Theatre "Morlacchi" in Perugia: Determination of the Acoustic Characteristics and Proposal of Improving Quality Solutions

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Abstract

This paper deals with the evaluation of the acoustic quality of the theatre Morlacchi in Perugia, Italy; some improving solutions have been individuated too. Acoustic quality parameters have been measured by means of a data processing system. Sound pressure levels due to a dodecahedral source placed on the theatre stage have been measured for 40 measurement points. Data acquisition system has processed the measured levels in order to evaluate the theatre acoustic quality parameters. Measurement results have been compared to their optimum values. The comparison has shown the necessity to improve the theatre acoustic quality. Simulations have been carried out by means of a numerical code in order to individuate improving solutions. Some different methods have been proposed for prose spectacles and concerts. Simulations has shown an approximately 22% increase for STI and RASTI parameters by using the proposed improving quality solutions.

1. Introduction

The acoustic characteristics of the theatre Morlacchi in Perugia have been investigated in order to individuate some improving quality solutions. Acoustic quality parameters such as RT30, EDT, Clarity Index (C_{80}), Definition Index (D), STI and RASTI have been evaluated by means of a data acquisition system. Measured parameters have been compared to their optimum values. The comparison has shown that the Morlacchi acoustic quality has to be improved in order to obtain optimum acoustic performances. Improving solutions have been individuated by means of numerical simulations. Two kinds of improving quality solutions have been individuated relative to:

1) prose spectacles. Low reverberation times have to be obtained in order to have an optimum speech intelligibility.
2) concerts. reverberation times higher than 1) configuration ones are necessary in order to induce a good notes mixing.

Simulations have shown that the proposed solutions improve the theatre acoustic quality both for 1) and 2) configurations.

2. Theatre Morlacchi in Perugia

The theatre Morlacchi was built in 1777 in the historic centre of Perugia, Italy. It has been enlarged and restored in 1874 and after the second world war. The theatre is often destined to prose spectacles; thus, an optimum speech reproduction is its main purpose. However, concerts are sometimes performed. The theatre architectonic characteristics are the followings (see Fig.1):

- the pit is characterized by a horseshoe shape with the following prevailing dimensions: length=18.6 m, width=14.4 m, height=15.5 m. The floor is realized in varnished wood partially covered by two 29 m^2 moquette carpets; 300 velvet-covered seats are placed on the floor. 26.4 m^2 area velvet drapes cover the lateral exits, the theatre entry and the under-stage wall.
- The stage is characterized by an irregular asymmetric shape with the following prevailing dimensions: length=18.0 m, width=22.0 m, height=15.7 m. 78 m^2 area velvet drapes are placed at a 3.40 m distance from the stage edge.
- Five boxes orders are characterized by an irregular shape with a 2.20 m average height and a 991 m^3 total volume.

Figure 1: the Theatre Morlacchi in Perugia

3. Measurement Method

The acoustic quality parameters of the theatre Morlacchi have been measured by means of Symphonie data acquisition system. A MLS sequence

method has been chosen [1]. MLS sequence has been generated by a dodecahedral source driven by the data processing system. Two source positions (S1 and S2) have been chosen respectively at a 5 m and a 10 m distance from the stage edge. Sound levels have been picked up by a G.R.A.S. microphone (model 40AR) for 40 measurement points (see Fig. 2). Microphone height was 1.15 m, which corresponds to the ear height for a seated listener. Sound levels have been processed by the data processing system in order to evaluate the acoustic quality parameters values.

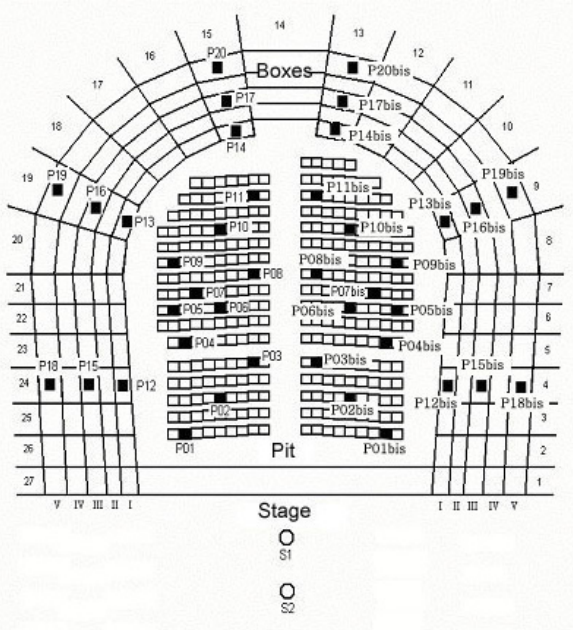

Figure 2: Source and microphone positions

4. Measurement Results

The following acoustic quality characteristics have been measured:

- Pit RT30 values are close to the boxes ones both for source S1 and S2; they are in the 1.2÷2.4 s range (optima for lyric spectacles but 500Hz RT30 value is higher than the optimum value) [2].
- Reverberation phenomena are not uniform. In fact, EDT values for source S1 are approximately 0.3 s higher than the source S2 ones.
- C_{80} optimum values (0±1.6 dB) are measured only for 250-2000 Hz frequency range [3].
- Definition Index measured values (less than 50% for frequencies lower than 3kHz) show that the theatre acoustic quality is not good for speech spectacles, but optimum for music [4].
- Speech intelligibility is medium (STI and RASTI measured values are in 0.48÷0.56 range) [5]. Measured STI and RASTI distributions are not uniform. They are maxima (0.55-0.56) for the points nearest to the source and the central boxes (P01, P17, P17bis positions); an intelligibility fall occurs in the pit central zone (STI and RASTI are in the 0.48-0.52 range). STI and RASTI values for S1 source are better than the ones for S2 source (more useful for prose spectacles). This is due to the stage lateral dimensions which increase with the distance from the stage edge (the stage is asymmetric).

The Morlacchi acoustic quality has been also simulated by means of a numerical code (Ramsete 2.0) [6]. A numerical three-dimensional model has been realized (see Fig. 3). It is constituted by 1990 surfaces.

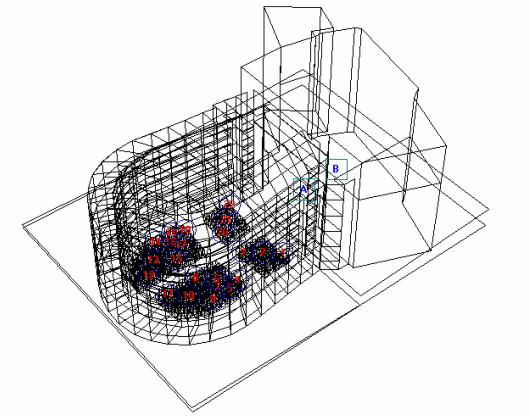

Figure 3: Theatre Morlacchi numerical model

The model has been calibrated by means of the measurement results. Thus, numerical simulations results agree with the measurement ones. A sound level map has been realized by simulating the acoustic field due to a source placed on the S1 position stage. The map (see Fig. 4) show that the acoustic field is asymmetric due to the stage asymmetry. Besides, the stage is equipped with an acoustic chamber constituted by 45° up-slope wood panels when concerts are performed. A numerical simulation has shown that the acoustic chamber increase the sound level into the theatre but it cause sound focalisations and great disuniformities (see Fig. 5).

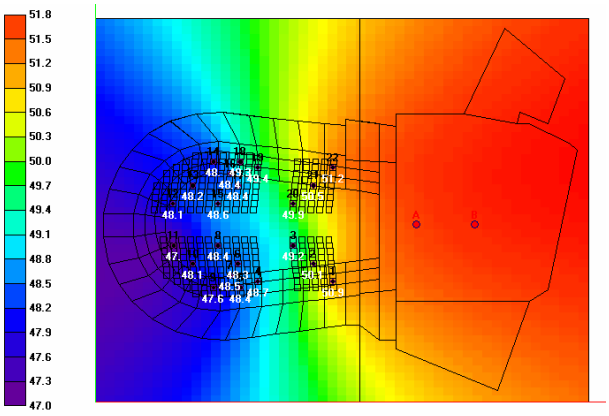

Figure 4: Leq map obtained by a numerical simulation without the acoustic chamber.

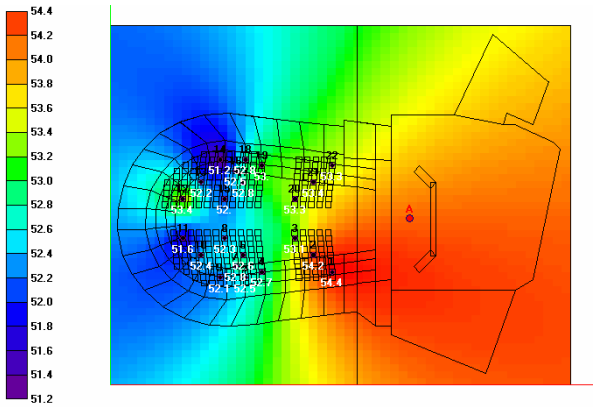

Figure 5: Leq map obtained by a numerical simulation with the acoustic chamber.

5. Individuation of Acoustic Improving Quality Solutions

Measurements and numerical simulations have shown the necessity to improve the theatre Morlacchi acoustic performances. The following solutions have been proposed:

A) the installation of a panoramic scenery constituted by velvet panels parallel to the stage lateral walls and PVC panels placed on the stage bottom wall. The scenery has to be installed only for prose spectacles because it allows to reduce the reverberation times values; besides, it may be used to reduce the stage asymmetry and so the sound field disuniformities;

B) the wood floor has to be coated with a 5 mm thick moquette in order to reduce the reverberation time values;

C) the realization of an acoustic chamber to be used for concerts. The chamber is constituted by some quadratic residue diffusors and an inclinable panel in order to reduce the sound field disuniformities [7].

Numerical simulations have been carried out by introducing a 15.50 m height panoramic scenery (A solution) and the moquette coating (B solution). Results show that:

- low-medium frequencies RT30 and EDT values have been reduced by means of A) and B) solution. Thus, optimum values for prose spectacles have been obtained [2].
- C_{80} values are higher than 1.6dB when the panoramic scenery is used. A great harmonic transparency occurs for musical spectacles [3]. Thus, the panoramic scenery has to be characterized by an automatic rewinder in order to be easily removed for concerts.
- D index values are higher than 50% also for frequencies lower than 3kHz [4]. Thus, A and B solutions allows to improve the theatre performances for prose spectacles.
- An approximately 22% average increase is obtained for STI and RASTI values. STI and RASTI average values are 0.63, which corresponds to a good speech intelligibility [5].

As an example, Fig. 6, 7 and 8 show the comparison between measured and simulated EDT, C_{80} and RASTI without A and B solutions and simulated EDT, C_{80} and RASTI with A and B solutions.

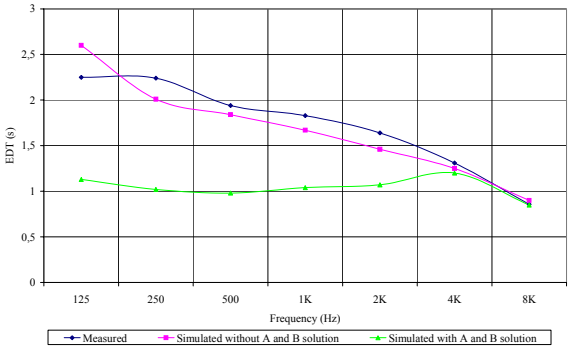

Figure 6: Comparison between EDT values without and with A and B improving acoustic quality solutions

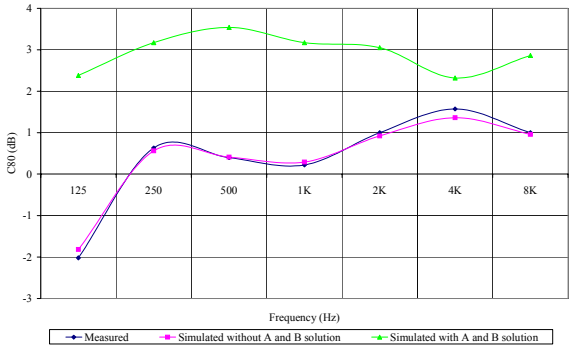

Figure 7: Comparison between C_{80} values without and with A and B improving acoustic quality solutions

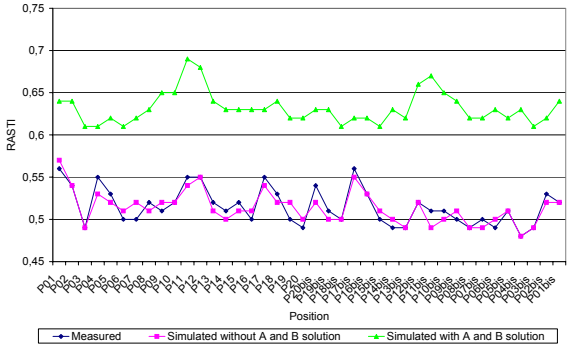

Figure 8: Comparison between RASTI values without and with A and B improving acoustic quality solutions

STI and RASTI distributions are more uniform than the ones which characterize the theatre without the proposed A and B solutions. The intelligibility fall which occurs in the pit central zone is now reduced. As

an example, Fig. 9 shows RASTI map for the theatre when A and B solutions are adopted.

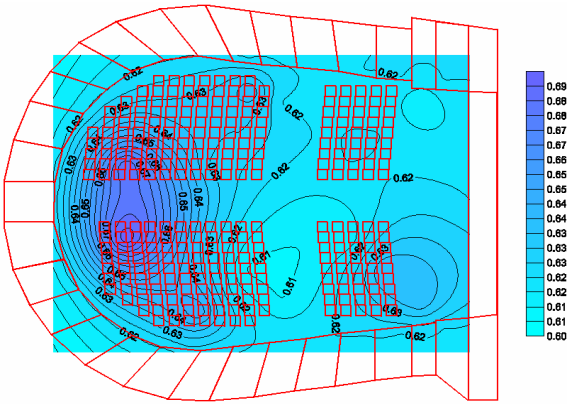

Figure 9: Theatre Morlacchi RASTI map when the A and B improving sound quality solutions are adopted.

At last, C solution allow to reduce the acoustic field disuniformities which occurs when the wood acoustic chamber is used. This chamber may be substituted by an original acoustic chamber constituted by some acoustic towers to be used for musical spectacles. Each tower is made by some quadratic residue diffusors and an inclinable panel (see Fig. 10).

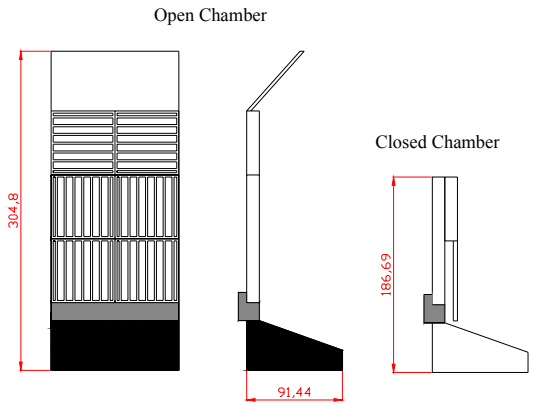

Figure 10: the proposed acoustic chamber for concerts.

The chamber characteristics are the followings: height (open chamber) = 304.8 cm; height (closed chamber) = 186.7 cm; width = 121.9 cm; length = 91.4 cm; weight = 158.8 kg. The number of the towers is determined by the number of musicians which play the concert. 50 musicians are able to stay on the Morlacchi stage. Thus, the acoustic chamber has to be constituted by 10 central tower and 16 lateral towers (8 for each side).

6. Conclusions

The theatre Morlacchi acoustic quality has been investigated in order to individuate suitable improving solutions. A measurement campaign has shown that:

- speech intelligibility is not good for prose spectacles.
- the theatre characteristics are good for concerts but the stage architectural asymmetry induce acoustic field disuniformities which are particularly increased by the wood acoustic chamber used for musical spectacles;

Acoustic quality improving solutions have been proposed. In particular, the installation of a panoramic scenery constituted by velvet panels parallel to the stage lateral walls and PVC panels placed on the stage bottom wall may worsen the acoustic quality for music spectacles. Thus, an automatic scenery rewinder has to be realized in order to use the panoramic scenery only for prose spectacles. Speech intelligibility may improve also by coat the theatre floor by means of moquette. Numerical simulations have verified the proposed solutions efficacy. In particular, an approximately 22% STI and RASTI average increase has been obtained. The obtained STI and RASTI average values are 0.63, good for prose spectacles. The acoustic field disuniformities which occur specially for concerts may be instead reduced by means of an acoustic chamber constituted by quadratic residue diffusors. The proposed solutions are going to be realized. A measurement campaign will be carried out in order to verify the results obtained by the numerical simulations.

7. Acknowledgements

The authors thank Dr. Domenico Montino for the precious collaboration.

8. References

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