THE ACOUSTICS OF THE MUNICIPAL THEATRE IN MODENA

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ABSTRACT

Following the program of a campaign of systematic acoustical surveys inside Italian historical theatres [1], new acoustical data started to be accumulated. This work reports on the acoustics of a well-known Italian theatre, the Municipal Theatre in Modena. This hall, whose design follows the Italian-style opera house, had never been acoustically investigated in detail before the year 2000, when the surveys took place. Moreover a major refurbishment was made in the theatre before the measurements and some insight on specific acoustical aspects have been achieved by means of the measured data.

INTRODUCTION

The Municipal Theatre in Modena was built in the years 1838 - 1841 by the architect Francesco Vandelli. At present the theatre, which is included in the outstanding group of 24 Italian “theatres of tradition”, hosts regular seasons of opera, concerts and ballet. The hall has an elliptic plan shape and it houses 1030 people: 398 seats are located in the stalls and the rest is distributed among the four tiers of boxes (summing up to 116) and the gallery. The stage, which is moderately sloped (5%), is 17.50m long, 20.00m wide, and the stage tower is 18.50m high. As reported in detail in [2], during the years from 1996 to 1998 the theatre has undergone a major refurbishment, mainly to comply with the latest safety norms. The works involved both the outside and the inside of the building. In the main hall the plasters, the painted decorations of the ceiling and the ornaments were polished. The seats in the stalls were refurbished and the furnishing of the boxes was restored too. From the acoustical point of view no reference data had been collected in the past (before the renovations), but the theatre has generally had a good reputation among the public. Despite this an unfavourable balance between the singer on stage and the orchestra in the pit was detected before the refurbishment [3]. This fact is probably due to the lack of an overhang in the pit as shown in Fig. 1. Moreover, during the works the floor of the pit was hardened and, on the opinion of the technical staff, the problem seems now to be even more evident than before. In the year 2000 a detailed acoustical survey of the theatre was done. This campaign gave a thorough qualification of the acoustics of the theatre and in particular the specific problem regarding the balance was investigated.

THE ACOUSTICAL MEASUREMENTS

The objective acoustical qualification followed the document [4] which was developed expressly to meet some special requirements of historical theatres and already applied to other historical theatres of different styles and periods [5].

The Position Of Sound Sources And Receivers

Two different kind of tests were done:

1) Coupled hall and stage: the fire curtain was up and no stage scenery was present. In this case the source on the stage is named A3 (shown in Fig. 2) and that in the orchestra pit is A1.
2) Uncoupled hall and stage: the fire curtain is down. In this case the pit source is called B1.

In both cases the source, which was dodecaedric loudspeaker, had its acoustic centre at 1.25m above the floor and laid on a line parallel to the symmetry line, at 1.00m distance. The position A3 was at 2.00 m to the border and in the pit it was fixed at 1.5m to the pit rail. The receivers were a Neumann KU100 head and Soundfield SUST250 B-format microphone. These probes were put side by side at nearly 0.7m to minimise their mutual influence. The receivers were distributed only on one side of the cavea due to the architectural symmetry. Nine positions were chosen in the stalls, three in the first and second order boxes, three in the gallery, one on the stage and another one in the pit. A map including sound sources and receivers is reported in Fig. 3. During the measurements the orchestra and the stage of the theatre were completely empty and no listeners were present.

The Measurement Chain

The measurement chain allowed the parallel spatial sampling of binaural and B-format data of the sound field created by the dodecaedric sound source. The test signal consisted in a 16th order Maximum Length Sequence which was repeated at least 32 times at each position to improve the S/N ratio. The raw data consisting in the sequences at various positions were digitally stored on magnetic tapes and later processed for the extraction of impulse responses. Then the group of indicators recommended in [6] was obtained by using the omnidirectional signal enclosed in the B-format coding (called W). The Y channel of the same coding was employed to calculate the parameter called "lateral fraction", whereas the binaural signals and the other B-format tracks served to implement other kinds of analysis not reported here.

THE RESULTS

The results of the measurements are presented mostly in the form of graphics of the frequency distribution of the acoustical parameters. The error bars of one standard deviation are included where there are sufficient data for a basic statistical analysis. The all pass "Lin" values are also plotted as reference. The figures refer the stalls only, and different curves for each position of the sound source are included. Completely similar graphics were obtained for the boxes and, even if not reported here, they will be also referred to in the discussion of the measurement results.

Reverberation Time

The parameter RT20 is shown in Fig. 4. The three curves referring to the source positions A1, A3 and B1 have a similar course but they present some typical differences. In fact, while in the lowest band (1/1 oct. centred at 125Hz) the measured values almost coincide, in the range from 250Hz to 1kHz the spacing between the curves is quite evident. In the upper frequency range (2kHz and 4kHz oct. bands) there are only minor differences. The range covered by the parameter for the three source locations is surely representative of the span of possible values from the most reverberating condition (A3) to the lowest (B1). The data show that RT20 would be always within an interval quite in line with the values generally suggested for opera. Only in the highest octave the values below 1s could be considered too short. In the boxes the courses of the three curves are in agreement with the respective cases in Fig.4.

Clarity

As reported in Fig. 5 in the stalls the trend of the parameter is coinciding for A1 and B1 and the average values lay within –3dB and +3dB. The range of the average C80 values is appropriate notwithstanding the remarkable variations of the parameter from one position to another in the same area. This dependence on the location is probably exacerbated by the shielding of the pit rail which influences in a different manner each impulse response. The data measured for the stage source (condition A3) are markedly higher and the resulting curve for the average values is nearly 3dB higher then the two former curves for the source in A1 and B1. This fact gives to the voice from the stage a plus of clarity which might compensate some unfavourable balance with respect to the orchestra pit, as explained below. When considering the boxes (not shown) C80 for both A1 and B1 is increased probably due to better lines of sight from the source to the receivers, and the gap with respect to A3 is reduced.

Strength

The wide band data of the parameter G measured in the stalls are reported in Fig. 6. When each sound source is operating alone the values are quite satisfactory since for most positions they are close to 6dB or more. In the figure it is also included the level difference between the sources A3 and A1. This particular set of data can be used as a measure of the balance between the singer and the orchestra. In fact the sound source, though it was not directional as suggested by some previous researches on balance [7], operated at the same power level in the pit and on the stage. Fig. 6 shows that all of the positions in the stalls have unfavourable balance since indicative values for the parameter can be set around +2dB (see again [7]). The results of G for the boxes (not reported here) showed an overall decrease of the values of strength in most of the positions. Furthermore the balance obtained as A3-A1 in the boxes gave values even lower than in the stalls, so that the dominance of the pit over the stage seems here quite evident. This findings confirmed that the balance problems are common to all of the listening positions and a specific solution should be elaborated.

Lateral Energy Fraction

This parameter considers the ratio between the sound energy coming from the sides in the time interval from 5ms to 80ms (the direct sound is excluded) and the whole omnidirectional energy arriving during the interval from 0ms to 80ms. A good sensation of envelopment is obtained when the values are higher than 0.2. Looking at Fig. 7 it is seen that the data marked A1 are high in most positions due to the shielding of the pit rail. In this case in fact the most of the sound is reaching the listeners after reflecting on the lateral walls of the stalls. When also the reflective surface of the fire curtain is inserted (condition B1) the values for the same locations in the stalls are clearly decreased, because a marked reflection from the frontal direction is now arriving. Also the condition A3 produces lower values since directional reflections govern the first part of the responses when the source is on the stage. In other words the sound from the pit should appear quite enveloping whereas the stage should be more focused at the listening positions. Passing to the boxes the discrepancies between the source locations are reduced significantly. The overall values are now much lower than those in the stalls due to a limited effect of the lateral reflections from the side boxes and the ornaments.

Support 1 (ST1)

This parameter is one of the tools to evaluate the acoustics for the players. Good values for ST1 are in the range between –11dB and –13 dB. As shown in Fig. 8 almost the same result was obtained for A1 and B1 with an appropriate value, that is to say that the pit provides the musicians with a notable set of useful reflections which give a good support to the performance. On the contrary the value measured for A3 is out of the indicated range. This is due to the absence of any important reflective surface in the proximity of the singer. This condition can be improved during the performances by the stage scenery which, if properly designed, can partly fill the lack of reflections. A permanent improvement of the singing conditions would require to locate some fixed reflectors.

CONCLUDING REMARKS

This work gave a scientific qualification of the Municipal Theatre in Modena which, to the knowledge of the authors and from inquiry to the management, was not acoustically investigated in the past. The measurements here reported refer to the condition of the theatre after major renovations and the lack of acoustical data before the works does not permit to validate the restoration work. This point is critical in some respect because some specific problems regarding the balance between the singer and the orchestra, which were reported before the renovations took place, seem now more evident due to an hardened pit floor. This fact was confirmed by the measurement. As regards the acoustical quality, the theatre presents values of the parameters quite in line with the indications of the literature [8]. The listening conditions were investigated for three source positions and some notable differences were reported. In particular the sound field in the stalls has higher level and more favourable envelopment whereas the clarity is higher in the boxes. The reverberation time RT20 has appropriate values in each case and only minor changes between stalls and boxes were measured.

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[7] M. Barron, *Auditorium Acoustics and Architectural Design,* E&FN Spon, 1993

[8] H. Mueller, *Roomacoustical criteria and their meaning,* Proc. of the Conference “Acoustics and Recovery of Spaces for Music”, Ferrara, 1993.

Fig. 1 – A view of the orchestra pit from the gallery. No overhang is present.

Fig. 2 – A view of the hall from the stage with the sound source in the position A3.

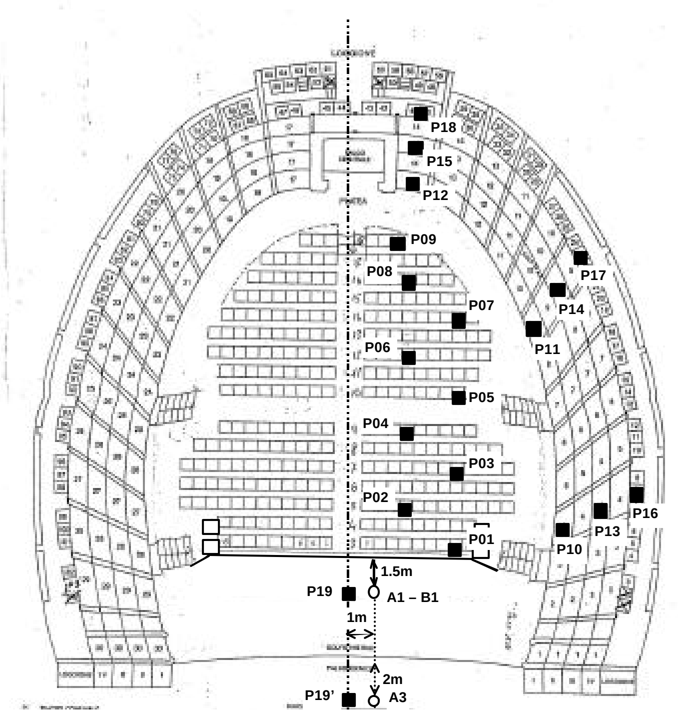

Fig. 3 – The plan of the sound sources and of the receivers employed for the measurements in the theatre.

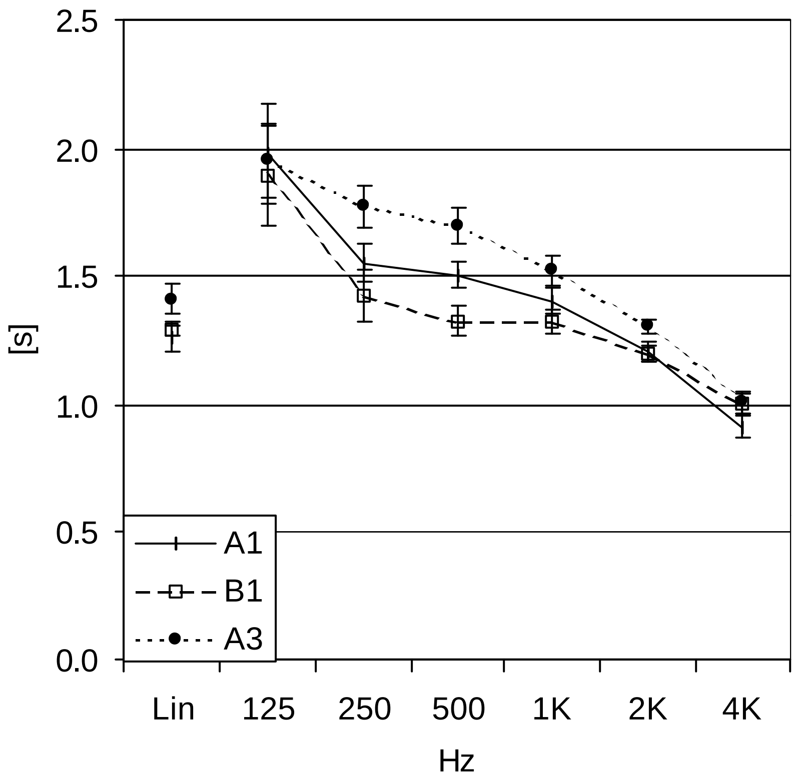

Fig. 4 – The parameter RT20 measured in the stalls of the theatre for the three sound source positions A1, A3 and B1.

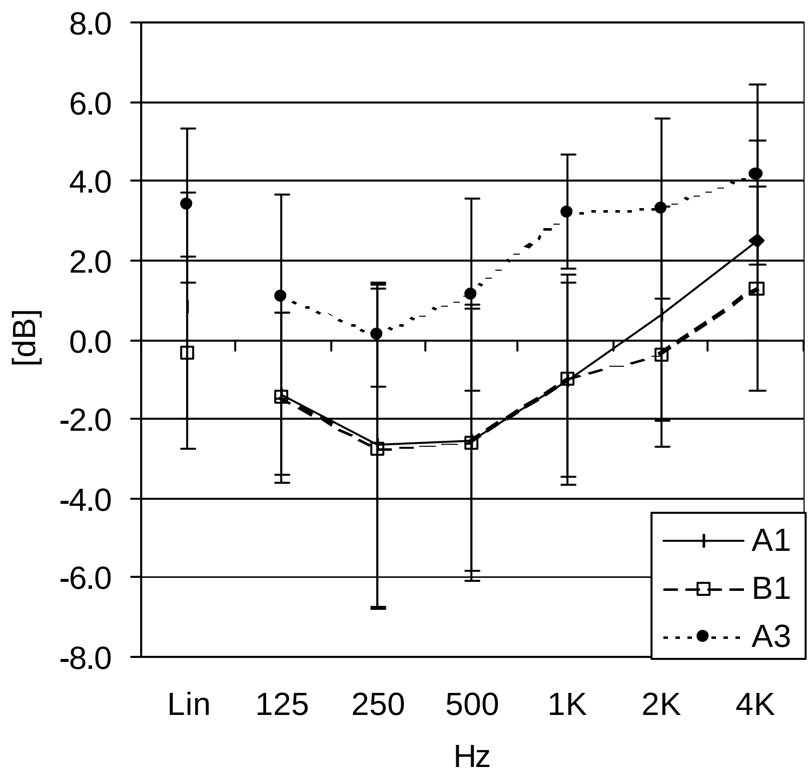

Fig. 5 – The course of the clarity C80 in the stalls for the different postions of sound source. The error bars refer to one standard deviation.

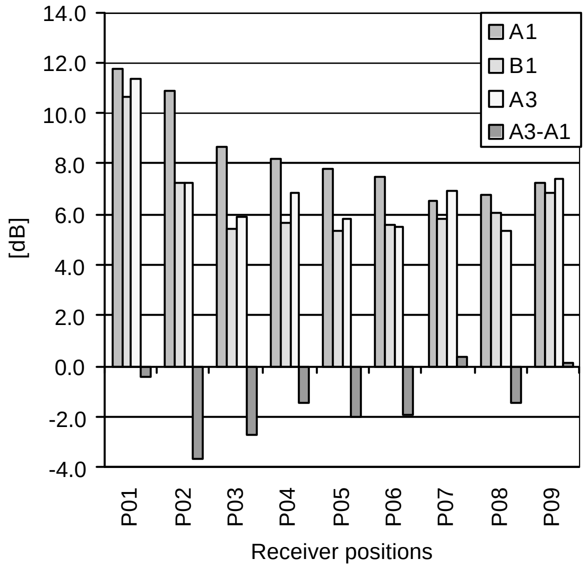

Fig. 6 – Measured data for the parameter G in the stalls.

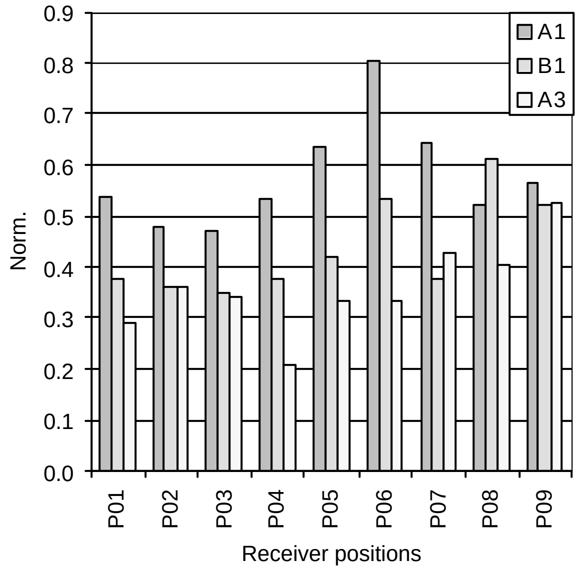

Fig. 7 – The values of lateral fraction LF in the stalls.

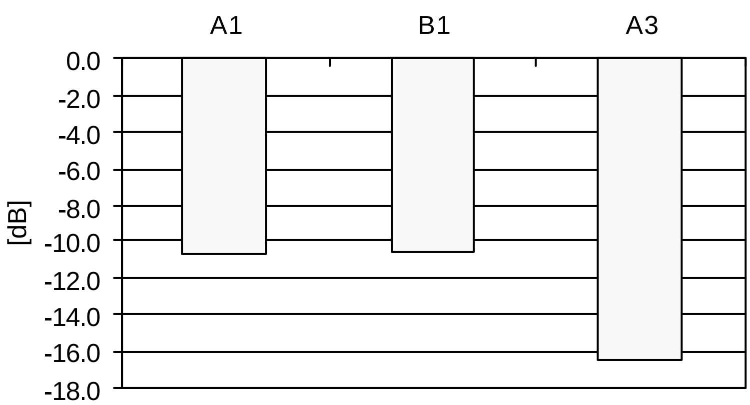

Fig. 8 – Support ST1 for each sound source position.