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## THE USE OF RESONATORS IN ANCIENT GREEK THEATERS

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### Abstract

Vitruvius in “Architectura” describes the use of bronze vases in ancient Greek theaters in order to improve their acoustic quality. Nevertheless, their effectiveness in theaters is still doubtful. Onorio Belli (1580) refers that the theater of Lyttus in Crete was built with three rows, each one of them included 13 chambers of acoustic vases. Based on the detailed description of Onorio Belli, a model of the theater of Lyttus was simulated. Following the instructions of Francesco di Martino and Floriot, the acoustic vases, which actually act as resonators placed in cavities under the audience seats, were added into the model. The response of two models, on the overall performance of the theater with and without resonators, was compared in order to study the resonators’ effect, on the overall performance of the theater.

### Keywords

*Vitruvius, Acoustic Vases, Ancient Theatres.*

## 1. Introduction

The Greek and Roman theatres are among the most precious and spectacular items of cultural heritage in the Mediterranean countries. Most of them were constructed with highly reflecting materials, stone and marble. Beyond the purely architectural aspects, there were some items used to improve their acoustics, as for example the actors' masks and the sounding vessels. Regarding the vessels of the Roman architect-engineer Marcus Vitruvius Pollio, who lived around 50 B.C., illuminates the construction technology of his age in his work titled "Ten Books on Architecture" [1]. Although Vitruvius used the Greek word "echea" which means sounders, the purpose of Vitruvius's vases was probably not the amplification of sound but the improvement of sound quality. In the fifth chapter of his book he explains that sounding vessels *are made of bronze and must be placed in the theatre structure to reinforce the quality and harmonic structure of sound*. Hence, he clarifies their resonances, their form in detail and the right way of installing them in theaters. According to Vitruvius, in spite of having the vessels placed following the musical laws, probably to improve the sense of music, the reason and mainly their effectiveness is still unknown. There are several conflicting aspects concerning their use [2-4].

According to the Italian Painter-Engineer Francesco di Giorgio Martini (1478) the Vitruvian vases were placed in such a way in order to build up a kind of "wave guide" having the illusion that the sound would reach the audience sitting at the highest seats in higher volume and more clear supplying us a sketch of the cavities where the vessels were placed (see figure 1a) [5]. Rene Floriot, (1964), who studied these vases for almost twenty years, believed that they improved the sound quality both in musical and theatrical events and came up with a sketch of these cavities with acoustic vases as implants (see figure 1b) [6]. On the other hand, Izenour (1977) believed that the efficiency of the vases was very poor. Figure 1c shows a conjectural restoration of sounding vases in a cavity found at a Roman theatre of Skythopolis at Beth Shean (Israel).

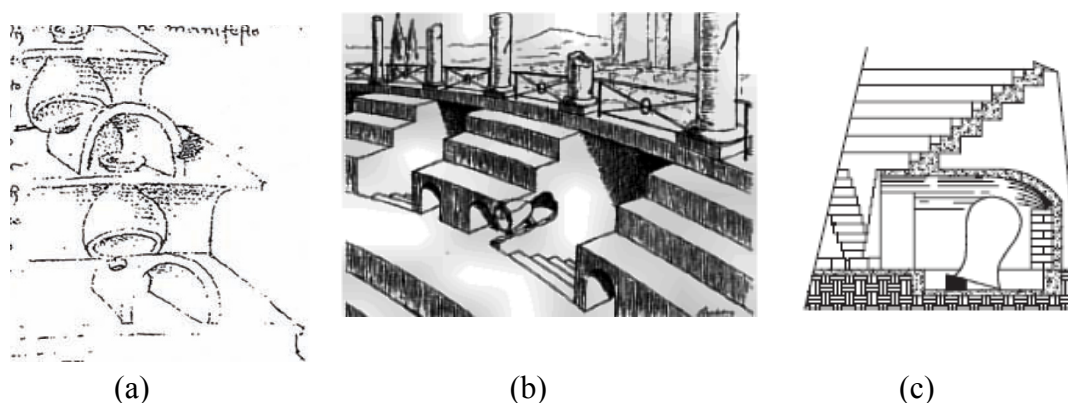
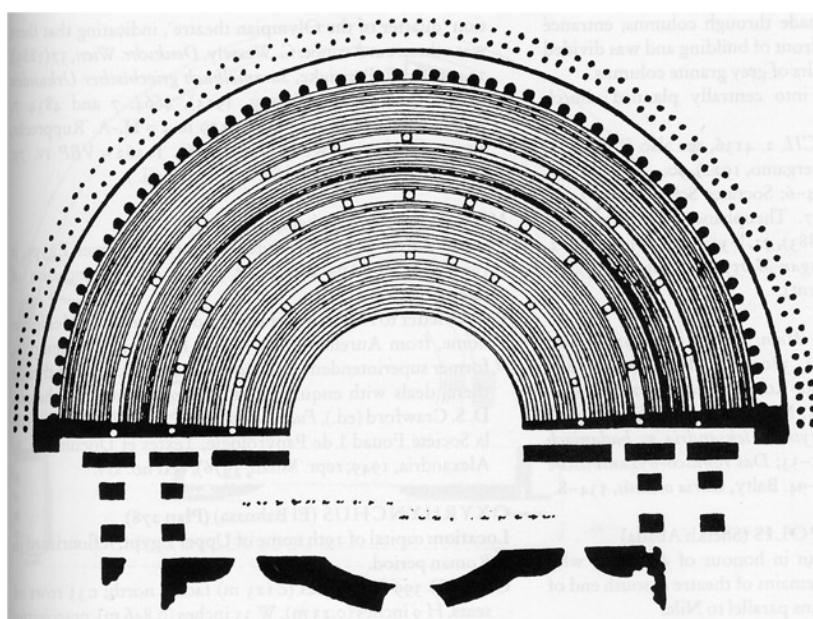


Figure 1 - Pots in ancient theatres according to Francesco di Martino (a), Floriot (b) and Izenour (c).

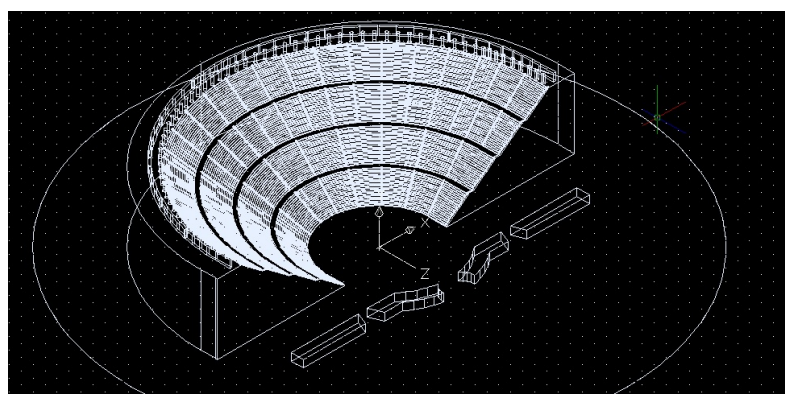
## 2. Model establishment

Lytos, was one of the most important cities of ancient Crete, and was located at the eastern side of Knossos. Polybius depicts it as the oldest Doric town of the island. It is one of the seven Cretan cities mentioned in the Homeric epics, the Iliad and Odyssey.

The largest theater in Crete was the theatre of Lyttos. The ruins were visible until 1583, when Venetian traveler Onorio Belli was captured. Unfortunately as time was passing by, it was covered by dust and today the exact location is unknown. Based on Vitruvius's writings of the theater, the theatre of Lyttos (Crete) is most luckily the described one. Onorio Belli traveling the Aegean recorded the plants as well as the Roman and Greek theatres of Crete. In his manuscript "History of Candia" describes in detail the construction of the theatre of Lyttos. Figure 2a presents a plan of the theatre at Lyttos (Crete), depicting three rows of 13 chambers of acoustic vases in each. This figure was used in order to design a 3 dimensional model in Autocad as shown in Figure 2b. Figure 3a shows a detail of the cavity with the acoustic vase. All vases were geometrically identical corresponding to a resonant frequency, within the 125 octave band. Figure 3b shows a detail of the theatre where the vases were placed, as well as the receivers positions located in front (F) middle (M) and back (B) seats.



(a)



(b)

Figure 2 - Plan of Theatre of Luttos according to Onorio Belli (a) CAD model for the theatre of Lyttos (b).

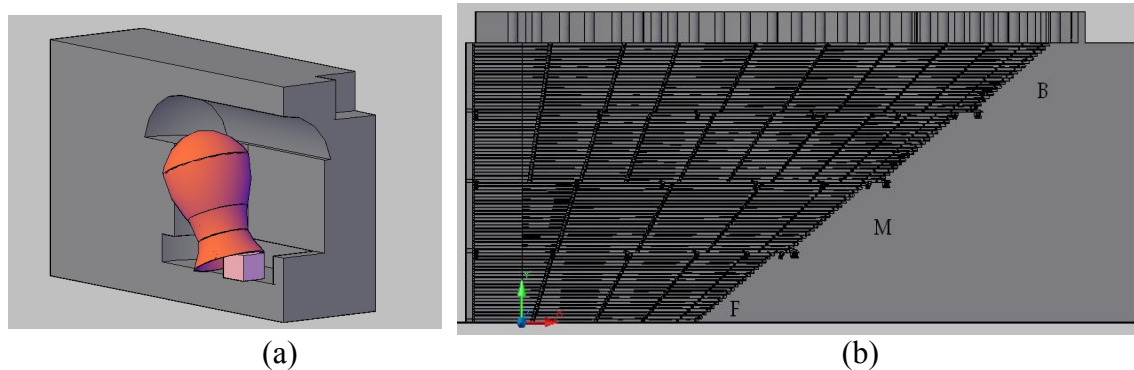


Figure 3 - Details of the model cavity with vase (a) Receiver positions in the theatre (b)

### 3. Results

The resonators seem to have a minor effect on the overall acoustic indices. An increase of absorption factor is observable (Figure 4), for receiver positions at the front, middle and back of the theatre mainly in the high frequency region.

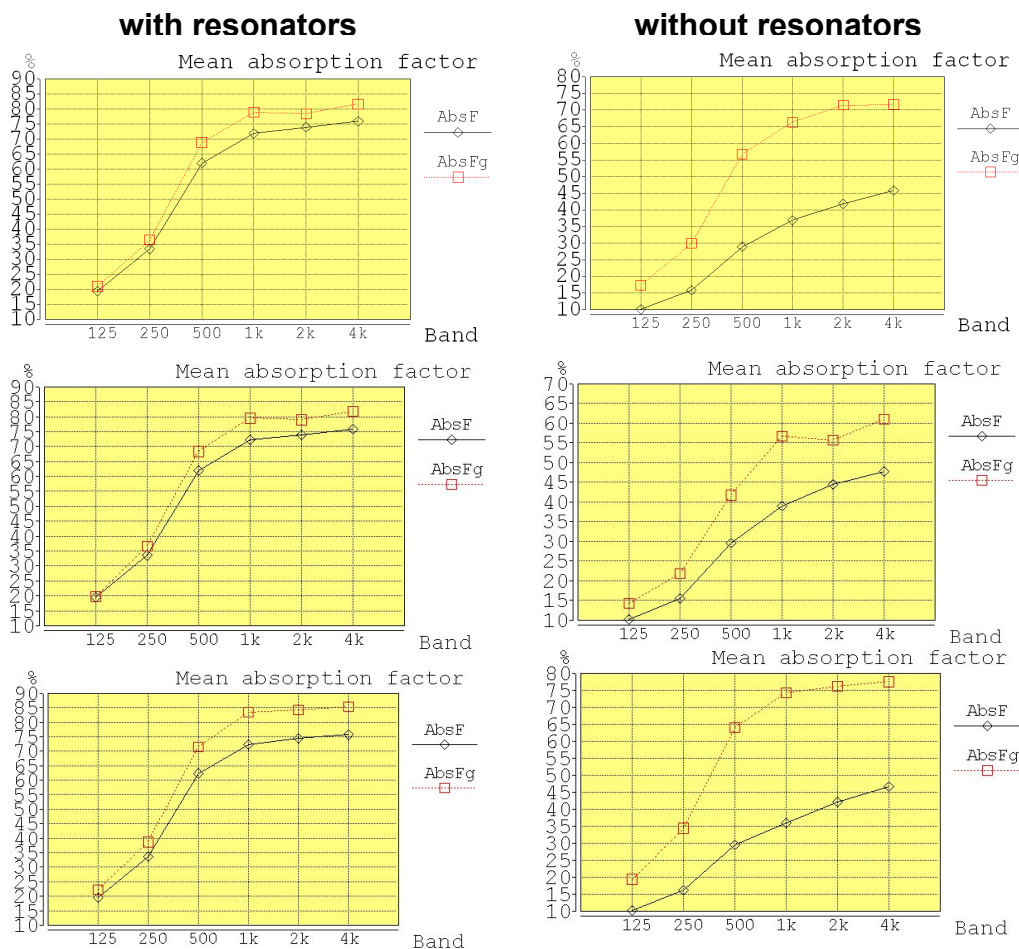


Figure 4 - Mean absorption factor for Front (up) Middle and Upper (down) seats

For the octave band of 125 Hz where the resonant frequency exists, an increase of T15 and T30 were observed (see figure 5).

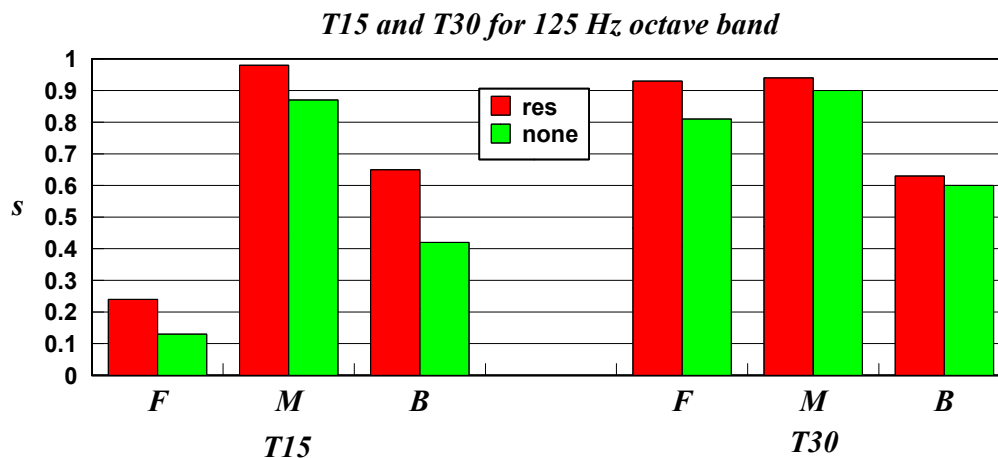


Figure 5 - T15 and T30 for the 125 Hz octave band

Although the resonators reradiate sound, no increase of sound pressure level was observed in all frequency bands and in all positions. This is probably due to the relatively small number of resonators and the fact that their radiation has only a near field effect (boosting the resonance frequency). The receivers' energy at the position located in the lower half of the theatre was greater in the absence of resonators as shown in figure 6.

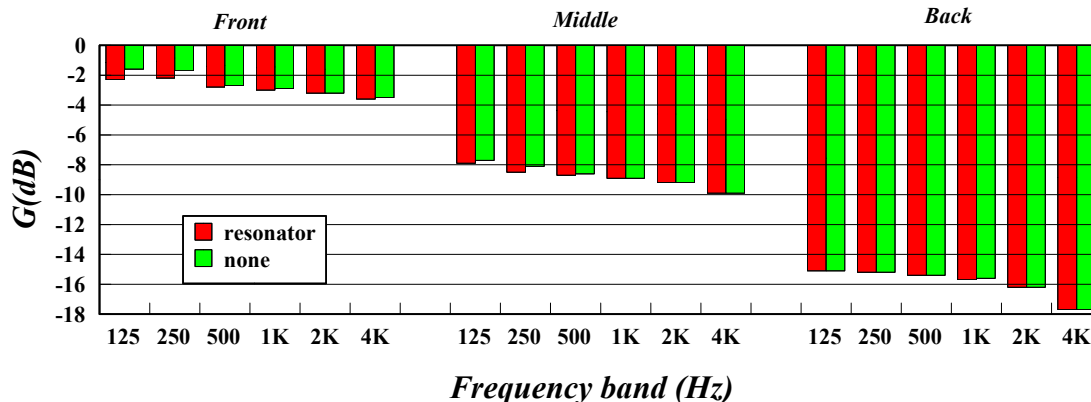


Figure 6 - Source strength

Differences (increase in low and decrease in high frequencies) observed in Clarity index (C80) for the front half of the theatre, but the situation is rather confused (see figure 7). For the same area an increase of the lateral measure LEF1 was observed, but this effect is gradually decreasing, at the upper seats.

#### 4. Conclusion

Summing all above we conclude that the effect of resonators on the Ancient Theatres is poor. This effect is negligible for the upper part of the theater. The small number

of resonators for a such large theatre is rather inadequate to improve the room acoustic indexes. This is probably the reason of their abandonment.

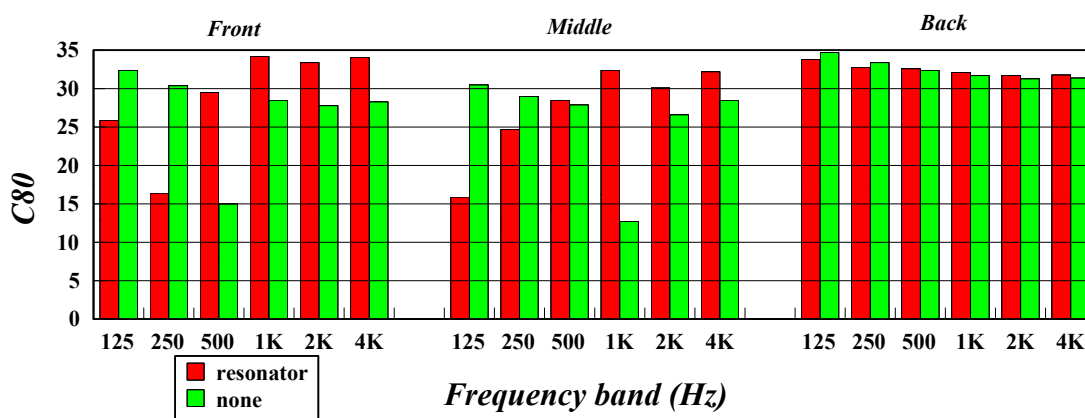


Figure 7 - Clarity (C80)

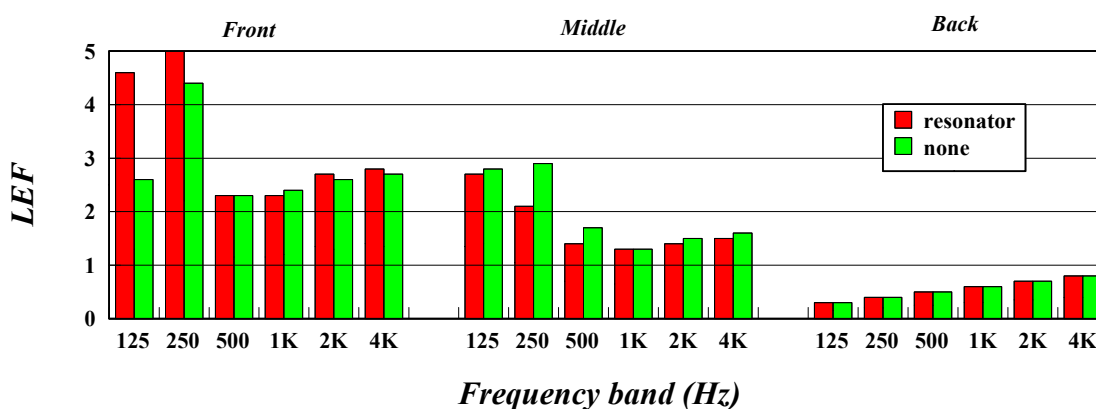


Figure 8 - LEF

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