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ACOUSTIC RECOVERY OF A 200 YEAR OLD NATIONAL OPERA HOUSE: THE TEATRO NACIONAL DE S. CARLOS IN LISBON

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1. INTRODUCTION

Opera acoustics is one of the most complex fields that the science of acoustics has to handle, for several reasons.

First, the art of opera itself is one of the most complete, if not the most complete, since it is a combination of visual, musical and theatrical effects that may compete acoustically against one another.

To understand why the acoustical problems become intricate, one has to consider that the sound results from the emission by many kinds of sources that must complement one another subtly in the hall, on stage and in the orchestra pit.

For Opera as well as for symphonic music, the sound must develop widely, reverberate, surround the listener and generate musicality. These requirements contradict bluntly the conditions that the sung words need in an opera house: the lyrics must remain clear and intelligible.

As if the problem was not arduous enough already, it is also necessary to create on stage and in the hall excellent acoustical conditions for concerts: a mobile orchestra shell is then erected on stage and it must fit symphony orchestras as well as soloists.

Recently built opera houses meet sometimes major difficulties if the acoustics has not been dealt with from the very beginning; the acoustical requirements must be included even in the architectural brief and in the first sketches.

2. ACOUSTICS AT THE TEATRO S. CARLOS

Fortunately, the case of the Teatro S. Carlos is quite different: it is one of the oldest surviving opera house and one of the most classical. Built on the model of the best eighteenth century Italian theaters, its shape and its capacity are most favorable since they create intimacy, closeness between actors and spectators; its volume is compatible with the required musicality and clarity.

The materials used for the construction of the theater play an important role: natural wood, in particular, contributes to the hall's warmth and roundness without coloration of the sound.

The Teatro S. Carlos contains some special acoustical devices such as a resonating volume, which resembles the inside of a wooden ship, located under the orchestra pit.

3. THE PROBABLE EVOLUTION OF ACOUSTICS AT THE S. CARLOS

Every hall is subject during its existence to modifications, for a number of reasons, whether it is a question of updating its technical equipment or to improve safety or, simply, for preservation or maintenance.

The Teatro Nacional de S. Carlos has been preserved remarkably well over the last two-hundred years but it obviously has been modified. Strangely enough, even though the acoustical quality of such a hall can be considered an utmost priority, these modifications or "improvements" have generally resulted into a deterioration of the very fragile acoustical equilibrium, which is so essential to opera.

To evaluate roughly the acoustics of a concert hall or of an opera house, one may refer to a very straightforward physical quantity, reverberation time, which describes how sound behaves in time and space. Every time absorbing materials are added to a hall, curtains, upholstered seats, borders and the like, the hall becomes acoustically dryer and dryer, sometimes so dry that it looses its musicality. Every time new constructions are being added inside the hall, for example under the stage, the hall may lose its qualities.

During the renovation of the theater, a very simple experiment was conducted: the curtains that decorated the boxes were removed; the acoustical change that this apparently minute modification triggered was quite obvious to trained listeners and was easily measurable in the hall as well as on stage.

It is very difficult to imagine what the acoustics of the S. Carlos was like originally but it is possible to identify its weaknesses and unbalances and to attempt, during the renovation, to reconstitute acoustical characteristics that are favorable to opera music and singing and which fit adequately this type of theater.

4. AN OVERVIEW OF ACOUSTICS AT THE S. CARLOS

The measurement techniques that are available today to the acoustical consultant are extremely sophisticated compared to those of the past. The main difficulty is to deal with an extraordinarily large quantity of data that describes the sound field as a function of time, space and frequency...not to mention subjective effects. Today, microcomputers are capable of dealing with this problem in real time and on site.

The system emits a specific acoustical signal, analyzes it and translates the result into readily understandable quantities: the room's acoustical response or values of physical parameters over the full musical frequency range.

This experiment is repeated for several positions of the source on stage and in the orchestra pit and for several seating positions in the stalls and the boxes. The tests are repeated with and without opera settings on stage, to simulate concert conditions with an orchestra shell.

With this method, one can identify the acoustical "blemishes" of the hall as, for instance, echoes and focalization.

Before the renovation, it was quite obvious that the hall was very dry in all cases, with a reverberation time under one second at medium frequencies; for high frequencies, it was much worse because of all the cloth that had been added over the years, thus absorbing high notes.

The acoustical response of the hall is very homogeneous in the stalls but, on stage, it is the opposite and acoustics vary strongly from one point to another. This is why singers had to choose very carefully the spots where they stood or their movements.

It is quite easy to imagine how these weaknesses can complicate the task of the producer and how they may hinder spontaneity.

5. ACOUSTICAL IMPROVEMENTS OF THE TEATRO S. CARLOS

During the renovation of the hall, many detailed modifications have been introduced to improve the acoustics. The principle consisted in taking advantage of this renovation to integrate elements that would be acoustically favorable, but with one inescapable constraint: the preservation of this historic monument. It was obviously out of the question to introduce contemporary technology or materials that would have endangered the aesthetics of the hall.

5.1 The orchestra pit

An orchestra pit raises very serious acoustical problems since its acoustics must be such that musicians can hear one another, and themselves, but also that sound propagates throughout the hall and stage.

These complex functions result, not only from the airborne propagation of sound but also from propagations in the solid materials that the hall is made of: in the present case, wood. At the Teatro S. Carlos, one has rediscovered, as in many ancient opera houses, a magnificent volume located directly under the orchestra pit, which is entirely made out of wood and strangely resembles the interior of a wooden boat. It is tied to the wooden construction around it and one may assume that since it resonates at low frequencies, it reinforces the response of the hall, in particular for low notes. Since the speed of sound is much higher in a solid, such as wood, than in air, more sound reaches the ear very early making the lyrics intelligible and the music clear. The extension of this phenomenon, a kind of structural reverberation, tends to make the sound more round and soft. This is probably why the S. Carlos sounds so "warm".

Even though, the renovation of the orchestra pit was not really part of the first phase of work, its acoustical properties have been measured since it obviously plays a key role.

The only element of the orchestra pit that has been modified is the "guardrail" which separates the stalls from the pit. It has been reinforced and the absorbing materials that covered it have been replaced by stiff and damped wood panels that reinforce the projection of orchestra sound on stage.

It is of course essential to preserve this orchestra pit and to improve its acoustical mechanisms.

It is unfortunately common today, when an opera house is being renovated to destroy objects that seem useless and whose function has been forgotten. The "boat-like" volume under excellent orchestra pits, which were very similar to that of the S. Carlos, have been replaced by a concrete

box, which sometimes even contains mechanical equipment. After such an irreversible modification, it will be no surprise to anyone to learn that some of the acoustical qualities of these theaters have been lost.

5.2 The stalls and the seats

In a concert hall or in an opera house the seats play a vital role since they represent most of the absorption. Moreover, depending on their shape and on the materials used in their design, their effect on the acoustics of the hall can vary considerably if they are occupied or empty.

This means, for example, that when the rehearsals of a production take place in the empty hall, acoustical effects may be very different from those in a full hall.

The seats of the S. Carlos have been modified without major visual changes to make the acoustics of the hall as stable as possible: the cloth has been carefully selected to provide the adequate amount of absorption and the backs and under-seats have been covered with thick wooden shells.

The floor carpeting has been reduced to a minimum and has been maintained only in the aisles; its thickness is only a few millimeters to avoid excessive absorption.

5.3 Acoustics of the boxes

The stalls at the S. Carlos being completely surrounded by boxes, it is quite obvious that the acoustical characteristics of the boxes and of the wooden panels that enclose the hall itself play a key role not only for spectators sitting in the boxes but for the theater as a whole since sound travels back and forth.

A wooden construction tends to age and dry; some of the panels become loose and tend to vibrate more freely when sound is emitted in the hall. This usually results into excessive low frequency absorption and a deterioration of the hall's musicality. The acoustical tests conducted in the theater before renovation have shown that this effect was widespread and that it was necessary to fasten the wood panels.

Of course, this work had to be conducted without leaving any visible scars.

All the wood panels that constitute the boxes were treated in this manner. The low frequency response of each box and of the theater as a whole has thus been enriched.

The boxes suffered also from excessive medium and high frequency absorption because of an excess of carpeting or wall cloth coverings. Much of this has been eliminated, in particular, carpeting and borders. The choice of the cloth covering the walls results from laboratory absorption tests that were performed on various samples: the types of cloth and undelayer that were acoustically the most suitable were then selected and installed.

5.4 Stage and orchestra shell

It was not one of the goals of the renovation performed in 1992 and early 1993 to modernize the stage or under-stage. Now that the acoustics of the public areas have been uplifted, it is possible to implement further improvements.

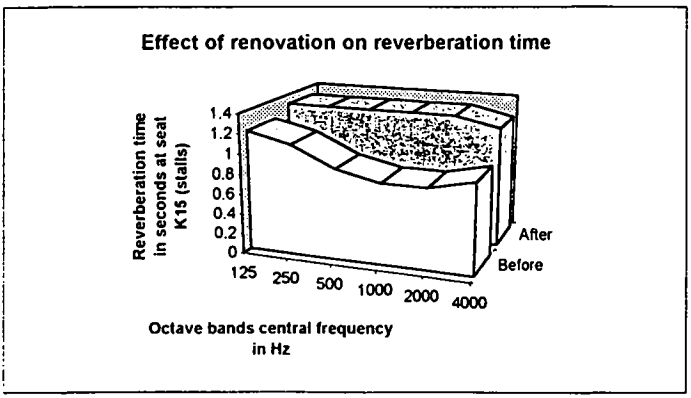
The coupling of acoustics of the stage, under-stage and hall must be restored: a considerable quantity of constructions clutters the theater and prevents adequate airborne and solidborne sound propagation.

The Teatro S. Carlos, like many opera houses, is used for chamber music or symphonic concerts. Since its reverberation time has been enhanced, it is better suited to such events than before. The quality of the results depends now mostly on the orchestra shell that is a special stage setting built on stage around the musicians.

To improve concert musicality, the old orchestra shell must be discarded and replaced by a new shell, with the proper shape and built out of reflecting and diffusing materials. Its design is tailored to the acoustical features of the theater.

6.THE RESULTS AND THE FUTURE

The measurements performed after the renovation was completed show significant improvements: reverberation time, in particular, is much higher than it was when the work was started.



It is not up to the designers but it is up to the music-lovers to decide whether the S. Carlos acoustics has been significantly improved.

The renovation of the stage machinery and architecture will give another chance for further improvements. The ultimate goal is to preserve the unique architecture of the theater and to limit the much needed technical improvements to what is strictly needed. Thus will be preserved what has become one the last remaining authentic 18th century opera houses in Europe.