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Acoustic description of the Great hall of the Moscow P. I. Tchaikovsky Conservatory

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ABSTRACT

The Moscow P. I. Tchaikovsky Conservatory is situated in a 19th century building located in the center of Moscow. The Great Hall (Bolshoi Sal) of the Conservatory is probably the most loved concert hall in Russia by both musicians and audience, both for its visual appearance but not least for its acoustic conditions. The hall will be renovated for the Tchaikovsky competition in 2012. In connection with the renovation design, the existing acoustic conditions in the hall have been assessed, both by means of objective impulse response measurements in the hall as well as by questionnaires handed out to orchestra and audience members. In addition a 1:20 acoustic scale model has been built and tested, and the geometry of the hall has been studied in computer models.

This paper presents the acoustic conditions of the Great Hall based on the measurement, modelling and listening studies and aims at providing some insight to the acoustic community as to why this hall is so successful.

GENERAL DESCRIPTION OF THE HALL

The Bolshoi hall is basically a shoe-box form, with one, very deep rear balcony and side balconies extending to about 3 m from the stage front. The stage is a semi-proscenium stage, with about half of the stage being behind the proscenium and half on a stage extension in front of the proscenium opening.

The overall dimensions of the Bolshoi hall are: overall length (from behind organ to back wall) is 56 m, from the edge of the stage to back wall 45 m. The overall width of the hall is 21,8 m and the width between the balconies is 17 m. The height in the auditorium itself is 17,7 m

The height of the stage is 1,2 m. The depth of the stage is 10,7 m, measured from the edge of the stage to the front of the organ. The width of the stage-house is 17.4 m and the height in the stage house is 11 m. The seat count for the Bolshoi Hall is 1737 seats.

The surfaces of the hall are highly ornamented, both the side walls and the balcony fronts. The seats on the parterre and on the side balconies have a very light upholstering on the seat but hard backrests. The seats on the rear balcony are very hard, essentially just wooden benches.

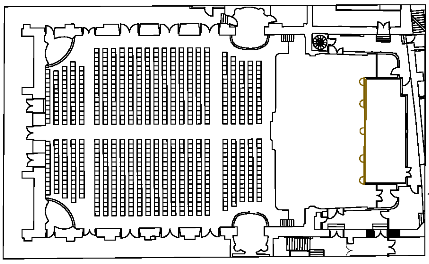

Figure 1: Parterre plan of the Bolshoi Hall

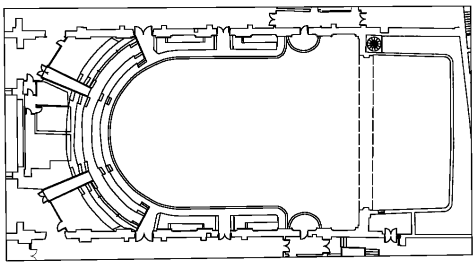

Figure 2: Lower rear balcony plan

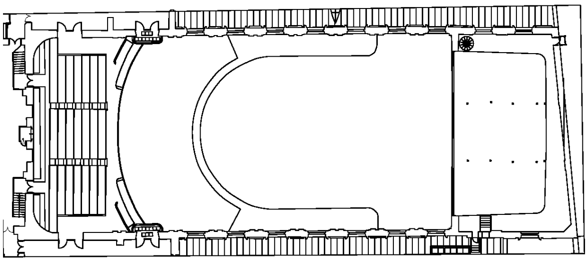

Figure 3: Upper rear balcony plan

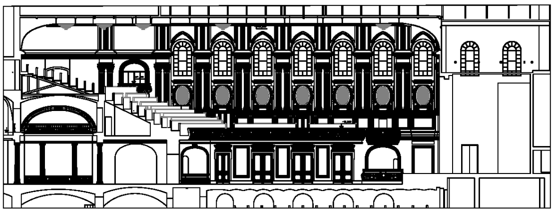

Figure 4: Long section of the Bolshoi Hall

The hall can be seen in the concert-DVD “Horowitz in Moscow” which is recorded in the hall.

Figure 5: View from the rear balcony towards the stage

When comparing the Bolshoi to other great shoebox halls in the world, two distinct features stand out:

- The rear balcony of the Bolshoi Hall extends further from the stage than in any other similar hall
- The proscenium of the Bolshoi hall is more pronounced than in other halls

Figure 6: Side wall of the Bolshoi hall

Figure 7: View towards the rear of the hall

The main purpose of the acoustic design for the renovation of the hall is to preserve the acoustic conditions of the Bolshoi Hall. For this reason no major changes has been proposed.

SUBJECTIVE TESTING

The subjective acoustic quality of the Bolshoi hall was investigated by questionnaires to both an audience listening panel as well as to members of the orchestra during one concert and one rehearsal.

The program for both the rehearsal and for the actual concert was as follows:

- Richard Strauss – “Metamorphoses” for strings
- Bruch – Concert for violin and orchestra
- Brahms-Schoenberg – Pianoforte quartet

The program thus consisted of pieces with the orchestra (State Symphony Orchestra “New Russia”) varying in size. The maximum orchestra size was about 95 musicians.

During the rehearsal it was possible to move around in the hall to listen in different positions.

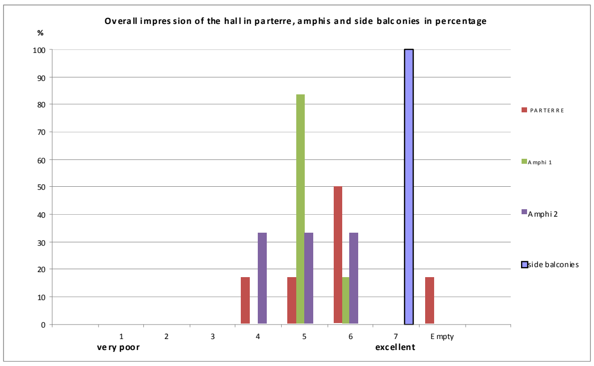

Figure 8: Audience overall rating of acoustics of the Bolshoi Hall

The results showed quite clearly that the acoustic conditions in the Bolshoi Hall are evaluated as good, both from the audience as well as from the musicians’ point of view. Obviously the listening test was done with a limited number of listeners, but also in previous discussions with musicians and concert goers, the evaluation has been almost unanimously positive.

There is a trend that the acoustic conditions on the rear of the rear balcony are not perceived as being as good as in the rest of the hall, but there were too few answers to make any decisive conclusions.

An interesting feature was that the answers from some of the listeners were in some cases ambiguous, with some listeners giving very poor evaluation of some aspects, while still in their comments pointing out the excellent acoustics in the hall. This seems to imply that the listeners were trying to pick the “right” answers to point out or even stress the excellent acoustic conditions in the hall.

As for the answers from the musicians, the questionnaires show no major problems on the stage, but do indicate some aspects that should be further investigated.

So all in all, the survey confirms that the Bolshoi Hall has good acoustics and is greatly appreciated both by the audience and the musicians.

RESULTS OF ACOUSTIC MEASUREMENTS

Background

The measurements in the hall have been done in two rounds: before the design project started the reverberation time of the hall was measured and during the design process a full set a acoustic measurements in accordance with ISO 3382 was done. The ISO 3382 measurements were done using WINMLS and the analysis were done using the Matlab based package called IRMA (documented in [3]).

In addition, the acoustics in the Bolshoi Hall have been investigated by a computer simulation, (ODEON Version 9.2).

The results from the measurements are compared to the simulated results.

Audience parameters

Reverberation time and Early Decay time

The measured unoccupied reverberation time (RT20) with the smallest (Min) and largest (Max) values shown is presented in Figure 9. In the same figure the values achieved by the measurements done by interrupted noise before the project started are shown and also the simulated reverberation time, RT(calc) as well as the measured Early-Decay-Time in the audience (EDT).

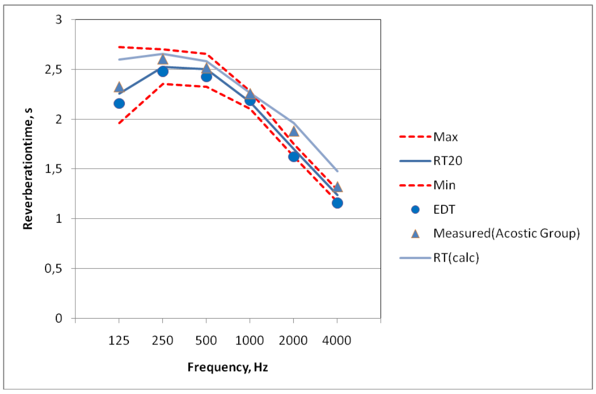

Figure 9: Measured and simulated reverberation time (RT20) with the spread of the results (Max & Min). Earlier reverberation time measurements and Early Decay Time in audience (EDT).

As can be seen, the values are very similar, with the exception of the reverberation time in the 125 Hz octave. The measurements reported by Makrinenko and Lannie in 1988 [1], shows a significantly longer reverberation time in the 125 Hz octave and somewhat longer in the 250 Hz octave. Also the reverberation times measured in the scale model were somewhat longer. There can be a number of reasons for this. First of all it should be clear that the measurement accuracy at low frequencies is not as good as at mid frequencies. This can also be seen by the larger scattering of the measurement results. Also for the measurements in the hall, there was a full orchestra setting of chairs and stands on the stage. Last but not least it is possible that the acoustic properties of the parterre floor have changed over the last 20 years. The floor, both on the parterre and on the stage is currently very “lose” and flexible and it is believed that this has a large influence on the measured reverberation time, at least in the empty hall.

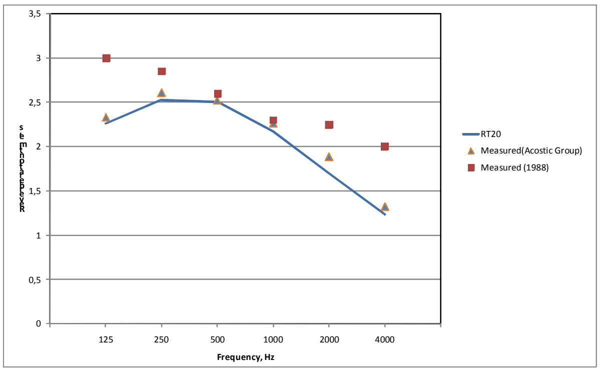

Figure 10: Comparison of reverberation time measurements

In any case when combining the measurement results with the result of the subjective survey in the hall, it is clear that the possible change in the reverberation time is not perceived as a problem.

From stop chords recorded during the test concert, we were able to estimate the occupied reverberation time at mid frequencies to 1,9 s.

It should also be clear that the measured reverberation is in line with the measured reverberation times of all the best concert halls in the world.

Table 1. Comparison of reverberation time of empty halls @ mid frequency

Hall	Seats	RT
Boston Symphony Hall	2625	2,5 s
Concertgebouw, Amsterdam	2040	2,5 s
Usher Hall, Edinburgh	2548	2,0 s
Musikverein, Wien	1600	3,0 s
Sibelius Hall, Lahti	1500	2,4 s
Bolshoi Hall, Moscow	**1737**	**2,4 s**

Energy fractions

The parameters calculated from energy fractions analyzed from the impulse responses measured in Moscow Conservatory Bolshoi Hall are presented in this section. The values for Clarity (C80) and Clarity (C50) are presented in Figure 11. In the same figure the calculated Clarity, C80(calc) is also shown.

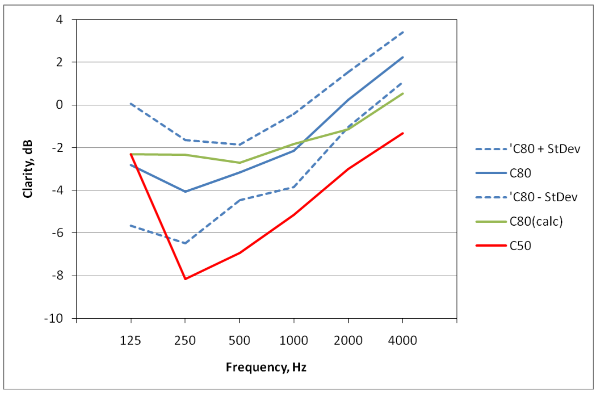

Figure 11: Measured Clarity (C80), simulated Clarity (C80(calc)) and measured Clarity (C50) for Moscow Conservatory Bolshoi Hall (unoccupied).

In general the measured and the calculated values for the C80 parameter show good correspondence. The difference between the measured and calculated values are within the standard deviation for all octave except for the 2000 and 4000 Hz octave.

The mid-frequency C80 is -2,6 dB, which is somewhere in between the values measured in Musikverein, Vienna and Concertgebouw, Amsterdam and the typical C80 values measured in newer concert halls. This makes sense when considering the geometric differences between the Musikverein, Concertgebouw and the Bolshoi hall.

Strength

The objective measure for Strength (G) with minimum and maximum analysed from the measured impulse responses is shown in Figure 12 for Moscow Conservatory. Also the computer simulated value for Strength is shown in the same figure.

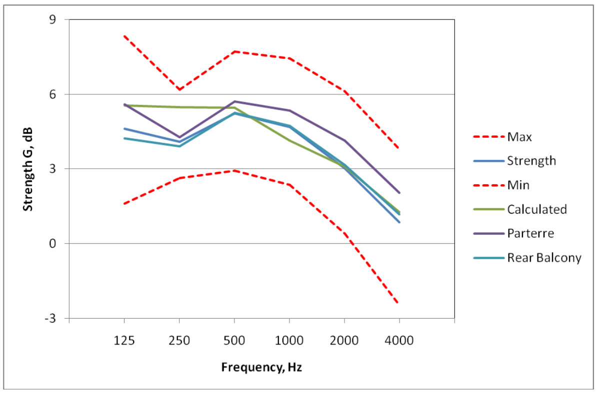

Figure 12: Measured and calculated Strength G for Moscow Conservatory Bolshoi Hall (unoccupied)

The average Strength at mid frequencies is 5,0 dB which in line with what is generally accepted as being ideal for classical concert halls, (normally the ideal interval is considered to be 3-6 dB).

As can be expected, the strength values are somewhat higher in the parterre area, but what is perhaps a bit surprising is that the measured values even in the rear balconies are quite good, with an average difference of only approximately 0,5 dB relative to the parterre area.

Spatial parameters

Parameters for lateral fraction in octave bands from 125 Hz to 4 kHz are shown in Figure 13. The blue line (LF) represents the total lateral fraction for all receiver positions. Additionally the lateral fraction is presented for the parterre and the rear balcony.

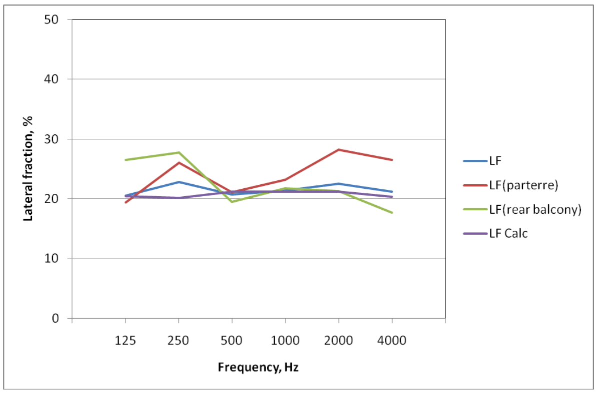

Figure 13: Measured Lateral Energy Fraction for Bolshoi Hall

The spread of the measured values is quite large. It is believed that the main reason for this is the general uncertainty of the measurements system. In general the two channel measurements will show larger spread than energy measurements. Also the values will naturally be much larger close to a side wall compared to in the middle of the floor.

However closer investigations with the computer model have shown that in particular the upper window structures do concentrate energy in some seats, which to some extent explains some of the abnormalities.

As can be seen from the figure, there is however quite good correspondence between the measured and the calculated results.

When combining the measured Lateral fraction parameters with the measured Gearly, one can calculate the Efficient Spatial Impression [2] as between 0,19 and 0,21. This result confirms that the spatial impression in the Bolshoi Hall is very good.

Stage parameters

Early Decay Time on Podium (EDTP)

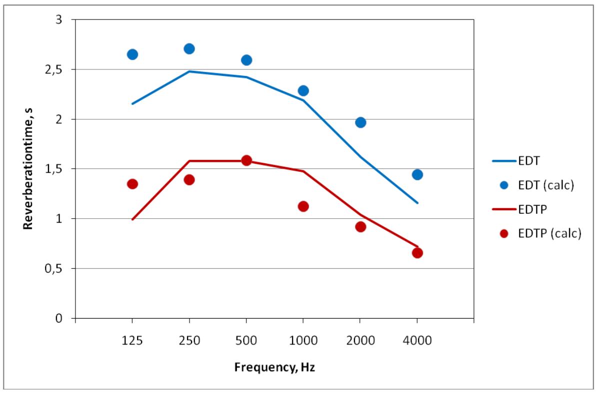

Figure 14: Measured and calculated EDT and EDTP.

As can be expected from a hall with some sort of proscenium structure, the EDTP is significantly lower than the EDT. However when combining this with the musicians responses in the subjective questionnaire, it would appear that this is not perceived as any problem.

Support parameters

In Figure 15 both the measured as well as the calculated results for the STearly and STtotal parameters are presented.

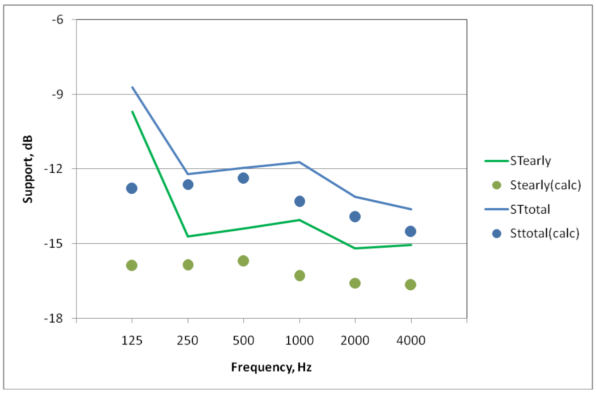

Figure 15 Measured and calculated (calc) support values for the stage in Bolshoi Hall.

The big difference between measured and calculated values at low frequencies, is mainly due to measurement uncertainties. For STtotal, the measured and calculated values correspond quite well, whereas there are some more differences between the measured and calculated STearly values. One explanation is that the STearly values are more sensitive to stage layout, that is amount and placement of orchestra chairs and music stands. This is of course impossible to simulate in a computer model – at least at present -, but measurements will normally be done on a furnished stage. In any case the measured values do not indicate any problems of lack of support on the stage.

CONCLUSION

The measurements and investigations presented in the paper basically show that the Bolshoi Hall of the P.I. Tchaikovsky Conservatory in Moscow has very good acoustics and is quite comparable to the other great halls of the 19th century.

When studying the layout, the hall has however some very distinct differences from the "typical" shoe box halls: a very deep rear balcony and a pronounced proscenium. Both these features could be considered acoustic defects, in particular when taking the sight lines from the rear part of the rear balcony into account.

However, both the measurements and the listening experience in the hall have confirmed that the acoustic conditions in the hall are generally very good and acceptable even on the rear part of the rear balcony.

Also surprisingly neither listening tests nor measurements indicated any major problems with sound projection from the rear stage or balance problems between the rear and the front stage. This merits further investigations.

ACKNOWLEDGEMENTS

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