500 Hz simulata al livello della platea e della galleria (con la fossa d'Orchestra coperta)

To ensure an acoustic response similar to the current one, we performed some simulations of the Hall within the design model, using the Ramsete® 2.7 raytracing simulation software [19]. Simulation of Reverberation Time (T30) and Sound Strenght (G), run within the design model in the stalls and gallery, are shown in Figures 16-17. These show that the acoustic response of the stalls and gallery in terms of Reverberation Time (RT) and Sound Strength (G) at 500 Hz, in the design configuration, is quite homogeneous, furthermore, the acoustic parameters of the design state, resulting from the simulations, are very near to those measured at the current state.

6 | Conclusions

The renovation of the Theatre of Arts Academy in Tirana involved the refurbishment of all interior finishes (plaster, curtains, flooring etc.), the replacement of all the armchairs and the opening and extension of the Orchestra pit, as well as the refurbishment of all installations. The project aimed to maintain the Theatre's original appearance and acoustic response.

According to the results of the simulations based on the results of the measurements described in the previous paragraph, the acoustic response of the room is slightly more reverberating at the medium frequencies (see Figure 12). However, this modification falls within the limits of tolerance and uncertainty of the calculation method and in any case should not alter the acoustic perception in the Theatre compared to the current condition.

The new design of the Orchestra pit should allow for better acoustics inside the pit for both musicians and actors on stage and the audience, while preserving the visual requirements and the original configuration of the space.

Conclusioni

Il progetto di restauro del Teatro dell'Accademia delle Arti di Tirana ha comportato il rifacimento di tutte le finiture interne (intonaci, tendaggi, pavimenti, ecc.), la sostituzione di tutte le poltrone e l'apertura e l'ampliamento della fossa orchestrale, oltre al rifacimento di tutti gli impianti. Il progetto mirava a mantenere l'aspetto originale del teatro e la sua risposta acustica.

Secondo i risultati delle simulazioni basate sulle misure descritte nel paragrafo precedente, la risposta acustica della sala è leggermente più riverberante alle medie frequenze (vedi Figura 12). Tuttavia, questa modifica rientra nei limiti di tolleranza e incertezza del metodo di calcolo e in ogni caso non dovrebbe alterare la percezione acustica del teatro rispetto alla condizione attuale.

Il nuovo design della fossa orchestrale dovrebbe consentire una migliore acustica all'interno della fossa sia per i musicisti e gli attori sul palco che per il pubblico, preservando al contempo i requisiti visivi e la configurazione originale dello spazio.

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