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ON THE ACOUSTICS OF THE GALLO-ROMAN THEATRE OF SANXAY (FRANCE)

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Abstract:

The Gallo-Roman theatre of Sanxay is staying against a natural 13 meters high hill, on the right bank side of a small river (the Vonne) near Poitiers (France). In fact, it is a sort of "half-amphitheatre".

It is characterized by an unusually circular and large *orchestra*, by the *vomitoria* which are parallel of a narrow *scænæ*, without any *frons scænæ*. The *cavea* could receive more than 6500 spectators on wood steps.

Every year in August, an important festival is held in the place (Bizet's Carmen in 2011 http://operasanxay.fr). The "acoustical qualities" are subjectively appreciated by the musicians and the audience.

Answering the request of the organizing committee, we investigate different acoustical criteria (RT60, EDT, Clarity80, Definition50, STI, RASTI, $IACC_{E3}$, sound strength G_{mid}…) by means of in situ experimental measurements (based on MLS technique) and compare them with those of Greek and Roman theatres previously studied, for example, in ERATO or ATLAS projects. Although the amphitheatre is mostly covered with grass, we find out the same magnitude criteria and similar general trends.

The aim of some computer simulations with *CATT Acoustics*© was, firstly, to confirm some of the measurement results, and, secondly, to evaluate the influence of a future - but unplanned - restoration.

Keywords:
Gallo-Roman theatre; Sanxay (France); acoustical criteria; in-situ measurements; computer simulations;

1. Introduction

The abstract of the guidebook [1] says: "*With its temple, theatre and baths, the Gallo-Roman sanctuary of Sanxay functioned as a centre for thermal cures under the patronage of a pair of divinities… This site came to attract a constant flow of oracle consultants, patients and devotees from the surrounding countryside. Here, in this*

centre of information, exchanges and distractions for the local peasantry, the inhabitants of the valley gathered to celebrate festivals associated with the cult of the divinities, attend the liturgies and theatre performances… the first digs (were) carried out by Father Camille de La Croix in the 19th century".

As can be seen below (fig.1), the theatre is characterized by an unusually circular and large *orchestra* (36 meters diameter), by the *vomitoria* which are parallel of a narrow *scænæ* (about 1 meter high and 2 meters depth), without any *frons scænæ*. The *cavea* (90 meters maximum diameter) is divided in three different *mænania* and could receive more than 6500 spectators on wood steps. Nowadays, large ruins of rough stones edge the *vomitoria* (till two meters high) and are outcropping on the *cavea*.

The shape and the slope (about 25° angle) allow good sight from all positions, but there is neither stage wall, nor colonnade.

Figure 1 – View of the Gallo-Roman theatre from the narrow *scænæ* and the *vomitoria*

Both the artists, the audience and the organizing committee of the opera festival (fig. 2) having praised the "acoustical qualities" of the site, it was decided to compare some experimental in situ measurements to both computer simulations and results from investigations covering a lot of Greek and Roman famous theatres. In fact, for us, the main question is: are the classical acoustical criteria (RT60, Clarity80, Definition50, STI, RASTI, $IACC_{E3}$, sound strength G_{mid}…) [2] largely influenced by the preservation state of the site, which is rather poor compared with other Greek or Roman theatres such as Aspendos, Jerash, Taormina, Delphi, Beneventum, Pompei, Siracusa, Segesta, Ostia and of course Epidaurus ?

Figure 2 – Aerial view of the site The theatre during the opera festival

2. Measurements and results

We present first measurement exploratory sessions of the empty site, realised in spring 2011. Some complementary sessions during the opera festival would certainly be necessary… later.

2.1 Methods and materials

We use “Maximum Length Sequences” technique and “Hadamard transform” to measure impulse responses with a dodecahedron loudspeaker source located in the centre of the *orchestra* and a dummy head in ten different places in the *cavea* (fig. 3):

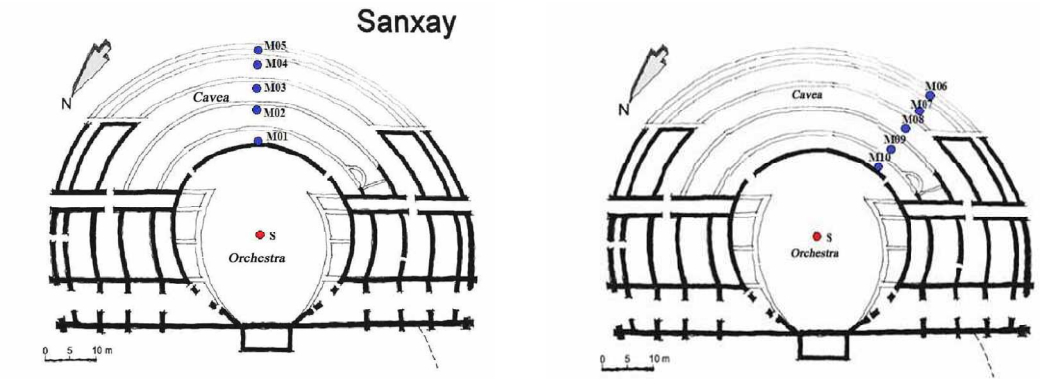

Figure 3 – Plans of measurement positions

Some of the acoustical criteria (RT60, EDT, C80, D50, STI and RASTI) were directly calculated by our software dBBati©, a product of "01dB-Metravib". Only G_{mid} and $IAAC_{\mathbf{E3}}$ were obtained by specific mathematical treatments of the impulse responses at the left (p_L) and right (p_R) ears. After bandpass filtering the impulse responses (with dBFa© software), we calculate strength factor G (1) and "early" interaural cross-correlation function $IACF_{\mathbf{E}}(\tau)$ (2), as defined by L. Beranek [2]:

$$G = 10 \log \frac{\int_0^{\infty} p^2(t)\,dt}{\int_0^{\infty} p_A^2(t)\,dt} \quad (1)$$

where p_A is the free-field sound pressure at a distance of 10 meters.
$G_{\mathbf{mid}}$ is the average of the G values obtained for 500, 1000 and 2000 Hz octave bands.

$$IACF_{\mathbf{E}}(\tau) = \frac{\int_0^{80} p_L(t)\, p_R(t+\tau)\,dt}{\sqrt{\int_0^{80} p_L^2(t)\,dt \cdot \int_0^{80} p_R^2(t)\,dt}} \quad (2)$$

The "early" interaural cross-correlation ($IACC_{\mathbf{E}}$) is the maximum value of $IACF_{\mathbf{E}}(\tau)$ for τ varying from -1 to +1 ms. $IACC_{\mathbf{E3}}$ is the average of the same three octave band values.

Although there were small variances between the two ears, or from one position to another, we essentially present average results for octave bands from 125 to 8000.

The reverberation time (fig. 4 below) presents a maximum value at the 500 Hz centred octave band. Is it surprising to obtain here the same trend for measurements results than in older Roman theatres like Beneventum [3], Pompei Odeon [4], Taormina [5] or in the modular scale model of Siracusa without gallery [6]? Growing absorption of both materials (stones, grass…) and air explain the decay of the curve for higher frequencies. In the low frequencies, our results would be coherent with the theory of N. Declercq and C.S.A. Dekeyser [7][8] about the "diffractions and high-pass filtering due to seat rows"… if in Sanxay the seat rows had been preserved, which is not the case.

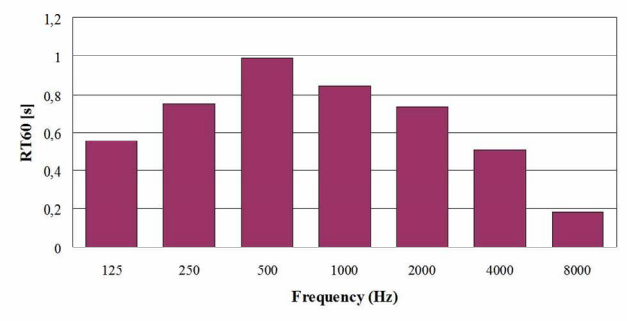

Figure 4 – Reverberation time vs frequency (average values)

The results for the two criteria (fig. 5) based on acoustical energy balance are coherent with observed impulse responses which show most of the energy in the early sound : in mid frequencies the Clarity80 factor is over 15 dB and the Definition50 factor higher than 90 %.

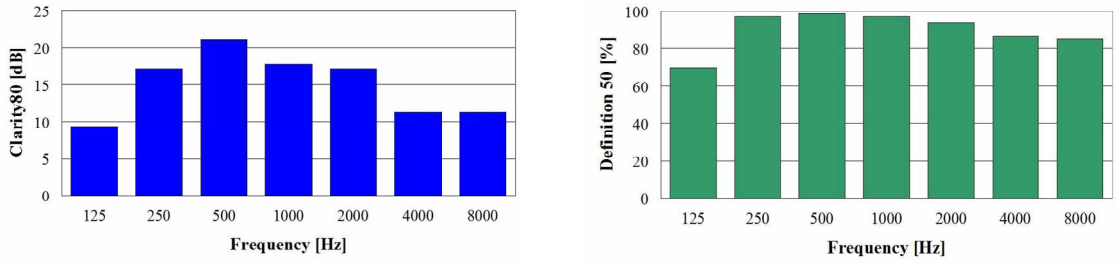

Figure 5 – Clarity80 and Definition50 vs. frequency (average values)

The curve of G_{mid} (fig. 6) is quite similar to those for Delphi, Segesta, even Jerash [5].

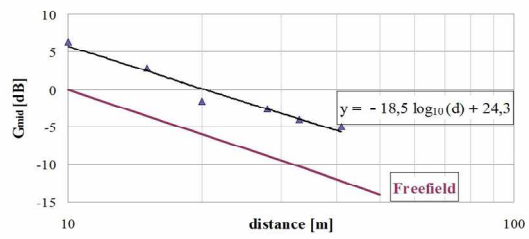

Figure 6 – Source strength G_{mid} vs. source-receiver distance

As expected from values of the Definition50 factor, average values of STI (0.92) and RASTI (0.91), very comparable to some measurements in Beneventum [3] or Ostia [9] or even calculations for Epidaurus, Dodoni or Patras Theatres [10], confirm the "excellent" intelligibility of oral messages.

The Early InterAural Cross-correlation Coefficient (fig.7) is very high, though it decreases slowly with frequency. The $IACC_{E3}$ increases with the distance (fig. 7). As defined by Leo Beranek [2], the Binaural Quality Index (BQI = 1 – $IACC_{E3}$)) is consequently weak, that certainly means the "envelopment" is poor.

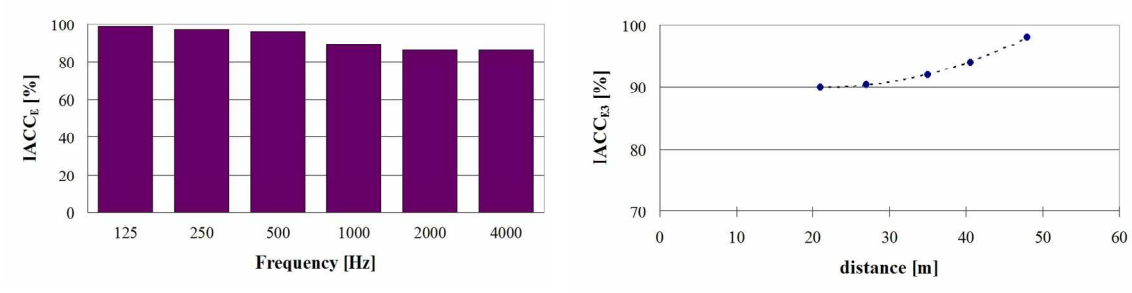

Figure 7 – Interaural cross-correlation coefficients $IAAC_{E}$ vs. frequency (*left*) and $IACC_{E3}$ vs. source-receiver distance (*right*)

3. Acoustical simulations

A simple geometrical model (fig. 8), without tiers, was implemented for the software CATT-Acoustic©. The absorption coefficients of the grass for floors (in green and orange) and the stones for walls (in grey) were complemented by the largest possible ones for the yellow boundaries to "close the box", avoiding complete absorption. The source is in A0 and the receiver in 01 (M03 measurement position, an about 35 m source-receiver distance). The comparison between calculated and measured reverberation time is satisfactory (fig. 8).

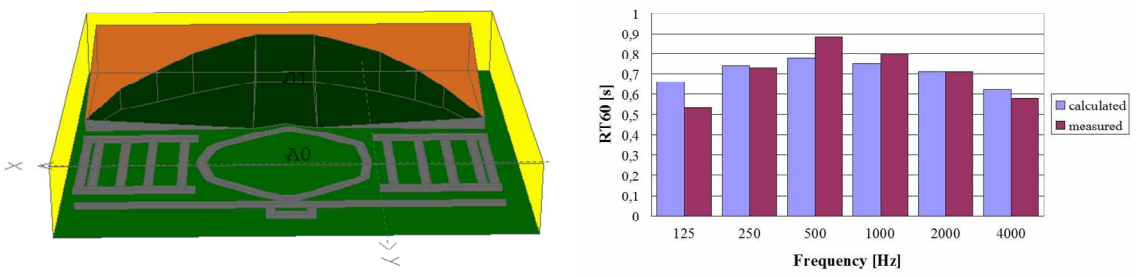

Figure 8 – A perspective of the modelled theatre (left) and RT60 vs. frequency (right)

Probably due to the simplicity of the geometrical model and boundaries absorption hypothesis, the results are comparatively more satisfactory for RT60 (fig. 8) and Definition50 (fig. 9) than for Clarity80 (fig. 9). They are however very similar to those calculated, for example, for the Pompei Odeon using Odeon© software [4]. Otherwise our measured and calculated intelligibility criteria STI (0.80 / 0.83) and RASTI (0.79 / 0.81) are quite close.

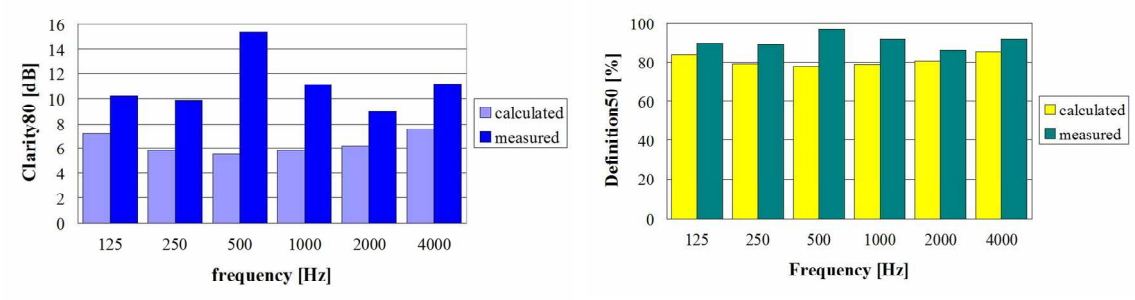

Figure 9 – Clarity80 and Definition50 vs. frequency (M03 position)

4. Conclusion

Compared to some of the most famous and well-preserved Roman and Greek ancient theatres, this first exploratory acoustical study of a Gallo-Roman theatre shows, in conclusion, similar general trends and same order of magnitude criteria, in spite of the state of preservation of the site. Some other simulations were realised to forecast the influence of the presence of wood or stone tiers on the acoustical criteria, for a first approach in view of a possible but yet unplanned restoration. More detailed measurements, analysis, simulations (with more adapted Odeon© software ?) and comparisons with the rich but not exhaustively cited bibliography would be necessary to validate our work. Nevertheless, responding to a musician, an opera singer or anyone in the audience asking : "How is the acoustics ?" is always tricky!

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