Teatro 'La Fenice', Venice — The secrets of the acoustical reconstruction of the destroyed theater according to historical and modern requirements

Jürgen Reinhold

Müller BBM GmbH, Robert Koch Strasse 11, D 82152 Planegg/München, Germany
juergen.reinhold@muellerbbm.de

The reconstruction of this artistically and architecturally very important opera house that was completely destroyed by a fire and which was famous throughout the world not least for its excellent acoustical qualities, was a brilliant challenge also for an acoustician.
The historical planning requirements – complete reconstruction ”as it was; where it was” – the latest findings in room acoustics as well as a huge number of ‘modern’ requirements are to be brought in line. The theatre hall as heart of the *Teatro La Fenice* was reconstructed in its classical horseshoe shape with five tiers in pure wooden construction.
Modern standard specifications had to be met for ventilation and air conditioning, the installation of a modern stage machinery as well as an improved safety and fire prevention concept. Furthermore the space allocation plan had to be extended by the integration of new rehearsal rooms and technical equipment rooms. From the point of view of building and room acoustics this was a very complex task – if in addition the cramped conditions of the *Teatro La Fenice* in Venice are taken into consideration. The lecture provides an insight into the building and room acoustical planning, its realization and the achieved acoustical results.

1 Introduction

After the fire disaster and the complete destruction of the opera house in 1996, the faithful reconstruction of the unique beauty of the *Teatro La Fenice* was immediately agreed on. Following the concept *com’era e dov’era* (ital. as it was and where it was), the throughout the musical world remembered, excellent acoustical conditions of the opera house had to be recreated as well.

But what is necessary to ‘reconstruct’ excellent acoustics? Is it enough to reconstruct the shape and the formal appearance of the hall?

An essential factor in recreating the acoustics of the main hall, the *Sala Teatrale*, was the reproduction of the hall's original horse-shoe shape with its five galleries, the shape of the ceiling and the original room-volume. In addition to recreating the shape of the surfaces, it was also necessary to reconstruct their original vibration behavior through the correct choice of materials for the construction and the cladding. In this context, the rich decorations on all the surfaces in the hall were of particular importance.

During the reconstruction, numerous additional requirements and desires arose, concerning the compliance of necessary safety standards, the creation of a better building comfort, plus newly arranged and a possibly enlarged number of rooms and facilities.

For the planning process of the architects and engineers, this meant integration of fire-prevention measures throughout the whole building, integration of a ventilation and air-conditioning system and enhancement of the existing heating system. Concerning the building section *Apolinee* and the *Sala Teatrale*, all these newly planned or modified technical systems had to be integrated nearly invisible and acoustically unnoticeable.

These technical requirements and intentions, together with the demand for additional rehearsal rooms, added up to the necessity of creating more rooms and a different room layout in the building. The restricted space for the building and the close integration of the theatre into the urban structure of Venice, surrounded by water, streets and directly adjacent buildings, made it clear that these enlargements could only be realized within the existing confines of the building shell and only to a fairly limited extent.

The solution and realization of the acoustical questions at the forefront of this task are described in the following acoustical planning concept.

View into the hall of the rebuilt Teatro La Fenice

2 Room acoustics

From the architectural, design and acoustical point of view, the *Sala Teatrale* including the orchestra pit and the stage, set the main focus for the reconstruction of the *Teatro La Fenice*.

When architect Selva first built the original theatre in 1792, and later, architect Meduna and his associates rebuilt it in 1836 after the first fire disaster, they did a fantastic job – particularly for the *Sala Teatrale* – and thus created a difficult challenge for all those, participating in the reconstruction.

Certainly, many interested readers can still hear the much-praised acoustics, renowned far beyond the borders of Italy, in the back of their minds. Reconstructing the uniqueness and quality of this hall was obviously a particularly delicate task.

For a start, Meduna's drawings were studied very carefully, using today's available computer technology and the aid of physics, to understand the back then created excellent acoustics. Precise and detailed checks were also carried out on the new materials for the surfaces defining the room, which are also decisive for the acoustics.

Basic shape and load-bearing structure

The main hall, conceived as a classical Italian opera house, was faithfully reconstructed in terms of basic shape, geometry and volume, corresponding to the still existing planning documents of the architect Meduna. This meant that the reconstruction of the architecture and the acoustics was based on drawings dating from 1836 and not from the situation which existed before the fire, which in some places was different from the original plan.

Both the load-bearing structures of the *Sala Teatrale* and the floors of the boxes are made solely from larch-wood beams, installed independently of the perimeter auditorium walls of the *Cavea*, which are built as solid brick walls. These wooden beams are also used as load-bearing elements for the entire wooden structure of the theatre ceiling.

This relatively light structure, rebuilt according to the original acoustical and constructive specifications, provides the basis for recreating the previous acoustic conditions of the *Teatro La Fenice*. This method of using a construction body made up exclusively of wooden elements is quite rare in theatres, but due to the self-supporting nature of the structure, detached from the rest of the building, it offers many acoustic advantages, such as low transmission of sound from the adjacent rooms. Furthermore, it is easy to excite this wooden structure to perceptible vibrations, such as those caused by the orchestra when playing *fortissimo*.

Separated wooden structure inside the Cavea's brick walls

Theatre ceiling

The theatre ceiling, which is a very significant element in terms of room acoustics, was rebuilt in its original configuration, consisting of a very elaborate structure of wooden beams and slats with a special mortar – *Coochio Pesto* – applied on both sides. The ideal acoustic properties of this construction, which were also verified in the laboratory, based on its high mass per unit area of more than 50 kg/m², the high internal damping of the structure as well as on the frescoed and richly decorated surfaces. All these properties add up to create the acoustically optimal sound reflection characteristics of the original and now as well of the newly built ceiling. The same construction method was adopted for the proscenium ceiling and the central part of the *Loggione*.

Theatre walls – box parapets

The box parapets which in this type of theatre create the hall's boundary were reconstructed as heavy wood parapets. However, they were now made from several layers of glued wood – appropriate in terms of fire resistance, and offering acoustic characteristics similar to a solid wood construction.

The surface decorations were reconstructed and applied using traditional techniques and materials identical to the originals like stucco, solid wood or *Carta Pesta*. They are of particular acoustic importance, because their varying structures offer that most significant sound diffusion that is more or less non-existent in modern architecture.

Floor structure in the stalls

The structure of the floor in the stalls is also particularly important for obtaining good room acoustics. As in the historic building, a wooden floor was placed on wooden supports, creating a large air cavity underneath – a very valid technique that was much used in early theatres. This structure of the floor is decisive for absorbing the lower frequencies and can easily be excited to perceptible vibrations.

This latter function, together with the sound impression is of fundamental importance, particularly during *fortissimi* parts, when the structure of the floor transmits perceptible vibrations to the listener and noticeably intensifies the acoustic impression and the overall acoustic experience.

The previous inclination of the stalls was slightly increased to improve both visibility and reception of direct sound. The cavity underneath the floor was used as a ventilation plenum, silently ventilating the stalls area through holes in the wooden floor.

Orchestra pit

On one hand, an enlargement of the orchestra pit was requested. On the other hand, a reconstruction faithful to the original building, made a change of position and size of the open part of the pit impossible. However, it was possible to cut back the stage edge slightly towards the stage and to expand the orchestra pit underneath the forestage.

The integration of mobile wall elements along the rear wall of the pit now allows to change the usable size of its covered part. Using these furnishing elements, it is possible to vary the depth of the pit from 6.5 m to 8 m. Hence, the orchestra pit now holds a maximum area of 117 m², which can be reduced to 93 m². The enlarged pit area now accommodates about 90 musicians.

Two mobile podiums have been installed in the open part of the pit which allow an acoustically optimal, flexibly stepped positioning of the musicians.

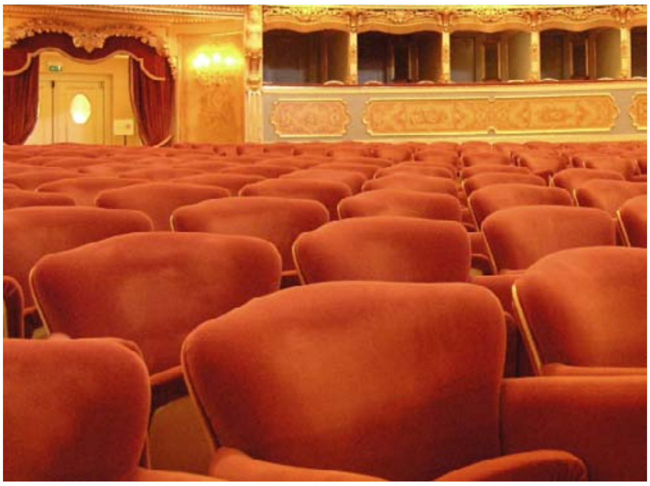
Proscenium ceiling

Before the fire, the proscenium ceiling was built horizontally. Detailed studies of the room acoustics showed that only with an inclined ceiling, the necessary sound reflections created by the proscenium could reach the back parts of the stalls. It is most interesting that such a inclination was already included in the original drawings by Meduna dated 1836.

Auditorium seats

With respect to the historic model, a seat was designed with a sound absorption capacity that would remain almost unchanged when the seat was either occupied or empty. This allows rehearsals to be carried out in an empty hall under acoustical conditions almost identical to those when the audience is present.

In addition, the absorbing surface area of the seats was limited to the necessary minimum. This meant reducing the sound absorption of the surfaces not affected by people's presence – the rear of the backrest and the sides – to the minimum. It was for this reason necessary to make some alterations – not visible from the outside – to the structure of the seat. Due to this detailed analysis and modification, the best possible acoustical properties could be achieved for the seats.



Newly constructed auditorium seats

Sound absorbing surfaces – reverberation time

The listening preferences of people who today attend opera performances call for greater resonance in the hall, i.e. longer reverberation times than what are normally obtained in classic Italian opera houses. In order to make these 'dry' theatre-acoustics 'more lively', detailed studies were carried out concerning all permanently present, sound absorbing surfaces in the hall, with the aim to reduce their sound absorbing properties.

For this reason, the originally present, large number of curtains was – as far as possible – reduced and the composition of fabrics was optimized to further reduce the sound absorption. Other sound absorbing surfaces like upholstered arm rests on the balconies, carpets in the corridors, etc. were either modified, regarding their acoustical behavior, or were completely replaced by reflecting surfaces. In the boxes, a complete elimination of the curtains originally located in front of the doors was possible.

In the two upper galleries – the *Galleria* and the *Loggione* – the room boundary does not follow the horse-shoe shape, but includes the attached corridors and room extensions into the hall's volume.

As subjectively confirmed by conductors, musicians and theatre experts, in total, a substantial extension of the reverberation time and the desired liveliness – *vivace* – could be achieved. Objective acoustic measurements show a prolongation of the reverberation time at mid-frequencies of up to 0.25 s.

Stage

At request of the theatre and in line with the demands of modern stage-technology, the stage was planned with a horizontal surface. This offers advantages for the construction and positioning of the scenes, but in particular for setting up the orchestra shell and the orchestra podiums to create the stepped arrangement necessary for classical concert presentations.

Alternatively, the entire area of the movable stage platforms can be slanted to an angle of up to 15° and thus can be returned to the historic stage configuration. From the acoustic point of view, this slant is very important because it clearly improves the transmission of sound, especially when the action takes place at the rear of the stage.

Orchestra shell

For symphonic concerts, the orchestra and an optional choir will be positioned on stage, i.e. inside the stage house.

With three walls plus the ceiling reflectors, the orchestra shell then forms the boundary towards the stage house. The shell also creates the reflections necessary for the acoustic contact between the musicians and allows the sound energy to be directed towards the audience rather than being mainly absorbed by the volume of the stage house.

The individual wall and ceiling elements of the orchestra shell allow great assembly flexibility and hence allow the shell to be adapted to the size of the orchestra. With the help of mobile wooden platforms, it is possible to vary the stepping and arrangement of the orchestra inside the orchestra shell.

Orchestra shell on stage

3 Structural acoustics and building services

Excellent acoustical conditions inside the theatre hall can only be obtained, if it is possible to reduce the transmission of noise from the outside, noise from inside the building itself and noise created by the technical equipment to a level that makes them practically imperceptible.

For this reason, much attention was paid to the acoustical insulation of the building.

Clearly, the possible measures in the areas close to the theatre hall could only be of modest proportions, due to the constructive requisites given by the historic template for the reconstruction. Nevertheless, one acoustically very effective measure was realized in the form of an acoustic joint, that separates the structural body of theatre hall and stage from the adjacent structural components.

Unlike the original building, the stage roof and peripheral windows in the stage house were constructed with excellent soundproofing properties and therefore offer sufficient acoustical insulation against the traffic in the canals near the theatre, and – not to be underestimated – the vocal performances of the gondoliers.

For reasons of acoustical insulation and fire protection, a reinforced concrete floor was installed between the theatre hall and the plant room above.

Due to the separation of this floor from the load-bearing structure of the wooden ceiling beneath, whose support is completely independent of the concrete construction, a very high level of sound insulation could be achieved in this critical area.

Furthermore, an optimal insulation of the building from structure borne noise was obtained by a double flexible mounting of the ventilation units and by consequently separating all pipes and ducts from the structure of the building using flexible mounts.

The allowed noise level, produced by all technical equipment together, but particularly by the ventilation system, was limited to an overall sound pressure level of ≤ 25 dB(A) at all positions in the theatre hall, in the orchestra pit and on stage. This limit demanded all technical equipment to work nearly unnoticeable – a challenging but achieved goal.

To meet this demand, the fresh air from the ventilation system is admitted through a plenum fitted with outlets in the floor, close to the spectators. For the boxes, separate air outlets were installed in each box, with the air ducts concealed in the rear wall of the boxes.

Exhaust air is removed through the centre of the ceiling above the chandelier. In this case, too, it was necessary to dimension the size of the openings large enough, so that fairly low air flow speeds could be achieved and disturbing flow-noises in the hall could be avoided.

4 Conclusions

The analysis of the historical drawings from 1836 had shown, that – by chance or on purpose – certain acoustically relevant and intelligent details had already been included in the more than 170 years old design of the former *Teatro La Fenice*. Taking up these ideas and evolving them by means of modern computer technology and a better physical understanding of sound, created an opera house with outstanding acoustics. With the latest fire prevention technology installed, there is even hope that this time, the *Teatro La Fenice* will prevail long enough, to be enjoyed by many listeners.