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Theatres from roman age to renaissance: on the meaning of reverberation time measurements

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ABSTRACT

In the mind of C.W. Sabine, reverberation time was thought as a numerical index of what was happening in a closed hall when a sound source acting within was suddenly stopped: the original idea was that sound rays where travelling in any direction reinforcing residual sound energy, but at the same time overlapping audible messages that these rays where carrying to the listener's brain. x

As well known, he stated a formula linking the R.T. value to the hall volume and to the capacity of the impinged surfaces of keep a fraction of the sound energy: from one hundred years to now, many authors researched in the field and stated the best R.T. values for the listener of different kinds of sound.

Surely Greeks and Romans did not know the possible existence of such a parameter, as they acted in open spaces, neither Vitruvius and, successively Alberti, Milizia, Poletti and so on, even if the tile cover utilized by the Romans to preserve from sun light and rain was avoiding that some sound energy dispersed in the sky.

Surely the modern computer assisted measurements techniques are able to keep some kind of sound decay even in an ancient theatre, but we are aware, as Greeks were, that they are derived only from reflections travelling quite horizontally, between vertical structures, or inclined between actors and spectators via orchestra floor, when not occupied from public.

Keywords: acoustical parameters, reverberation time, running strength

1. INTRODUCTION

In the last fifty years electronic instrumentation allowed us not only to memorize the signal received from a microphone but also to elaborate it quite in any possible way.

The first step of this "new age" was the automatic calculation of the reverberation time and this event signified the disappearance of protractor rule from our desk, soon after the availability of a reverberation time calculated on any possible temporary base, such as EDT, T20, T30, and so on.

A new step was to compare the amounts of energy received in different time intervals, so to have the various clearance indexes, like C50, C80, and so on.

A particular index was derived from the comparison of the really received sound level in a particular selected position to that hypothetically generated from the same omnidirectional source in an open field ten meters far, the strength G.

All these indexes are now well known to everybody involved in acoustical measurements in general and particularly within spaces devoted to theatrical performances and are really of strong interest for those involved in planning modern spaces like multipurpose auditoria or reuse of any other, like churches, sport arenas and, way not, Greeks and roman theatres.

They are of fundamental relevance also for those involved in restauration of ancient Opera Houses [1] so to save their original state, like for instance in rebuilding "La Fenice" theatre in Venice [2], or restoring "La Scala" theatre in Milan [3].

Many researchers involved in the history of ancient theatres utilized them trying to evaluate the acoustical ability of architects working in the past, from Greeks to the modern age, but in my really not short career I never found someone speaking of them. At the most, someone speaks of "reverberation" but not of "reverberation time", till the coming on the scene of W.C. Sabine [4].

2. STATE OF ART

It is possible to think that god-fearing is strictly linked with the man existence: so, even the need to involve others in our thoughts is originally linked with our existence and for theatrical expression may be the same.

We have proof of this when Egyptians began to leave some paper, at the time of the XVIII dynasty [5].

Looking to the archaeological remains, it seems possible to locate the beginning of the theatres building art in the VI century b.C. [see f.i. 6], with the transition in some century from the original squared shape to that best known semi circular one [7],[8].

We know that Greeks of the Pitagora's school, then Aristoxenus [9], were aware of many aspects of the generation and overlap of sounds, first of all the propagation spherical rule. So they probably found only on the field that some vertical surface or structure could generate reflected sound reinforcing the direct sound: for instance, the particular diffraction effect in the Hellenistic amphitheatre

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of Epidaurus generated by the nature of stone utilized for the seats was unexpected [10].

The first paper we found on the subject is the famous treatise by Vitruvius [11] where, it is well known, we can found many notes and geometrical details about the shape of a theatre either Greek or Latin, but quite nothing about natural reverberance: only some word is devoted to sound reflection, more is devoted to artificial reverberance dealing with sounding vessels.

The first appearance of reverberance derived by chance from the introduction of some kind of cover as sun or rain protection.

After a long period of silence about the buildings devoted to theatrical performances, in XVII-XVIII century the interest on these covered spaces raised, so we can find in Italian literature some writing speaking of them, like for instance Carini Motta [12]; in Europe Pierre Patte [13] was the first to announce in cover that his studies were placed upon "les principle de l'optique et de l'acoustique".

In particular, the declaration of Patte clearly confirms that, at least till the end of XVIII century, acoustical reasons were not the first problem for everyone involved in theatrical design.

Among the Italian architects involved in design of theatrical space during the XVIII century exploded a deep research about the best shape for the audience, but even in this case we found only visual reasons; may be there were also some acoustical reasons that each designer kept for himself or for his family, like in the case of Galli da Bibiena. We have the same impression reading [14] were the work of less famous architects who signed many proects in Italy, like Aleotti and Poletti, is taken into consideration.

In Europe, the situation is well represented, in my opinion, from the words of the famous architect C. Garnier at the opening of his Opéra in Paris, who declared that he afforded the big problem of the acoustical result like an acrobat launching himself in circus arena without any security net [15].

A very interesting book was written by F. Canac [16] in 1967, who put in clear evidence the very unique importance in an ancient theatre of reflections coming from the orchestra surface in the construction of some reverberated sound.

So, when W.C.Sabine [4] was charged to modify the agreeability of sound reception in the famous auditorium of Fogg Art Museum, nobody was able to measure what he called "reverberation time" and to link it to the sound absorption power of materials facing the sound source. It is of fundamental relevance that Sabine was acting within a closed space, in particular claiming for an uniform acoustical field, that is to say far away to what happens in an open space!

3. MODERN MEASUREMENTS

In the frame of the ERATO European project, many researchers were involved both in measurements and simulations in Greek and Roman theatres: 3 annual reports were published where in particular we can found reports about the results achieved. At the end a symposium was held in Istambul [17].

An unexpected result was the amount of RT, as stated also in [18]: RT was higher than expected while SPL was almost that of free field.

May be, it would be interesting to study the slope of the impulse response, slope that only some new instrument shows, while usually they give directly the numerical result evaluated on the base of a time interval selected from the same software: in these cases EDT, T20 or T30, parameters that practically take into consideration only the direct sound and some first reflections.

Rindel, who acted as Coordinator of ERATO research, analyses in [19] the results achieved in particular in acoustical simulations on Greeks theatres of the IV b.C.

About reverberation time, his conclusions are that "EDT is not a usable parameter" and that T20 "is highly unreliable".

Instead, "G … could be a usable parameter for open-air theatres".

At that point it seems relevant to debate on the meaning of the parameter G , originally proposed to quantify the amount of acoustical energy apported from the envelope to direct sound in a hall and usually related to a free field 10 meters far from an omnidirectional source.

In the case of an open space, like in general a Greek theatre, may be a comparison with the result achievable in the same place thought flat and free of any building. This new version of G was firstly presented in [20] as G_{re} relative strength and now ibetter presented as:

$$G_{re} = 10log_{10}\left[\int_0^T p^2\,(t,x)dt / \int_0^T p_{ff}^2(t,x)dt\right] \qquad (1)$$

4. CONCLUDING REMARKS

Reading the papers of Sabine [4], it is evident that it is out of discussion the possibility to apply his work to an open field: even if we have reflections. In the field fancied, the decay slope must be rather regular during the canonical 60 seconds. Nevertheless, it is possible to limit this time interval to put in evidence some particular effect like direct sound, early sound and so on [21].

When carrying out reverberation time measurements it is always recommended to catch as first element the full slope of the decay, from which it is possible to deduce many informations about the acoustic field generated from the impulse response.

It seems also more realistic to examine the strength of sound G better related to a real position in the field than to a fixed distance from the source, chiefly in the case of ancient Greeks and roman theatres.

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