Buenos Aires – 5 to 9 September, 2016
Acoustics for the 21st Century...

PROCEEDINGS of the 22nd International Congress on Acoustics

Concert Hall Acoustics: Paper ICA2016-320

A comparison of concert hall acoustics before and after renovation

Anton Peretokin, Nikolay Kanev, Natalia Shirgina, Anatoly Livshits

Acoustic Group, Russia, peretok@yandex.ru

Abstract

The aim of the report is to introduce the results of extensive study of concert Hall's acoustics before and after renovation. The study deals with objective and subjective acoustic measurements. Objective assessment is based on the detailed analyze, measurement and comparison of acoustic characteristics before and after renovation. Subjective assessment is based on the collecting and analyzing opinions of artists, teachers, professors and audience. Reported results were obtained by a long-term thorough study of Halls' acoustics used for classic music concerts. The Halls were built more than one hundred years ago and seriously renovated in last five years. A special attention of renovators was given to the maintenance of floors, ceilings and walls constructions, decoration materials. Every renovation phase was studied in detail.

Keywords: concert halls, chamber music halls, acoustic measurements

A comparison of concert hall acoustics before and after renovation

1 Introduction

Saving of the cultural heritage is one of the main tasks nowadays. Concert Halls have a great value for world's culture. That is why it's so important to save them for future generations. The importance of concert halls is not only in splendid architecture and rich history but also in their unique acoustics. Exploitation of any concert hall requires renovation on regular intervals. During the renovating process, it is very important to save both architectural and unique acoustical criteria.

3 unique Halls of Moscow Conservatory were renovated in 2011 – 2016: Great Hall and 2 chamber halls – Maliy (Small) Hall and Rachmaninov Hall.

The monitoring of concert Halls acoustics was carried out before and after renovation.

2 Halls description

The research covers 3 halls of Moscow Conservatory – Great Hall, Maliy Hall and Rachmaninov Hall.

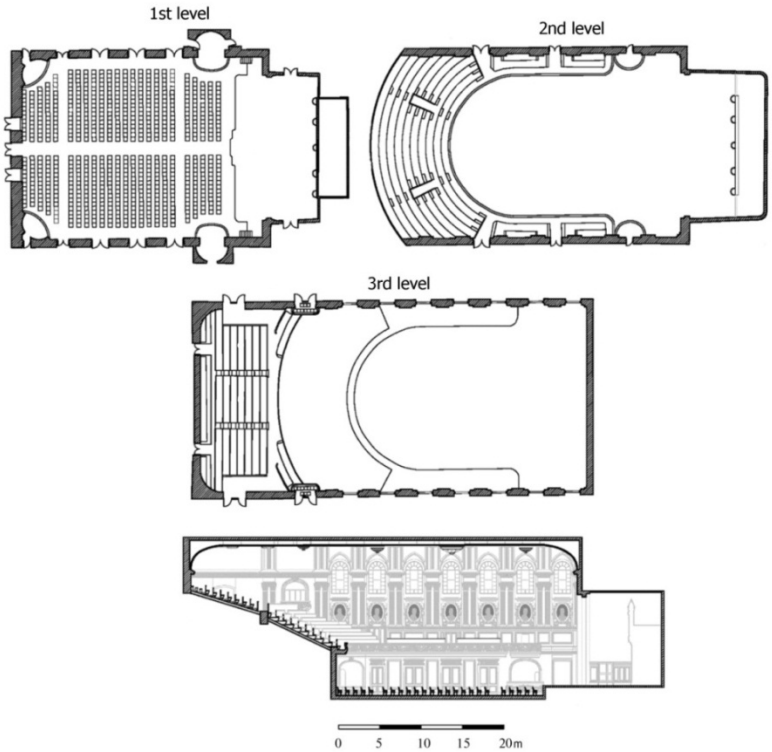

Figure 1: Great Hall

The Great Hall is the most famous and popular concert hall in Russia. It is located in the building designed by architect V.P. Zagorsky. The grand opening of the Hall was held on April 7, 1901.

The Hall has the classic rectangular shape, often called a shoebox. It is a feature of concert halls built in the second half of the 19th and the first half of the 20th centuries [4]. The plans and longitudinal section of the Hall are shown in Figure 1. The Hall has balconies along the longitudinal walls at the level of the first tier of the amphitheater. On stage, there is an organ, which almost completely overlaps the front wall of the stage space. There are 1737 seats. In the orchestra stalls there are chairs with soft seats and backs, and on the balcony there are wooden benches with hard backs. The volume of the hall is 15700 m^3. The specific volume per listener is 9 m^3.

The ceiling of the Hall is flat and made of softwood boards attached to a wooden frame with offset from the camp ceiling. Linen fabric is glued to the ceiling boards. The surface of the fabric is puttied and painted. The joint of the ceiling and walls forms a quadrant vault with a curvature radius of approximately 3 m. The walls of the Hall are made of mortared brick and covered with decorative molding. There are several windows in each side wall. The floor of the orchestra pit is made of block oak over a solid floor of pine boards on logs. The floor of the amphitheater is made of planks fastened to the wooden frame of the supporting structure of the amphitheater.

Maliy Hall was built and opened in autumn of 1898 [5]. There is an organ which was installed in 1959. Today the Hall is usually used for concerts of chamber and organ music.

Maliy Hall has the rectangular shape. The Hall has a balcony, which is located near rear wall. The plans and longitudinal section of the Hall are shown in Figure 2. There are several windows in rear side wall. There are 436 seats. In the orchestra stalls there are chairs with soft seats and backs, and on the balcony there are wooden benches with hard backs. The volume of the Hall is 2800 m^3. The specific volume per listener is 6.4 m^3.

The ceiling of the Hall is flat. The joint of the ceiling and walls forms a quadrant vault. The construction of celling has a form and properties like the Great Hall. The walls of the Hall are made of mortared brick and covered with decorative molding. The floor of the orchestra pit is made of block oak over a solid floor of pine boards on logs. The floor of the balcony is also made of block oak.

The oldest concert hall of the Moscow Conservatory is Rachmaninov Hall. It was built in 1890 for Moscow Synodal School. In 1968, the Hall was affiliated to the Moscow Conservatory and reopened in 1983 after long renovation [5]. The Hall was opened by concert of the famous Russian pianist Svyatoslav Rikhter.

Rakhmaninov Hall has the rectangular shape (shoebox). There is a balcony without seats along all walls. The plans and longitudinal section of the Hall are shown in Figure 3. The Hall is very beautiful due to many windows and elegant decoration of the ceiling and walls. There are 252 seats, which are located only in the orchestra stalls. There are chairs with soft seats and backs. The volume of the Hall is 2500 m^3. The specific volume per listener is 9,9 m^3.

The ceiling of the Hall is flat and made of softwood boards attached to a wooden frame with offset from the camp ceiling. Celling construction consists of wooden boards which are plastered and painted. The walls of the Hall are made of mortared brick and covered with

decorative molding. There is the decorative balcony balustrade. The floor of the orchestra stalls is made of block oak over a solid floor of pine boards on logs. The floor of the balcony was covered by wooden boards attached to a wooden frame of balcony construction.

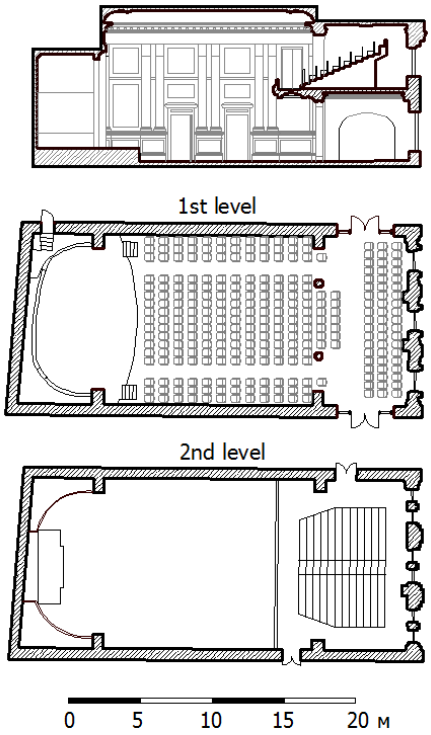

Figure 2: Maliy Hall

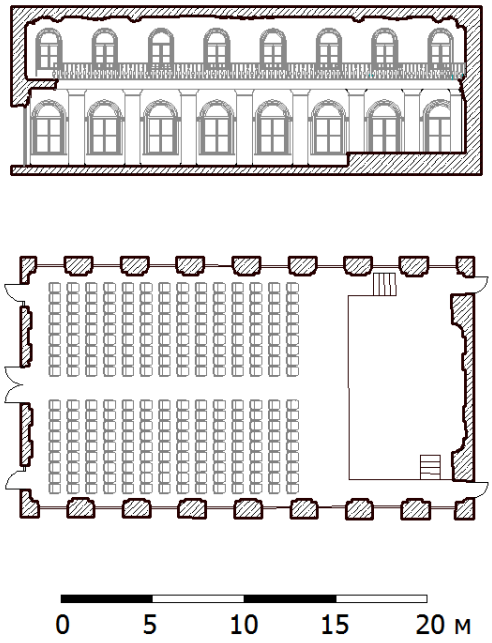

Figure 3: Rachmaninov Hall

3 Halls renovation

Some time ago, it appeared that the Moscow Conservatory Halls' condition did not meet the requirements for their normal exploitation. Halls' supporting structure was in wrecking condition, the ventilation system did not provide necessary air exchange, and the interior decoration needed a significant renovation. A large-scale renovation of the building of the Moscow Conservatory was planned for the period of 2011-2016. Our research team had been monitoring the process of renovation during all that period. The main task was to save the unique acoustic of the Halls. The project did not include changes of the lay-out concept and in general the interior decoration has been saved. The renovation activities which could impact on acoustical characteristics of the Halls are listed below.

The renovation of the Great Hall was held in period of 2010-2011. Ceiling of the Hall, which is constructed from wood planks fixed on wood beams, had been kept in a satisfactory condition. Only changing of some planks was needed. The primer coat and leveling filler coat which is reinforced with the linen cellular textile have been applied on the planks surface. The cloth has been exchanged for the cloth of the same kind, stuck to the planks, and painted. The walls of

the Hall and its stucco molding have only been renovated without changing any finish materials except for the final coat of putty and paint. Supporting structure of amphitheater was in wrecking condition that is why it has been completely replaced. A new supporting framework for the spectators seats has been made out of laminated beams. Amphitheatre floor covering has been performed out of glued board laid on wood rails. Flooring is an oak block parquet stuck on a glued board. In the structure of parterre floor the beams have been remained on which the planks with the surface of oak block parquet have been laid. Parterre chairs and balcony benches have been made from scratch but strictly in accordance with the original model. Reverberation index of sound-absorbing of the old and new types of seats are shown in the Figure 4. Acting space conception has been partially changed. The organ and its location has been remained without changes but the high of the wood panels which trim the walls of the stage has been reduced up to 2.8 meters starting from the stage floor level. The walls above the wood panels have been plastered and painted. Construction and material of the new teaser and box curtains have been selected to be at the most corresponding with the original. The same is for the carpet in the stalls aisles.

The renovation of the Maliy Hall was held in the period of 2014-2015. For the ceiling of the Maliy Hall, the renovation work that has been done is equal to the one in the Great Hall. During the work with the ceiling, a painting has been found under the paint layer and has been restored. The walls of the Hall and its stucco molding have been renovated with the only replacement of the final coat of putty and paint. The equal renovation has been done on the balcony but the vents for diffusers have been drilled in lateral of the balcony fence. Balcony platform has been renovated with partial replacement of worn-out elements. Classical chairs have been substituted for folding seats in the stalls. Seats on the balcony benches have been changed. Reverberation index of sound-absorbing of the old and new types of seats are shown in the Figure 4. The decoration of the stage has been partially changed as in Great Hall. The height of the wood panels, which trim the walls of the stage has been reduced up to 2.8 meters starting from the stage floor level. Carpets in the aisles have been abolished.

The renovation of the Rakhmaninov Hall was held in the period of 2015 – 2016. Ceiling plaster and its stucco molding elements have been renovated with partial replacement and then painted. The walls of the Hall and its stucco moldings have been renovated with the only replacement of the final coat of putty and paint. The old windows have been substituted for the new ones with the same thickness. Besides, fixing system for the new glass in a window frame has been improved. In the structure of the stalls and balcony floor, the beams have been remained and the planks with the surface of oak block parquet have been laid. Debris from the beams gap has been changed for the expanded clay filling. The structure of the balcony floor has been changed, the old planking has been renovated and the parquet strips have been laid on top. The old chairs have been substituted for the new ones with the sound-absorbing characteristics showing in Figure 4. The system of input ventilation from the backside has been moved to the lateral wall. For the purpose of fastening of the light equipment the new metal banisters have been set up on the balcony in addition to the current fence. Carpets in the aisles and in front of the stage have been abolished.

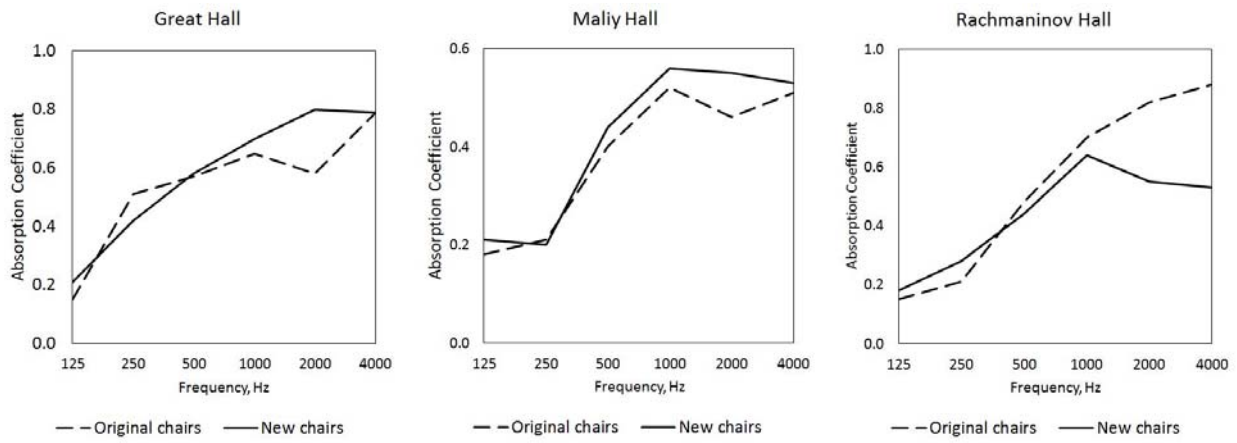

Figure 4: Chairs sound absorption coefficient

4 Measurement of Halls acoustical parameters

Measurements of acoustical parameters were made in the halls before and after renovation. The first measurements were made within six months before renovation launching. Measurements after reconstruction were made immediately after renovation ending.

Reverberation time RT (T_{30}), early decay time EDT and musical clarity index C_{80} were used for evaluation of hall's acoustics [1].

Figure 5 shows values of RT, EDT and C_{80} measured in Great Hall. The values of acoustical parameters were averaged for all seats in the Hall. The measurements were made according to [3], with the use of omnidirectional sound source (dodecahedron) placed on the stage in several positions.

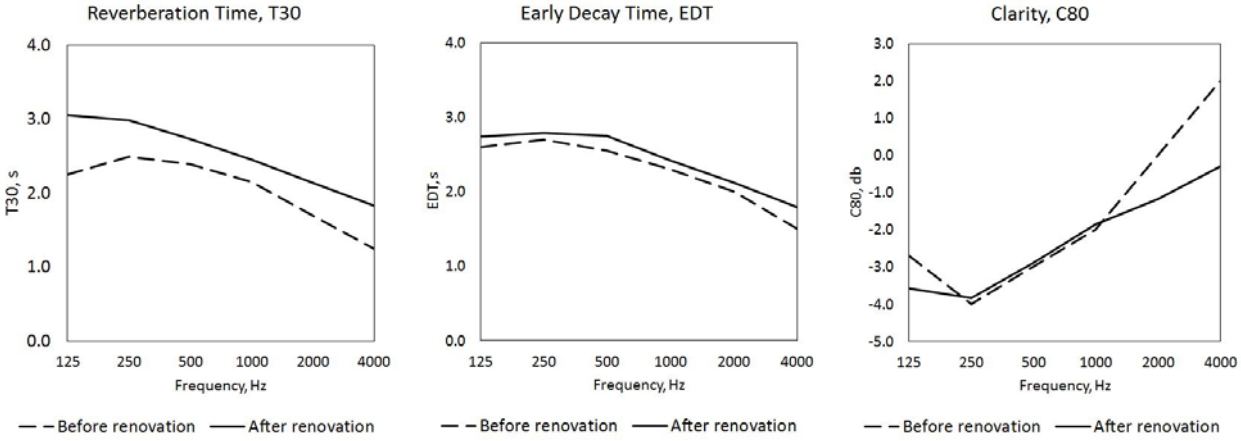

Figure 5: Acoustical characteristics of Great Hall

RT after renovation was higher in the entire frequency range than RT before renovation. At low frequencies (125 Hz) it increased by about 35%, at a high frequency (4000 Hz) it increased by

45%, and in the frequency range of 250–2000 Hz it increased by approximately 10-15%. The balance of low frequencies, determined by BR (base ratio) was 1.16, while prior to the reconstruction was 1.07. Value of EDT also increased but not essentially. Musical clarity index C_{80} at frequencies 250–1000 Hz hardly changed at all. But at the low and high frequencies, there is a decrease of C_{80} by about 2 dB, which correlates with the increase of the reverberation time at these frequencies.

Figure 6 shows values of RT, EDT and C80, which were measured in Maliy Hall. The values of acoustical parameters were averaged for all seats in the Hall. The measurement was made according to [3], also with the use of a dodecahedron placed on the stage in several positions.

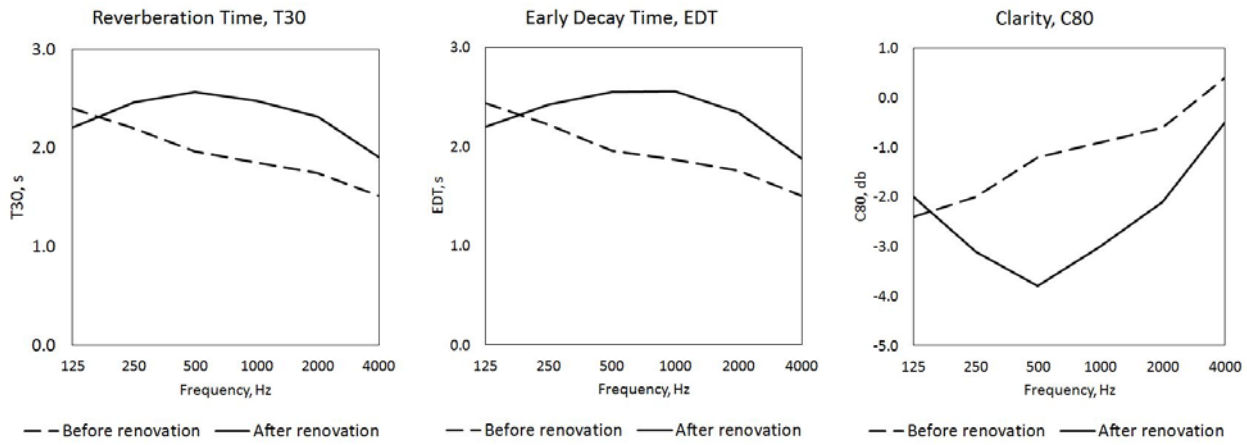

Figure 6: Acoustical characteristics of Maliy Hall

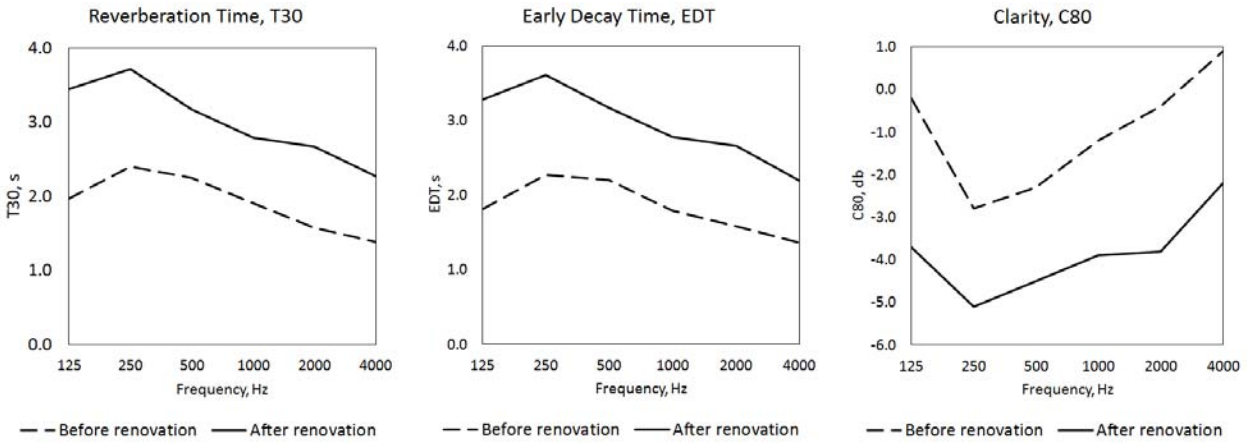

Figure 7: Acoustical characteristics of Rachmaninov Hall

The biggest increase of RT value achieved 0.6 s. In the frequency range of 500 – 2000 Hz it increased by approximately 30%, at a high frequency (4000 Hz) it increased by 25%. At a low frequency (125 Hz) RT value decreased by 9%. The BR before renovation was 1.2, while prior to the reconstruction it was 1.0. Value of EDT was also changed as a value of RT. Musical

clarity index C_{80} in the frequency range of 500 – 2000 Hz was decreased by 2 dB, that can be explain by growth of reverberation time.

Figure 7 shows values of RT, EDT and C_{80}, which were measured in Rachmaninov Hall before and after renovation. The values of acoustical parameters were averaged by all seats of Hall. The maximum increasing of RT was fixed in Rachmaninov Hall and achieved 1,4 seconds. The meaning of RT was changed approximately for 50-60%. BR achieved 1,2 while prior the renovation its meaning was 1.05. The values of EDT parameters and C_{80} also changed significantly. The main reason of such changes is a significant increasing of RT.

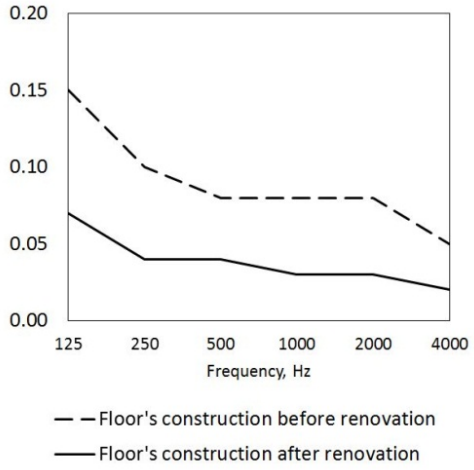

Figure 8: Floors sound absorption coefficient

Suppose that sound absorption characteristics of ceiling and walls in Rachmaninov Hall changed negligibly, we can assume that the reason of RT increasing is in the changing of floors construction and chairs. First and foremost, the changing of sound absorption characteristics is connected with upgrading of a deal floor and changing its stiffness.

Figure 8 shows the graph with approximately values of floor sound absorption calculated with computer model. The calculation was made for unoccupied Hall taking under consideration the changed chairs. According to the graph, floor sound absorption coefficient grown twice. The reason of such changes is a shabby floor construction and decreasing of its stiffness. Floor characteristics significantly changed during the time of exploitation till the moment of renovation in 2015. Such changings lead to RT decreasing in the Hall.

The measurements were also made in 2 full audience Halls: Maliy Hall and Rachmaninov Hall [2]. The occupation of Halls was approximately 70%. Figure 9 shows the results of these measurements. The RT values for occupied Halls before renovation were calculated by computer models.

Measurements before and after renovation show that the RT in unoccupied Halls is significantly higher than in the full audience Halls. Thus, the significant changes of acoustic parameters in unoccupied Halls are leveled with audience. So in the occupied Halls acoustic parameters changes are insignificant. RT on mid-frequencies (500 and 1000 dB) in occupied Maliy Hall increased on 10-15% and in Rachmaninov Hall – approximately on 10%.

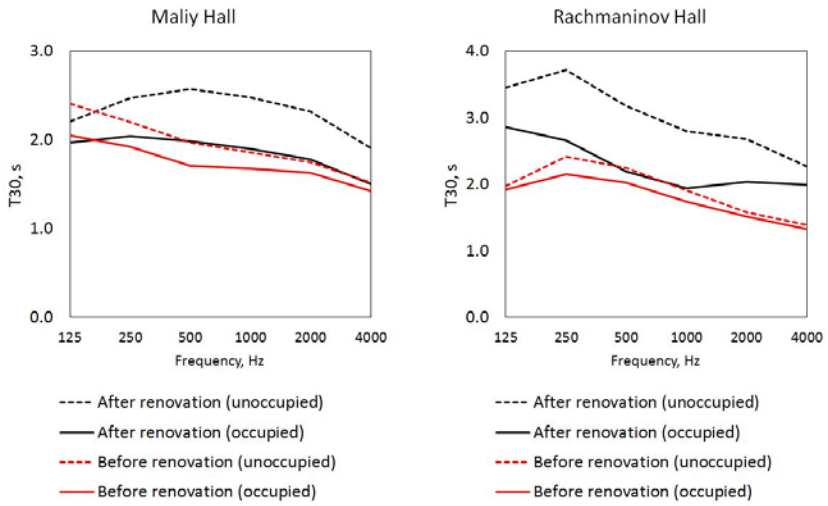

Figure 9: A comparison of values RT in occupied and unoccupied Halls

5 Subjective opinions about hall's acoustics

Concerts in the Great Hall after renovation made it possible to obtain the first subjective evaluations of its acoustics. The remarks of some musicians who performed in the hall are cited.
Dmitry Khvorostovsky, baritone: "The renovated Great Hall of the Conservatory is an acoustically excellent Hall. The sounding of the voice there became livelier, an unrestricted sound distribution is felt when singing".
Vladimir Fedoseev, Chief Conductor of the Moscow Radio Symphony Orchestra: "A hall with excellent acoustics, but after renovation it has become more demanding to the performers".
The first concert in Maliy Hall was held in the memory of Elena Obraztsova. It started with an opening speech of the Moscow Conservatory President. He defined the Hall's acoustic as perfect.
There are several remarks regarding the acoustic in Maliy Hall from musicians and professors:
Hibla Gerzmava, soprano: "I'm happy to sing in new Maliy Hall. The "piano" is sounded gorgeous. Acoustic is amazing".
Alexey Shmitov, organist and pianist, professor of the Moscow Conservatory: "Maliy Hall became louder and more exacting to singers and pianists. At the same time acoustic became more comfortable for organ music".
The first concert in Rakhmaninov Hall after renovation was conducted by famous Russian pianist Denis Matsuev. He said he had liked Rakhmaninov Hall since university time.
He said: "The Hall's acoustic after renovation is the same as in the past".
The majority of surveyed listeners said that all Halls after renovation became better in acoustic terms. According to some reviews, at full capacity it sounded like a beautiful musical instrument.
The marked improvement in the Halls' sound (according to subjective evaluations) can physically perceived because of the increase in the reverberation time and low-frequency balance.

6 Conclusions

In spite of all attempts to save most of building constructions and to make minimum external changes, the acoustical parameters of all 3 Halls significantly changed after renovation. For example, the reverberation time in Rakhmaninov Hall increased approximately by 75%. The main reasons of changes of sound absorption characteristics are:

1. Renovation of decorative shabby elements, elimination of slots and splits on the walls.
2. Increasing stiffness of flexible structures – floors, windows, ceiling decks. Changing of old shabby boards.
3. Elimination of nailed connections and their substitution on self-drilling compounds.
4. Replacement of old chairs for new ones with another sound absorption coefficient. Using of new curtains and elimination of carpets.

It should be noted that over time, there may be some changes in the acoustic parameters of the Halls, primarily because of stabilization of the temperature and humidity in the Halls, elapse of the first rapid aging phase of individual building materials (paints, fillers, adhesives, and primers); release of excess moisture from wooden structures, cement-sand screeds, and concrete; and final nail fixation and lapping of self-drilling compounds in wooden structures.

We can suppose that acoustic parameters of all 3 Halls after renovation became closer to initial historical values which the halls had more than 100 years ago. During the exploitation, Halls' acoustics will be getting close to the values they had before renovation. It happens due to deterioration of new materials. It will be a long-term period as new materials are stronger and more long-living than materials, which were used there originally.

Reference

[1] Beranek, L. *Concert Halls and Opera Houses: Music, Acoustics, and Architecture*. Springer, NY (USA), 2nd edition, 2004.

[2] Hidaka, T.; Nishihara, N.; Beranek, L. Relation of acoustical parameters with and without audiences in concert halls and a simple method for simulating occupied state. *Journal of the Acoustical Society of America,* Vol. 109, 2001, pp.1028-1042.

[3] ISO-3382. *Acoustics—Measurements of the Reverberation Time of Rooms with Reference to the Other Acoustical Parameters* Geneva, 2009.

[4] Kanev, N.; Livshits, A.; Möller, H. Acoustics of the Great Hall of the Moscow State Conservatory after Reconstruction in 2010-2011. *Acoustical Physics*, Vol. 59(3), 2013, pp.361-368.

[5] Fadeev, A.; Kanev, N.; Livshits, A.; Nechaev, A.; Peretokin, A.; Pimenov, E.; Rodenkov, V.; Shirgina, N.; Acoustics of new and renovated chamber music halls in Russia, Room and Building Acoustics. *Proceedings for the International Congress on Acoustics*, Buenos Aires, Argentina, September 5-9, 2016 (submitted).