Auxiliary equipments: how they can affect hall's acoustical quality

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Built spaces devoted to musical performances, like Auditoria, Opera Houses, and in general Theatres, were once designed with criteria derived chiefly from experience and only sometime from acoustical considerations about shape and materials: this happened in particular in Italy in seventeen and eighteen century. For instance, Richard Wagner designed the theatre in Bayroit based on musical considerations more than on physical considerations. In nineteen century Sabine began to consider the reverberation time as a mean suggestion to architects for a good listening quality, but only in the second half of the century other researchers found many acoustical parameters affecting the acoustical quality of an Opera House or a Concert Hall. Now it is possible, and in general requested, to design also multipurpose halls with acoustical instructions that allow us to avoid acoustical problems occurred in the past.

In any case noise coming from outside must be avoided, but nobody takes into consideration noise generated from machineries that are now more and more utilized for scenic effects and, during trials, for the contemporaneous utilization of bordering spaces: this paper will deal with this problem, showing in particular some recent example compared with the noise levels of a musical performance

Key words: opera house, concert hall, acoustical quality, noise level

1. INTRODUCTION

The design of a Theatre is first of all a problem of available place, as recently confirmed for the rebuilding of Teatro La Fenice in Venice. Even in ancient time, in the Greek's period, it was firstly necessary to locate the theatre having in mind the necessity to dispose of a hill, that could support the seat rows, then it was necessary to verify the availability of a river of something like this, to allow wastes to be removed, finally there were problems of orientation, so the sun can heat the seat rows during the afternoon and possibly to dispose of some mild wind coming from the sea. All these elements are present, for instance, in famous theaters like for instance Epidauro and Taormina. We don't find any document or outline that allows us to deduce some information about any acoustical study: we now try to find acoustical effects, like scattering and diffraction [1, 2] from seat rows, but may be these effects were casual, not foreseen from the Architect.

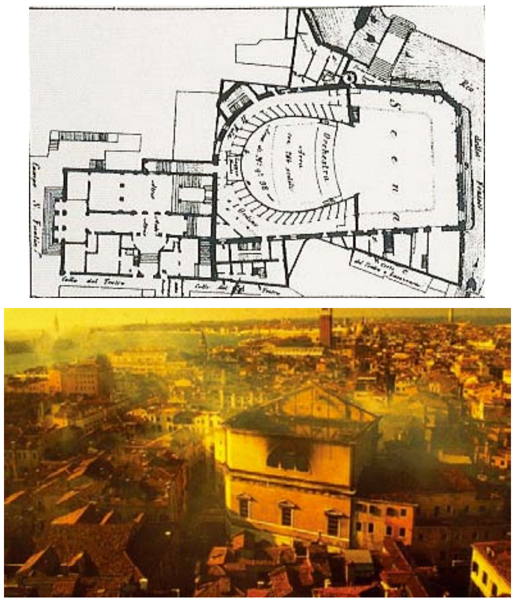

Fig. 1. In 1996 the La Fenice Opera House in Venice fired away: it was stated to rebuild it in the same place, but the place so obliged was very narrow

Fig. 2. Greeks built theatres on a hill (Epidauro, top and middle) and possibly near the sea (Taormina, low)

The only known acoustical support for actors was the mask they wore on the face, that acted as a little reverberant room.

Romans discovered the arch, so it was possible to be free from the hill, then they covered the stage first, like for instance in Aspendos, the cavea soon after, so creating more and more reverberation, but not being able to measure it.

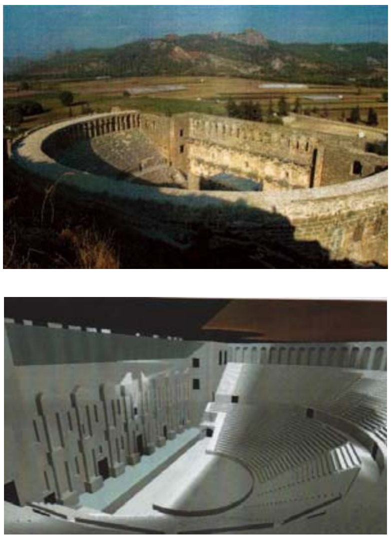
Fig. 3. Romans built theatres quite everywhere (here Aspendos, Turkey), then covered them

It was only with the Sabine's [3] works that it was possible to assume the reverberation time as the most important acoustical parameter for an hall devoted to the good hearing of speech and music: after that, Beranek [4] stated rules for good acoustical design of theaters and concert halls.

Soon after, with the availability of speedy means for developing wide calculations and post-processing of experimental data started the competition to find new acoustical parameters and new techniques for taking experimental data. In the meanwhile, Ando [5] proposed new preference criteria both to locate the best places in a hall and to allow to design most suitable shape for the cavea.

In the eighteen century we can find, at least in Italy that is the cradle of the Opera, some book dealing with also geometrical characteristic of the cavea coming from acoustical considerations [6], then in the well known Beranek's book [4] it is clearly stated that must be avoided geometrical defects, and that the geometrical study must prepare a cavea free from focalizations, flutter echo or lack of sound: only after that it will be possible to search for acoustical quality investigating reverberation time, early decay time, initial time delay gap, balance between direct and reverberated sound, speed of successive tones, definition or clarity, and so on.

It is not our purpose to give a deep insight in the history of the acoustic of theatres, but all above traced is only for putting in evidence that now the acoustical design of a hall is a very complicated job, to which scarcely correspond what it is possible to obtain in the reality.

Why this discouraging observation? May be as there is another parameter, so well know as usually assumed surely complied, and this parameter is the Signal to Noise ratio (S/N).

Again looking to the history, we don't know the customs of that time, but it is probable that during the performances Greek and Roman people kept silent or took part to it (in particular if they were religious events, as usual in theatres): environmental noise was not a problem.

In the middle age, people attending a theatric performance was either noble (so educated to keep silent) or servants (obliged to keep silent), so again there was no problem of S/N.

In the meanwhile, noise in surrounding streets was growing, becoming higher with the development of cars, so one of the common dictates in designing theaters was to keep the cavea well protected from noise coming from outdoor: see for instance Garnier's Opera in Paris.

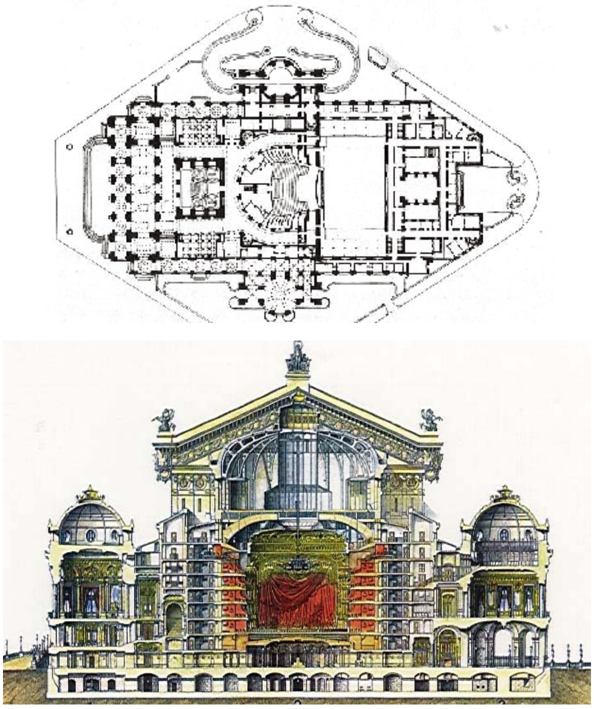

Fig. 4. Garnier's Opera House in the core of Paris is well protected from nearby traffic noise

2. NOISE COMING FROM INSIDE

Even if noise coming from outdoor is well controlled either in the building itself or stopping the circulation of cars during the performance (for instance in the open air performances in square and so on), listening may be disturbed from noises generated indoor, and we don't refer to services that can be stopped during the performance (like WC) but to physiologic activities like the "warm up" of singers whose walk on is foreseen only far during the performance, or movements of sceneries on the stage even near the singers; another problem usually arises from the HVAC plant.

In the occasion of refurbishing work within the Municipal Theater in Bologna, we had the opportunity to measure the sound level produced either as music during an Opera performance or as noise from the new air conditioning system.

Measurements were taken with the microphone placed at the level of the head of the Conductor, clearly with the Conductor at place during the performance and the HVAC standing, without the conductor out of performance and HVAC working.

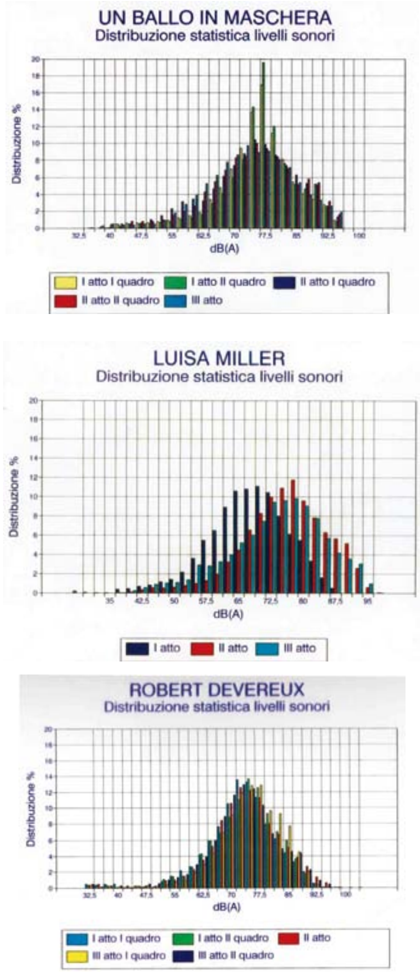

Fig. 5. Statistical analysis of levels recorded during the performance of some typical Italian Opera. Microphone position: the head of the Conductor

Fig.6. Frequency analysis of noise induced in the same position as Figure 5 from the Air Conditioning Plant located in the orchestra pit

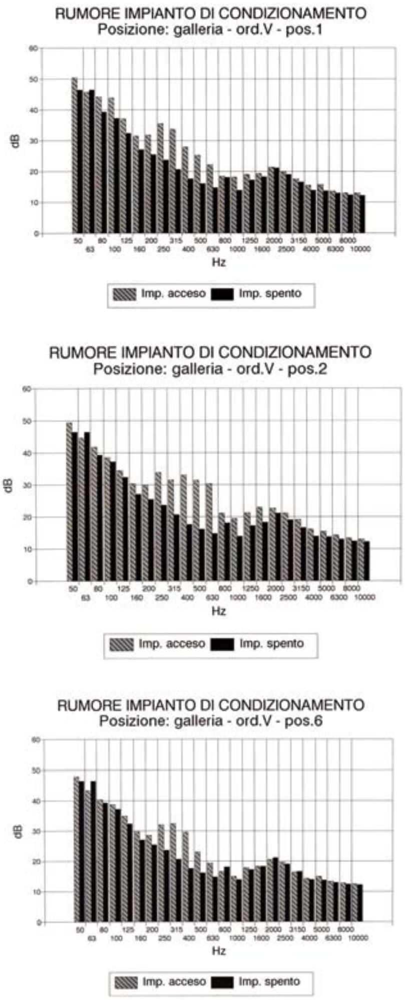

Fig. 7. Frequency analysis of noise induced at the upper balcony, different positions, from the Air Conditioning Plant located in the proscenium arch

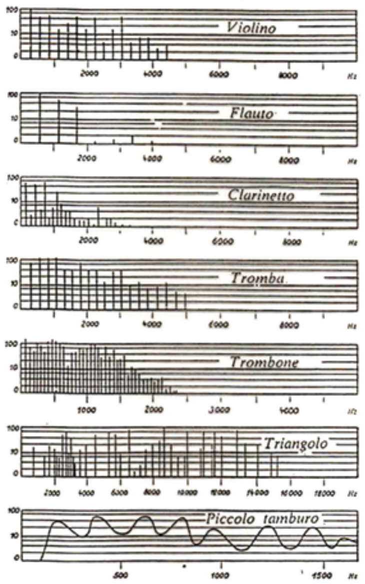

Fig. 8. Typical frequency analysis of sound generated from different musical instruments

3. CONCLUDING REMARKS

The results so obtained put in evidence first that during an Opera performance the signal level can reach very low values, of the order of no more than 30 dB(A): these values are exactly foreseen from the Author and exactly requested from the Conductor to create the desired effect; so they must not be disturbed, and we know that to avoid acoustical interference it is necessary a S/N value of more that 10 dB: this means that in these situations background noise must be of no more than 20 dB(A)!

This goal is very hard to be obtained, and it is unfortunately usual to stop the HVAC system during performances of this kind.

As concerns the movements of scenery, it is necessary to organize them in such a way that any movement will be avoided during that short periods as requested from the Conductor.

Looking at the frequencies involved in sound emitted from the different musical instruments, it will be necessary to avoid interferences with the HVAC plant even if its noise level is allowed as an A-weighted dB, due to the fact that this kind of measure strongly put down low frequencies, highly present in many musical instruments and well listened from people that usually attend musical performances.

REFERENCES

[1] Declerq, N.F., and Dekeyser, C.S.A. (2007). Acoustic diffraction effects at the Hellenistic amphiteater of Epidaurus: seat rows responsible for the marvelous acustics. J. Acoust. Soc. Am. 121, 2011-2022.

[2] Farnetani, A., Prodi, N., and Pompoli, R. (2008). On the acosutics of ancient Greek and Roman theatres. J. Acoust. Soc. Am. 124, 1557-1567.

[3] Sabine, W.C. (1922). Collected papers on acoustics, Harvard University Press, Cambridge, MA.

[4] Beranek, L.L. (1962). Music, Acoustic and Architecture, John Wiley & Sons, New York.

[5] Ando, Y. (1985). Concert Hall Acoustics, Springer, New York.

[6] Cocchi, A., Cesare Consumi, M., Shimokura, R., and Policardi, F. (2007). Influence of Geometric Proportions, Size and Materials on the Acoustic Field in Italian Opera Houses. J. of South China University of Technology 35, 21-24.