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COMPUTER SIMULATION OF THE EFFECT OF THE AUDIENCE ON THE ACOUSTICS OF THE ROMAN THEATRE OF BENEVENTUM (ITALY)

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Abstract

The acoustics of the Ancient Theatre of Beneventum has been object of attention by the authors since five years ago when measurements were carried out in the aim of its characterization in the present state. This theatre was built by Emperor Hadrian in the 1st century A.D. Later, historical events as barbarian invasions, earthquakes and floods determined its abandonment. A large part of the materials of the construction was used to build defensive walls in the Lombard period and for the embellishment of churches and palaces. During the course of subsequent centuries the theatre became the settlement of humble dwellings. At the start of the 20th century the crumbling houses were demolished to start the reconstruction of the theatre which was completed, as it appears in the present state, in 1950. This paper reports a computer simulation of the acoustics of the Roman Theatre performed by Odeon software. Calculated results are compared with those stemmed from the previous measurements carried out by the authors in the unoccupied theatre. Furthermore, a simulation of the effects of audience occupation on the acoustics is presented.

Keywords

simulation, unoccupied, audience, occupation, reverberation

1. Historical information

The Roman Theatre of Benevento, is located in Italy, and is distant about 70 km from the city of Naples. It is considered one of the most important work of Roman period in the south of Italy. It was built during the Trajanic period (98-117 A.D.), inaugurated in 126 and enlarged by Caracalla between 200 and 210 A.D. In origin it contained over 10.000 spectators. The cavea, built on substructures, is semicircular and has tree orders: Tuscan, Ionic and Corinthian. Actually only the lower order remains, it consists of twenty-five arches on pillars featuring Tuscan semicolumns. In the upper order it was probably decorated with masks. Accesses were provided by arches communicating with the interior through corridors alternating with flights of steps. The cavea was divided in two maeniana. Over this there was a gallery. The inner wall of the gallery was decorated with niches. The orchestra was semicircular and could be reached from the parodoi. The scaena featured three semicircular niches, the central one being the largest. The structures were built in opus caementicium (using river pebbles and mortar). The facade is faced with limestone and bricks also used; the steps and the scaena were in marble. In origin the diameter of cavea was of 98 m, otherwise the diameter of orchestra was of 30 m. After the Roman period the theatre was used as a quarry for building materials, and later the theatre was occupied by dwellings (Figure 1), which were gradually removed starting from the year 1920, onwards to restore the theatre's monumental appearance. The church (Santa Maria della Verità) built in XVIII century, over a part of the cavea has survived. Actually of the Roman theatre remains fifteen steps, and it can contain only 1.500 – 2.000 spectators. The actual dimension (Figure 2) are: diameter of orchestra equals to 13.50 m; external diameter of cavea equals to 23.50 m; each of the fifteen steps has an height equals to 0.40 m and depth equals to 0.70 m; the cavea slope is equal to 30°. A part of the scaena's lower order with the three doors is preserved (Figure 2). The theatre in the latest years is used for different types of shows: opera, drama, dance and symphonic, jazz and pop music concert. During the annual national cultural meeting "Benevento città spettacolo" the theatre becomes the centre of the most important performances as comedy, drama and musical shows.

2. Acoustic Measurements

The acoustic measurements were carried out on march 2007, the theatre was empty, the air temperature was 21 °C, and the wind was absent [1]. The acoustic parameters measured in according to ISO 3382 [2] were: RT, EDT, C80, D50 and RASTI. The measurement positions were chosen along three radial lines in the cavea (Figure 3), the first line was placed in the right side of the theatre (seen from the audience), the second line in the centre line, and the third line was placed symmetrically on the left. For each direction were chosen four measurement points along the cavea, (blue point) at different distance from sound source location . A dodecahedral omnidirectional sound source was placed on the scaena and in the orchestra. The height of the sound source from the pavement was 1.60 m, the microphone height was 1.0 m. The parameter clarity (C80) is relatively high, because there is a low value of reverberation time; the excellent value of RASTI confirms the presence of direct sound components only.

3. Computer simulation

The computer simulations were carried by "Odeon" 10.1 architectural acoustical software, the virtual model was drawn on geometrical measurements made "in situ" and on available drawings. The model is detailed, contains over 3600 surfaces, the cavea is defined with seat rows and stairs, furthermore there are the holes of "vomitoria", colonnade and the church surfaces to the left side of cavea. The Figure 3 shows the Odeon model. Because the theatre is open, a box closed the model with absorbent coefficient, at all frequencies, equal to 1.0. For the seat rows the scattering coefficient is very important, in this computer simulation it was set to 0.7. The first step was the virtual model calibration: the acoustic parameter considered was the RT (reverberation time) [3], choosing in appropriate way the absorbent and scattering coefficients. It was considered the position of sound source on the scaena.

Dwellings in the theatre's cavea (year 1927)

The ancient roman theatre of Benevento – Antonio Jolie – XVIII century –

Figure 1. Roman theatre: in the past centuries.

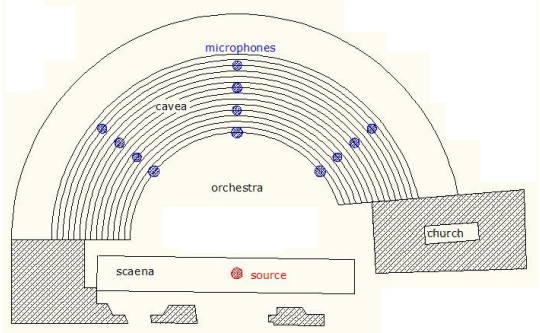
The scaena, with the three doors and the semicircular niches.

The cavea, with fifteen steps: height: 0.40 m; depth: 0.70 m - slope: 30°.

Figure 2 – Roman Theatre: actual state.

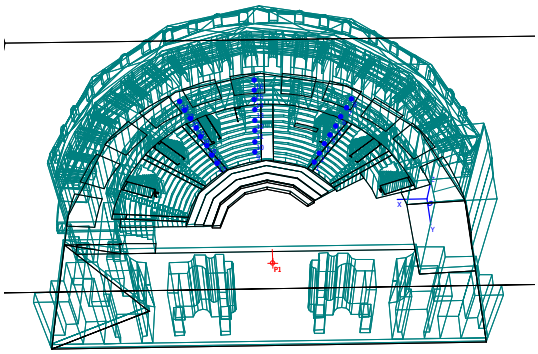
The calibration works were stopped when the error on the difference between the value of reverberation time measured and calculated was minus than 10% [4]. The Figure 5 reported the average reverberation time measured versus calculated values, and the values of EDT and D50 in frequency domain, of measured and numerical calculation by

"Odeon" software, at despite was made a good calibration of a virtual model, at the low frequencies there are not negligible differences.



(A)

Plans, with the measurement micro-phones points (four for each direction along the cavea), and the position of sound source on the scaena



(B)

View of Odeon Model. Red point is the sound source, the blue points are the micro-phone positions.

Figure 3

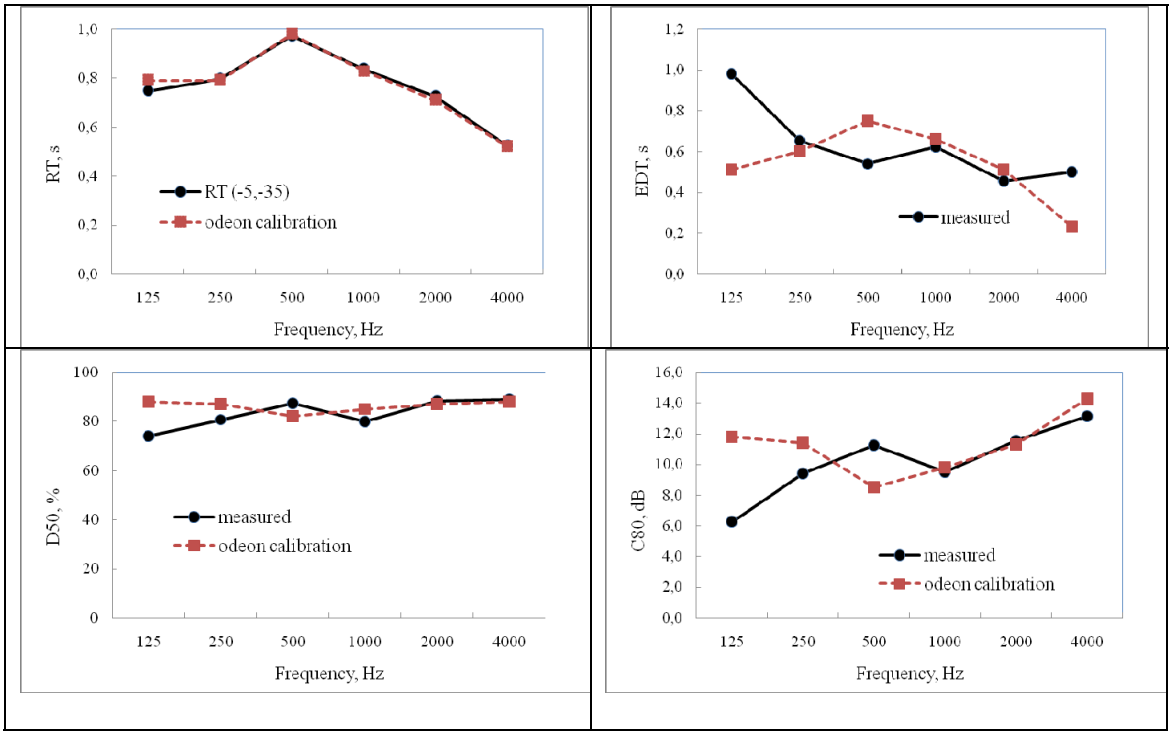


Figure 4 – Average acoustic parameters in according to ISO 3382 (RT, EDT D50 and C80). Measured (black line) versus numerical calculation (red line) values.

4. Computer simulation with audience effect

The audience effect was simulated with the "Odeon" 10.1 room acoustic software, the initial input parameters were the acoustic calibration values. To consider the audience effect, the absorbent coefficients of seats were changed. The values of acoustic properties of the scaena, of the orchestra and the cavea in the high zone (summa cavea) were not changed; because during the performances those are not occupied surfaces [5].

The Table 1 shows the audience absorption coefficient used for the computer simulation to obtain the audience effect; for the numerical simulation the absorption coefficients applied to the cavea surfaces match the configuration of maximum employment.

The Figure 4 shows the value of acoustic parameters (RT, EDT, D50 and C80) when values of the Table 1 were used. The results obtained by a numerical simulation, when theatre is empty and when it is occupied by audience, do not show significant difference between them. The effect of audience is negligible, because only a part of cavea is occupied from people.

Table 1 - Audience absorption coefficient

Frequency	125	250	500	1000	2000	4000
Minimum values	0.16	0.24	0.56	0.69	0.81	0.78
Maximum values	0.6	0.74	0.88	0.98	0.96	0.87

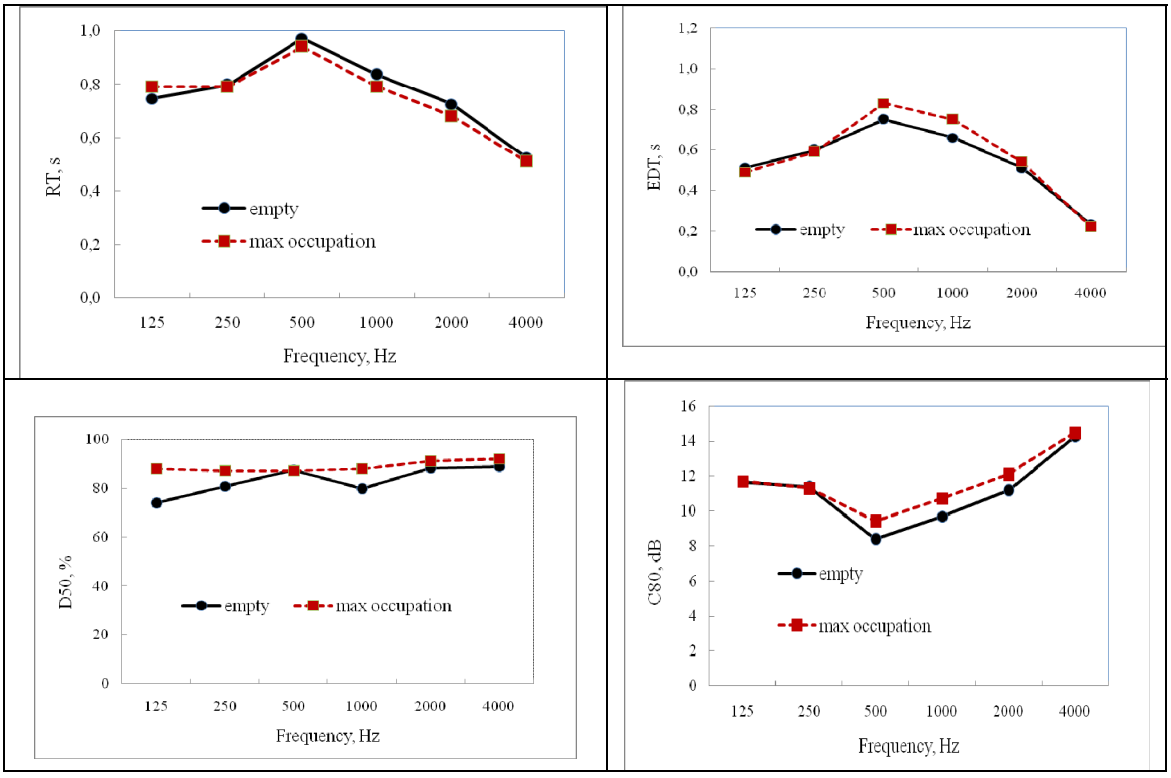


Figure 5 – Average acoustic parameters in according to ISO 3382 (RT, EDT D50 and C80). Empty theatre (black line) versus occupied theatre by audience (red line) values.

5. Conclusion

The audience effect is negligible on the average acoustic parameters (Figure 4) [6]. This effect is due to the cavea surface, because people seats only in a part of it, it is evaluated in about 50 % of the all surface. The original capacity (Roman period) was over of 10.000 spectators, today the actual capacity is of about 2.000 spectators, for the cavea small size and for safety reasons because escape router are reduced.

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