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Acoustic characterization of the ancient theatre at Syracuse

Marco Gullo, Armando La Pica, Giuseppe Rodono' and Vincenzo Vinci

DREAM, Univ. of Palermo, Viale delle Scienze, Edificio 9, 90128 Palermo, Italy
mgullo@dream.unipa.it

The ancient theatre at Syracuse, the largest open air theatre in Sicily, experienced many structural changes along its history. Today its very renowned drama festival attracts visitors from all the world that fill the entire cavea: customized seats accommodation and a prominent stage play an important role in the theatre acoustics. Because no data were available in literature on its acoustical performance a measurement session was carried out by our team in the framework of a wide research project on ancient theatres acoustics in the modern use. From data recorded "room criteria" parameters have been evaluated together with spectral analysis in order to gain deeper information on the acoustic field. Main results are listed and commented and a comparison among data collected on field during the team experience in the past years is reported.

1 Introduction

The acoustics of the ancient theater in Syracuse, in the south of Italy, has been studied under the basis of modern measurement technology. The theater is intensively used during the early summer season [1] so the purpose of the survey was to record the theater acoustics as a drama spectator would experience. In fact the theater place is strongly changed during classical representations: the *cavea* is covered with wood panels while the *orchestra* and the stage are prepared by the temporary stage manager. Usually the attitude is to follow the classical geometry: a large and medium raised stage behind a large smooth semicircular plane laying on the orchestra. This was the case during our acoustics measurement and two pictures are formerly presented to fully describe the environment under study.

It must be pointed however that unfortunately main measurements were carried out in an *empty state* for the theatre and only few of them were performed in a partially occupied state [2].

The theatre was the target of survey by several authors in the last thirty five years [3, 4, 5, and 6].

2 Theater overview

The ancient theatre in Syracuse is a greek-roman type. The *orchestra* is an semicircle with a 29 meters diameter and the stage (*scena*) is not preserved.

The cavea extends for 180° around the orchestra and continues with two wings for about 5 meters at the sides. It is radially splitted in nine sectors, *kerkìdes,* by eight stairs, *klimàkes*, 0.6 meters large: rougly each stair counts two steps every cavea step.

First twelve cavea steps, from the bottom, constitute the *ima cavea* which has an average slope of 22,5°. This area is bounded on the upper part by a step 0.86 meters high, after which rows slope is about 20,8°. This area, *media cavea*, is bounded on the upper part by a large passage, *diàzoma*. Further on this passage up to the last row we have the *summa cavea*, whith the same average slope of the media cavea. Most of the summa cavea is absent today and the grass appears after few rows.

During the 2007 drama festival most of the cavea was covered by wood planks hiding the stone below while there were two kind of stage. In fact two dramas were in program and alternated one day for each. The day of acoustic measurements Sofocle's Trachinie was in program: a large and small rised wooden stage, covered with polystyrene, and a not too high wooden backing wall was prepared.

Pictures below summarize theater's geometry and show stage and cavea during acosutic measurements.

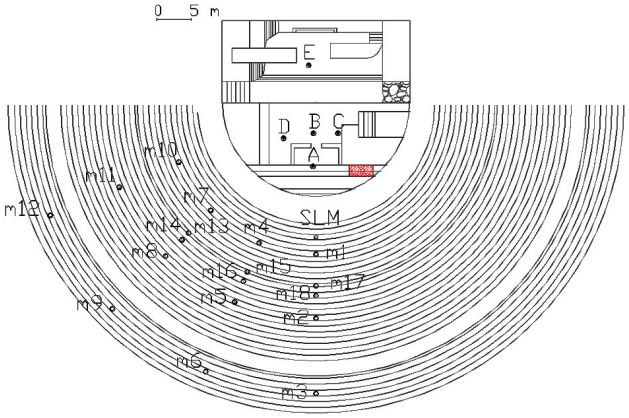

Fig. 1 Microphone and source positions in the theatre.

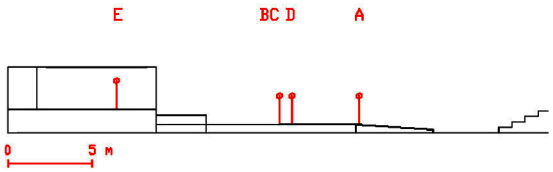

Fig. 2 Source positions on the stage (cross-section).

Fig.3 The stage and the cavea during acoustic survey.

3 Acoustic measurements

3.1 General setup

Measurements were carried out along a day. Several source-microphone couples (Figg. 1 and 2) were characterized using pink noise interrupted excitation and MLS based impulse response (IR) measurements in *unoccupied state*. Only few source-microphone couples were tested in a *partially occupied state* (about 15 %).

Five source position were used on the stage and up to eighteen microphone position were chosen in the cavea. A dodecahedrical sound source was used together with two free-field type I condenser microphones and a 2-channel real-time PC controlled analyzer. Finally, a sound level meter was used, in a fixed point as reference for the measurement session.

Six microphone locations, from m13 to m18, were chosen to investigate peculiar point as those near the raised step between ima and media cavea.

When audience began to take seat two microphone locations and two source positions were tested: B, D, m6 and m18.

3.2 Room criteria

The theater acoustic was studied using main room criteria as defined in [2]. This is justified by fact that a small reverberant field exists and, rougly, a linear SPL decay over the time occurs.

G behaviour over distance tell us that the theater's "gain" respect to a "free field" is on average about 2.5 dB while the decay rate is rougly the same (-5.6 dB/octave).

Reverberation Time, RT, calculated on 20 dB dynamic range, is derived from wide band pink noise interrupted: relatively high reverberation occurs in the mid-high frequency range.

EDT, C_{80} and D_{50} behaviour over the frequency range between 125 Hz and 4000 Hz, one octave band center frequency, is plotted in the pictures below.

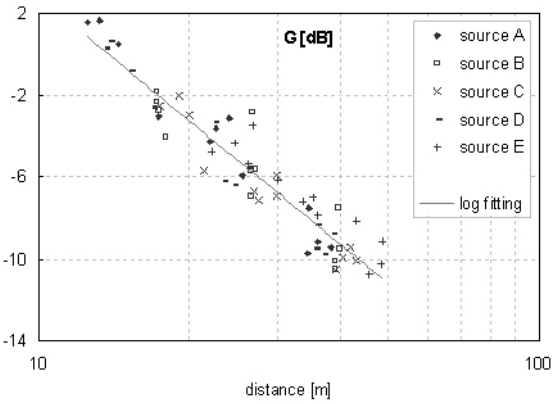

Fig. 4 Theater's strength versus distance (unoccupied state).

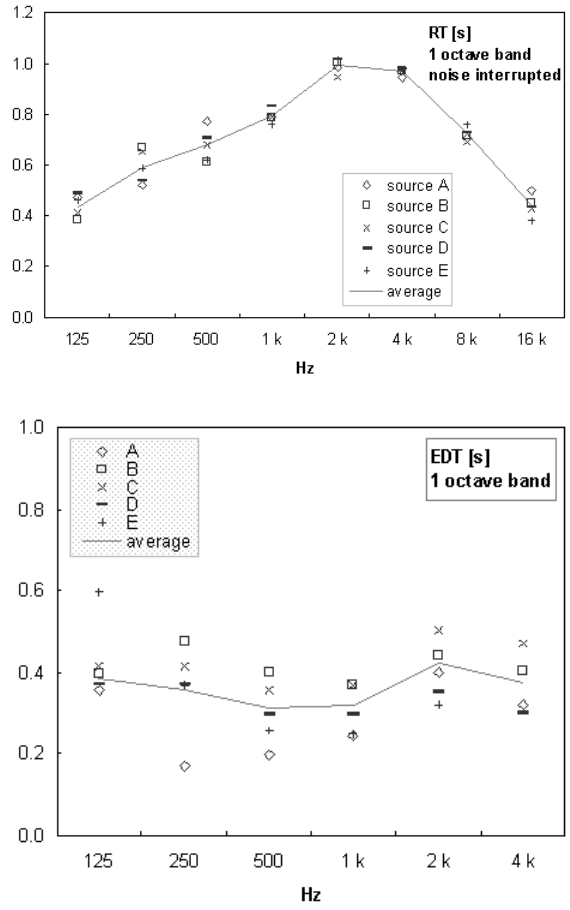

Fig. 5 RT and EDT (unoccupied state) differs greatly.

Acosutic indices are averaged for all microphone positions for each source position. Small variations from average value occur between source-microphone couples for all indices except EDT, where variations are larger due to the strong first reflections caracterizing such a space [7]. High values of C_{80} and D_{50} were expected due to the small reverberant field while RT could be affected from the polystyrene covering of the stage and the wood planks on seat rows.

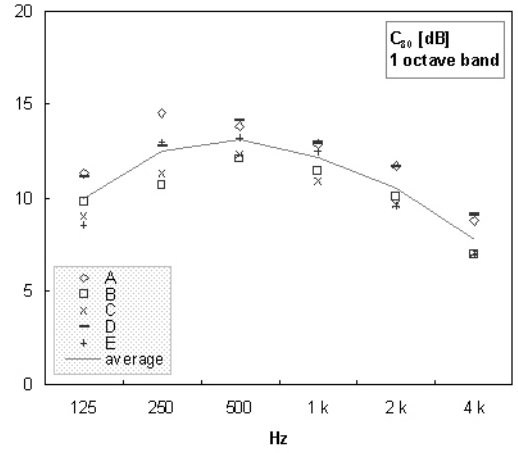

Fig. 6 High values reveals that energy content is mainly in the first hundreds of seconds of the sound decay.

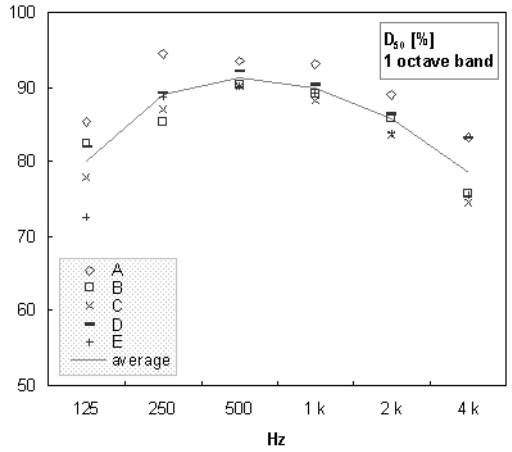

Fig. 7 As C80, D50 is good over all the frequency bands.

Two comparison diagrams are reported for RT and C_{80} when the theater is empty and partially occupied (see Fig. 13). Due to the audience we had to decrease excitation level, so the signal-to-noise ratio, leading to good measurement ony in the mid-high frequency range: high frequency are strongly affected by the audience.

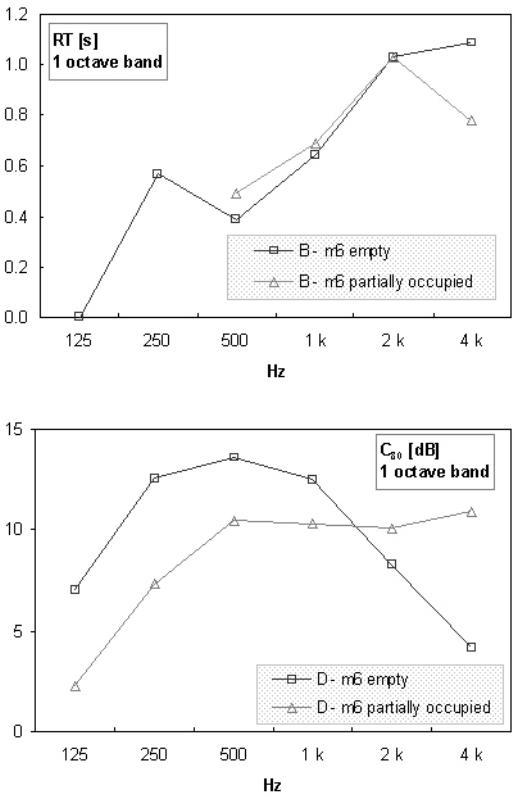

Fig. 8 Comparing RT and C80 when the theater is unoccupied and partially occupied.

In Fig. 9 a comparison on RT values between Syracuse and Segesta theaters is plotted (source on the stage – average of three microphone position along the central sector for both theaters). These large differences are due to the presence of the stage but others indices, as EDT, C_{80} and D_{50}, here not reported, do not differ at all [8].

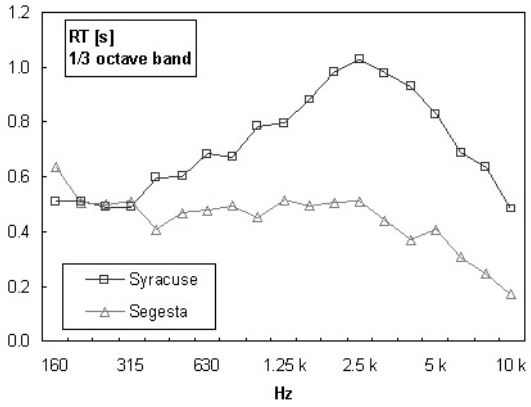

Fig. 9 RT comparison between Syracuse and Segesta theaters.

3.3 Spectral analysis

A classical spectral analysis was performed in third octave band. It reveals a changing spectral content with distance of the microphone from sound source. The strong reflection from the orchestra acts as a comb filter in the low frequency range. Figures show that microphone position and not source position is mainly responsible for the frequency at which the interference takes place.

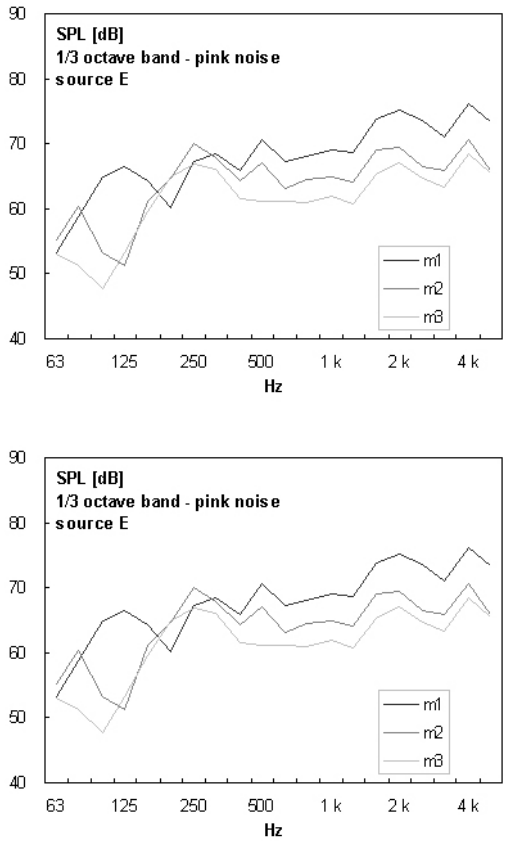

Fig. 10 Third-octave analysis in the central sector of the theatre.

Finally a time frequency plot is shown for the couples B-m1, B-m2, B-m3: X-axys shows linear frequency and Y-axys is the time: It simply explains how sound energy is packed in discrete arrival times: as we go from the bottom to upper cavea more energy is collected. Such plots are

somewhat poor in terms of signal-to-noise ratio due to the outdoor measurements involving large distances.

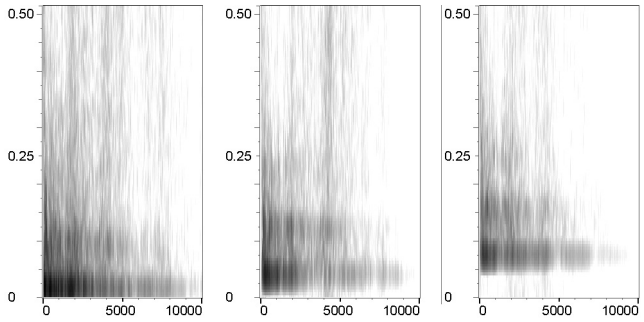

Fig. 11 Time-frequency analysis along a radial path in the cavea.

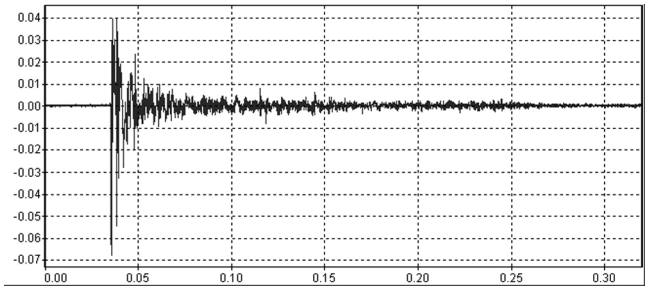

Fig. 12 IR for the couple A-m1 (Pa vs s).

Fig. 13 The theatre in the *partially occupied* state.

4 Conclusion

The acoustics of the ancient open-air theatre at Syracuse was investigated by means of ISO 3382 indices. This leads to relatively high reverberation time in the mid-high frequencies but small values for EDT, maybe indicating that the physical phenomenon of reverberation occuring in this environment is not possible to be totally perceveid. The energy content is then mainly in the first portion of the impulse response, see Fig. 12, and strongly affected by the orchestra reflection which is responsible for the interference that colours the energy spectrum in function of the microphone position in the cavea.

Finally, time-frequency analysis shows the sound energy packed in discrete arrival times: this features was already known to the authors in a previous study on the sound field in the ancient theatre at Segesta [7].

Acknowledgments

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