ACOUSTIC IMPROVEMENT OF THE INDOOR STADIUM IN GENOA

PACS REFERENCE: 43.55 GX

Foppiano Davide; Schenone Corrado; Tomasinelli Francesco
DITEC, Energy and Environmental Conditioning Department - University of Genoa
Via all'Opera Pia 15a
16145 Genoa
Italy
Phone:+39 0103532861
Fax:+39 010311870
E-mail: sche@ditec.unige.it

Abstract

The indoor stadium is the only building in Genoa that offers a covered surface of 20000 m^2 and can accommodate 15000 people. Unfortunately, the acoustics of this building are very poor because of the huge internal volume (340000 m^3) and the reflective building materials used (concrete, glass, polyester). This study proposes a solution which is able to improve the acoustic quality of the building without altering its functionality: a movable internal shell made of sound absorbing panels and curtains resonators that reduces sound reverberation and achieves acoustic indexes approaching optimum values.

Introduction

Indoor stadiums are often utilised not only for sports meetings but also for conferences, shows and musical events. Such uses demand careful acoustic planning and the elimination of problems caused by the large indoor volume of these buildings.

The indoor stadium of Genoa also hosts such functions, which are of considerable importance to the city, even though its acoustics are very poor. The aim of this study is to propose a design for the acoustic correction of the stadium that can achieve a harmonious result without undermining its functional capacity. Situated within the Genoa Fair complex, the indoor stadium occupies a strategic position in the city, being located close to the exit of the urban clearway and in proximity to the central railway station. The indoor stadium is the only building in Genoa that offers a covered surface of 20000 m^2 and is an important venue for all events that draw a large audience and require a covered space.

The indoor stadium is a circular building (Figure 1) with an external diameter of 160 metres. The structure is composed of 48 pairs of pillars standing in circles of 112 and 132 metres in diameter, which support 48 radial rafters that jut externally for 14 metres and internally for 22 metres. The ceiling of the building consists of polyester sheets supported by a stretched flexible structure. This structure is composed of a central body hanging in mid-air, a concrete perimeter ring, an upper warp of 48 cables and a lower warp of 144 cables that connect the ring to the central basket [1].

Acoustics of the indoor stadium of Genoa

In recent years, the indoor stadium of Genoa has hosted a large number of musical events of various kinds. While the exceptional capacity of the building makes it an ideal venue for such events, the poor quality of the acoustics has repeatedly given cause for concern.

Figure 1 External and internal views of the indoor stadium in Genoa.

The poor acoustics of this building are mainly caused by three features:

- the enormous volume (340000 m^3), which multiplies the reverberation effects;
- the building materials (concrete, glass, iron and polyester), which have low sound absorbing coefficients;
- the very complex indoor structure, which can generate multiple and multidirectional reflections.

The acoustics of the indoor stadium have been characterised by measuring the value of several objective parameters: these acoustic indexes define the sound quality of a room and enable us to assess the subjective judgement of a listener with regard the acoustics of the room [2].

The data survey was conducted by placing a sound sources in the area where the musicians are usually situated (red dots in Figure 2) and microphones (yellow dots in Figure 2) where the audience is usually situated. Tone bursts were generated by means of an omnidirectional source and the decay of the sound field was analysed. Reverberation time (EDT, RT20, RT30) and other acoustic parameters, such as early energy fraction (D), objective clarity (C_{80}) and centre time (T_S), were measured. Mean values for the whole audience area were calculated.

The results of the measurements taken (shown in Figure 3) were compared with the optimum values of the various acoustic indexes reported in the literature [3, 4, 5]. This comparison revealed the very poor acoustics of the indoor stadium in objective terms and enabled these to be expressed quantitatively. For example, for halls of similar volume, the optimum value of the reverberation time for middle frequencies varies from 2 to 2.5 s, according to the kind of music. In the present case, in the 250-2000 Hz range, RT30 was approximately constant and equal to 6 s. Similarly, over the whole field of frequencies considered, the measured values of the various acoustic indexes fell outside the range that defines good acoustic conditions.

It was therefore evident that very substantial intervention would be required in order to correct the acoustics of the building, even merely to achieve acceptable conditions for musical events and congresses. The type and scale of such acoustic improvement have been guided by the acoustic analysis described in this section, the objective being to bring the various acoustic indexes within their respective ranges of acceptability.

The lack of available space in the city centre, as well as economic considerations, means that the proposed intervention is preferable to the construction of a new building designed to meet the same needs.

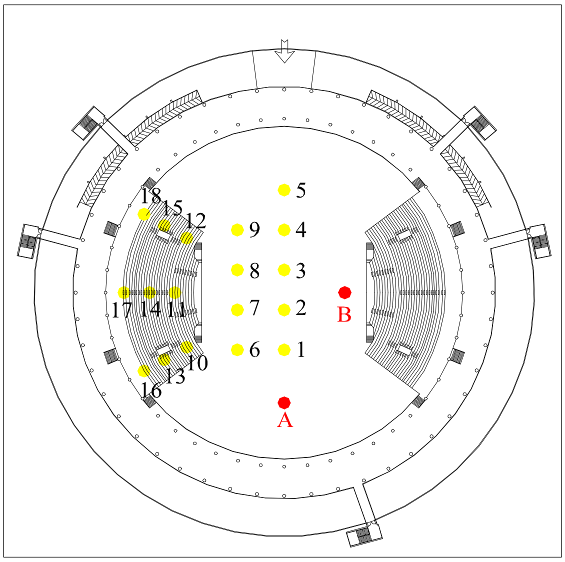

Figure 2 Location of source and microphones.

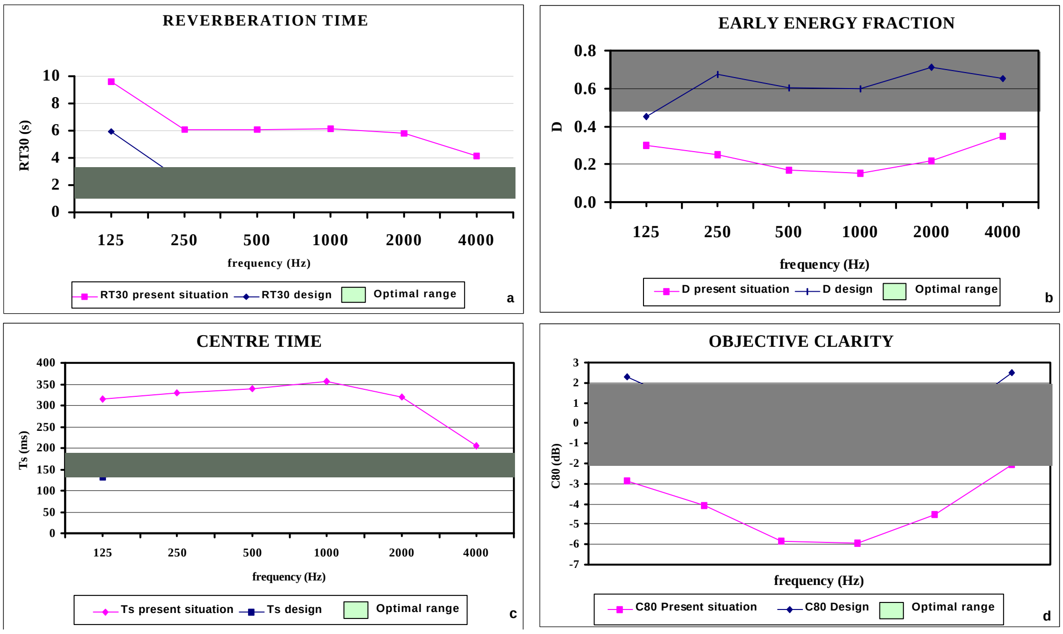

Figure 3 Mean value of acoustic parameters before and after improvement.

The project

The aim of improving the acoustic performance of the indoor stadium is to be pursued along two lines:

- reducing the volume within which the sound is propagated and excluding the peripheral part of the hall and the ceiling from the acoustic field
- increasing the total acoustic absorption by using materials with high absorption coefficients.

These objectives are to be pursued without interacting with the existing structure and without creating internal obstructions.

While aspiring to criteria of lightness, handling and flexibility of utilisation, the proposed design is also intended to provide a concrete and convincing solution for the management of the spaces and should therefore contribute to the artistic design of the activities.

As pointed out by other studies [6], respecting the architectural characteristics of the existing building is another meaningful aspect of design. The architectonic context has therefore conditioned the design phase and has been taken into account in the final project.

The design envisions the erection of a permanent structure inside the building to support a large dome that functions as a “sound shell”. Constructed of materials with high sound-absorbing properties, the dome markedly improves the acoustics inside the building by reducing the volume in which sound is propagated.

Figure 4 depicts an axonometric section of the indoor stadium showing the acoustic dome. In the area above the stalls, the dome is composed of PVC panels, which function as Helmholtz resonators, while in the area above the stands it is made up of sound-absorbing cotton curtains; the use of panels in the area above the stands would result in a considerable loss of seating space.

To study the acoustic behaviour of the indoor stadium, we used a commercial programme (Ramsete) [7], that was able to create a three-dimensional model of the building. The model was validated by means of the above-mentioned measurements. The use of a simulation code was fundamental in estimating the acoustic benefits of the hypothesised design and in enhancing its effectiveness.

In the development phase of the project, the following procedure was implemented: a numerical model of the hall was constructed, the model was validated on the basis of the data gathered experimentally, remedial measures hypothesised were introduced into the model, and the ensuing acoustic benefits were assessed.

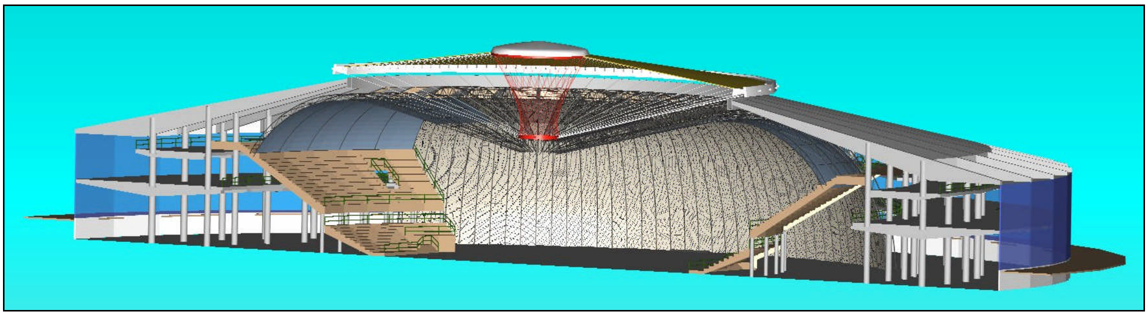

Figure 4 The acoustic dome.

The acoustic maps (Figure 5) generated at the level of the receivers show the improvement in the acoustics inside the stadium. In the present situation, the acoustic energy is concentrated in the area close to the source; the corrective measures cause the acoustic energy to spread uniformly inside the hall. The mean values of the acoustic parameters, as shown in Figure 3, improve markedly and are brought within the ranges of acceptability; the reverberation time is reduced from 6 s to 2 s, while the other acoustic parameters considered (D, C_{80}, Ts) approach their optimum values.

Analysis of the simulation shows that the acoustic quality inside the stadium improves for the following reasons:

- the internal volume is reduced from 340000m^3 to 290000m^3
- sound energy is uniformly propagated inside the newly-created volume
- the ceiling and peripheral area of the stadium (which mar the acoustics of the building) are acoustically excluded
- the absorption coefficients of the reflecting surfaces are increased.

In particular, the creation of an inner volume that acoustically excludes the peripheral part of the hall improves the acoustic performance of the building by enabling the sound energy to spread uniformly.

The acoustic dome

The framework of the acoustic dome (Figure 6), is composed of steel profiles; the static equilibrium of the stadium is not compromised as the proposed structure does not communicate with the existing structure of the building.

The structure is made up of 48 bays, the same number as the bays of the indoor stadium; 28 bays are used to support the panels and the other 20 support the curtains.

The course of the metal profiles has been influenced by the need to avoid creating an architectural feature that impedes access: all the profiles have two single points of support, one on the ground in the stalls or in the stands and the other on an infinitely rigid ring placed under

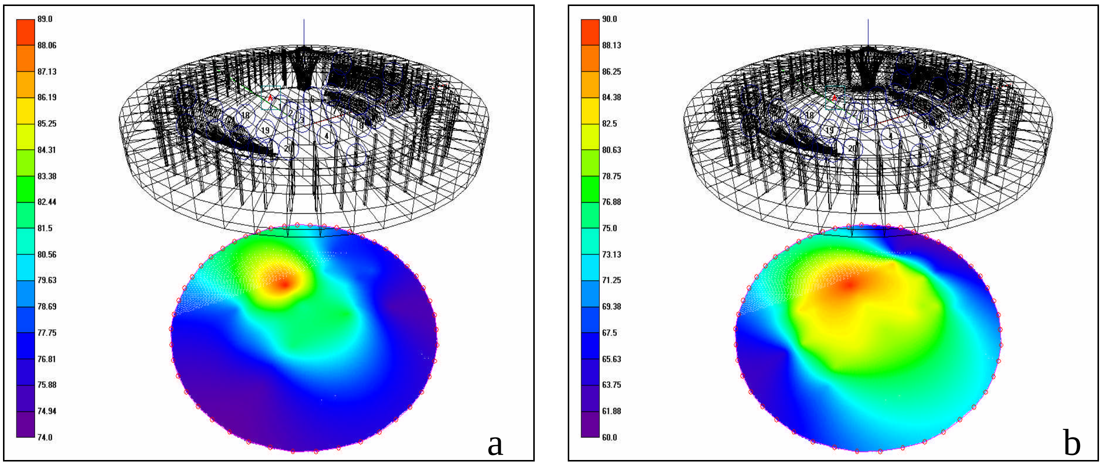

Figure 5 Acoustic maps generated by means of Ramsete: sound pressure level before (a) and after (b) the acoustic improvement.

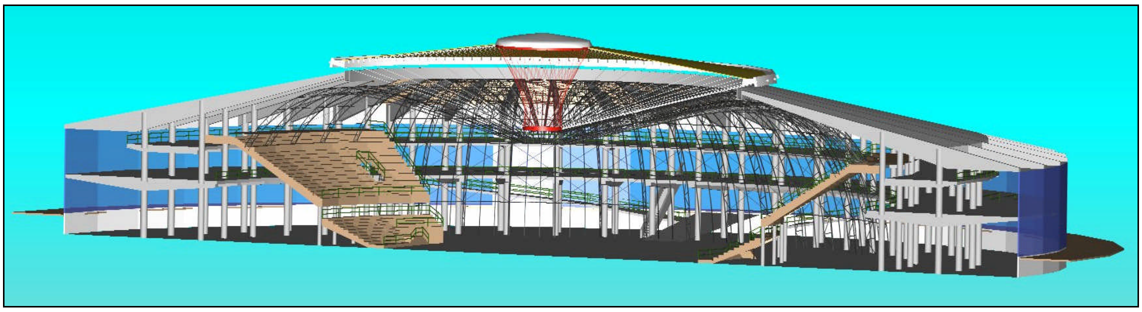

Figure 6 Axonometric view of the structure supporting the acoustic dome.

the central basket of the stadium. In order to create an effect of continuity of the acoustic dome, the course of the profiles is equal for both covered zones, even though the acoustic materials are different.

The acoustic shell is made up of PVC panels in the zone above the stalls and of sound-absorbing curtains above the stands. The PVC panels work acoustically like Helmholtz's resonators; each panel contains numerous resonant cavities, which communicate with the room through small fissures and absorb the sound energy (Figure 7). A telescopic arm is positioned at the top of each panel; this enables the panels to close and open and connects the panels with one another and with the structure.

The handling system is automated; each segment is connected by cables to electric winches that open and close the shell. In the stalls, spaces (2.3 m deep) have been created to lodge the panels and the winches; these spaces are easy to inspect and are closed off by steel panels so as not to hamper movement inside the stadium (Figure 8).The HEA 100 profiles, which are used as inferior stringers for both the zones to be covered, are perfectly suited to our use. Tracks are fitted in the space between the wings of the profile, along which the telescopic arms can easily slide.

The framework for the curtains is similar to that used for the panels. Space to house the curtains has been created in the reinforced concrete base of the stands, in which the curtains can be rolled up on supports (Figure 9). The great advantage of this solution lies in the possibility to set up the acoustic dome when necessary and to close it when it is no longer needed.

Conclusions

The proposed intervention to improve the acoustics of the indoor stadium of Genoa was seen to be effective in reducing sound reverberation and improving the acoustic quality of the building. Achieved by means of reducing the inner volume of the hall and increasing the sound absorption coefficients of reflecting surfaces, this result is compatible with current utilisation of the stadium and respects the architecture of the building itself. The entire system of raising and supporting the sound-absorbing panels and curtains that form the acoustic dome has been worked out in such a way as to ensure mobility and stability in the same time. When the system is not in use, it can be stowed out of sight. A preliminary estimate of the cost has revealed that this solution is cheaper than building a new covered hall of similar size in the city centre.

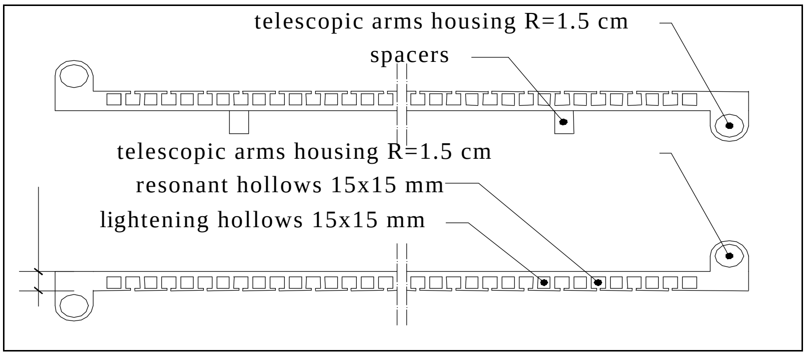

Figure 7 Panels in PVC.

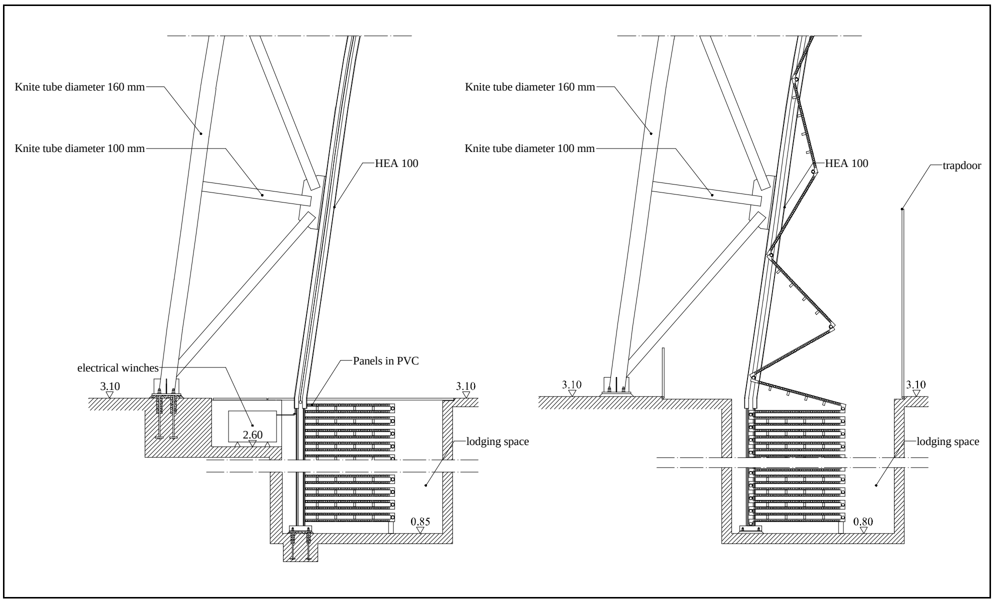

Figure 8 Opening and closing of the panels.

References

[1] Finzi L., Maier, G.: La tensostruttura del Palasport di Genova (in Italian), Costruzioni Metalliche n°6, pp.61-73, March-April 1964.

[2] Barron M: Auditorium Acoustics and Architectural Design, E & FN Spon, London, 1993.

[3] Atal B.S, Schroeder M.R., Sessler G.M.: Subjective reverberation time and its relation to sound decay, Proc. of 5th International Congress on Acoustics, Paper G 32, Liege, 1965.

[4] Cremer L., Muller H.A. (translation of Schults T.J.): Principles and Application of Room Acoustics, Vol.1, Applied Science, London, 1982.

[5] Reichardt W., Abdel Alim O., Schmidt W.: Definition und Messgrundlage eines objektiven Masses zur Ermittlung der Grenze zwischen brauchbarer und unbrauchbarer Durchsichtigkeit bei Musikdarbietung (in German), Acustica 32, pp. 126–137, 1975.

[6] Traldi A.: Palasport di Genova Progetto di riqualificazione acustica e funzionale (in Italian), Acoustics and Recovery for Music, Ferrara 27-28 October 1993.

[7] Farina A.: Ramsete – a new pyramid tracer for medium and large scale acoustic problems, Proc. of Euro – Noise 95 Conference, Lyon, 21-23 March 1995.

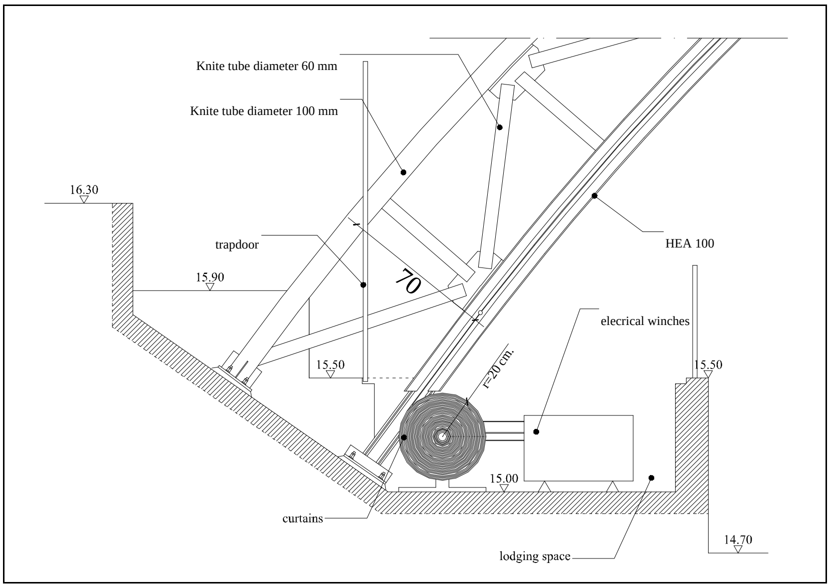

Figure 9 The sound absorbing curtains.