ACOUSTIC PROPERTIES OF AN OLD STONE ATRIUM USED FOR CONCERTS

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ABSTRACT

One of the most famous old buildings often used for concert purposes in Dubrovnik is the "Knezev dvor". Its atrium, where the concerts take place, has specific acoustic characteristics: there is no ceiling while the materials of which it is built are highly reflective. Accordingly, despite of the space liveness, there are no strong late reflections. A series of ETC measurements have been carried out to confirm the results obtained by a 3D sound pressure distribution simulation. The results of speech intelligibility, clarity and definition measurements for some characteristic positions showed specific acoustic properties due to strong reflections from walls and floor.

INTRODUCTION

"Knezev dvor" ("Lord's palace" in English) is a very famous old building in Dubrovnik built in the gothic and renaissance style. It was the governmental center of the historic Republic of Dubrovnik. Placed in the Old town of exquisite beauty, it gives a special feeling of historic envelopment to the visitor. It's stone atrium in nowadays often used for music events.
The plan of the atrium is shown in fig. 1. The whole palace is built of stone and hard lime plaster. Only exceptions are some wooden doors. The floor of the atrium is made of glazed stone blocks. There are stairs leading to the galleries on the first (fig. 2 left) and the second floor (fig. 3), which is at double height of the first floor. The structure of the atrium is very complex, with numerous vignettes such as columns of different dimensions, column capitols, stuccos, etc. This complex structure contributes to the diffuseness of sound. Vertical walls are mostly smoothly plastered while some parts are made of stone. During the music events, simple wooden seats are placed in the atrium and on the galleries. There are usually less seats then visitors, so there are a lot of standing people on the stairs and galleries. There is no ceiling in the atrium (except the sky), which influences the acoustic a lot as well as the overall impression of the atrium, mostly because of the variable lightening.
The main music events held inside the atrium are soloist (piano up to quartet) and orchestra concerts (even symphonic orchestra). In the case of soloist concerts, musicians are placed near to the main staircase in front of the fountain (fig. 2), sometimes beneath the base of the fountain (guitar concerts) as well as beneath the angel statue at the entrance of the "Knezev dvor". When the orchestra becomes larger, the musicians are placed on the centre of the floor. An interesting change of sound impression happens when it begins to rain during a concert; all

musicians change the position and hide beneath the portico of the atrium, thus being closer to highly reflective walls which change the sound of the orchestra, specially at lower frequencies. There are 290 sedentary places in the atrium, 20 more on the gallery on the first floor. Usually about 200 visitors are standing during the event, but when there is a very interesting concert, even 600 and more visitors can stand inside the atrium.

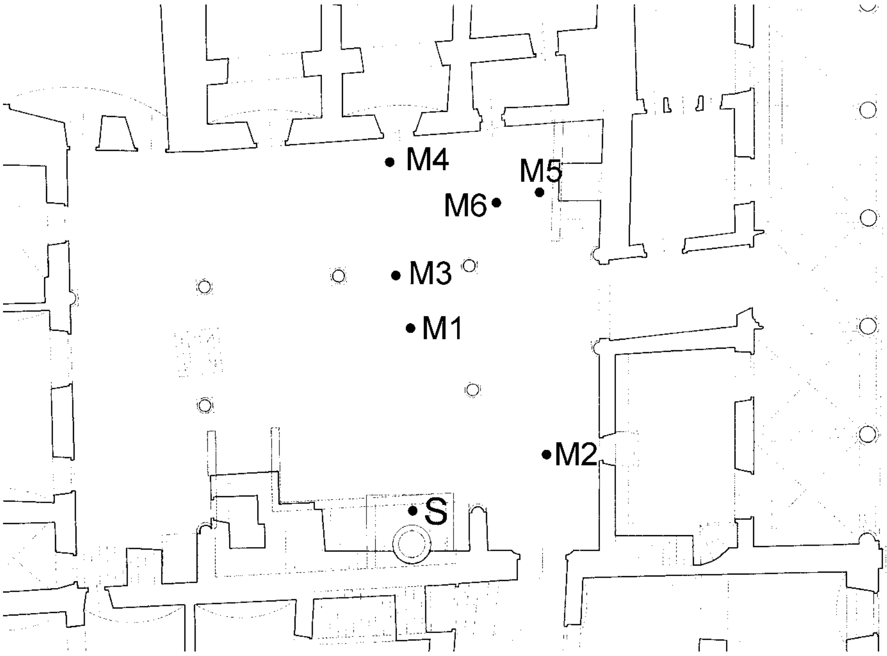

Fig. 1. Plan view of the atrium's ground floor.

Fig. 2. Left - back view of the atrium (with public chairs) with the gallery on first floor. Right - left side of the ground floor, at left there is the main entrance.

Fig. 3. Left - front view of the atrium with the fountain and stairs leading to the galleries on the second floor; Right – second floor of the atrium

MEASUREMENTS

Scope of the measurement

The goal of this paper was to measure some acoustic parameters of the atrium, specially the reflective behavior of the complex stone structure. It was obvious that not all places where the visitors usually stand or seat are equally "good" in terms of subjective quality listening. A series of Energy-Time Curves have been made to confirm this. Intelligibility measurements were made an the clarity and definition parameters were calculated.

Previous investigation

Prior to these measurements, a simulation of reverberation time for this atrium was made. It was supposed that a half-filled atrium equals 300 visitors and a full atrium equals 500 visitors. The results of the simulation can be seen in fig. 4.

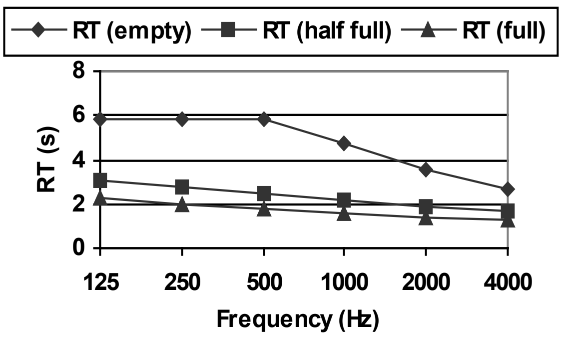

Fig. 4 Reverberation time simulation for the atrium.

Likewise, a simulation of sound pressure distribution was made in order to show the uneven distribution of sound pressure inside the atrium because of the complex structure of the building interior, [1, 2]. The simulation was based using the virtual source method and 3D Max software for visualization. The simplified simulation model, consisting of 325 triangles, is shown in fig. 5. Only the ground floor of the atrium has been considered because the reflections from the upper galleries do not contribute much in the sound pressure distribution on the ground floor.

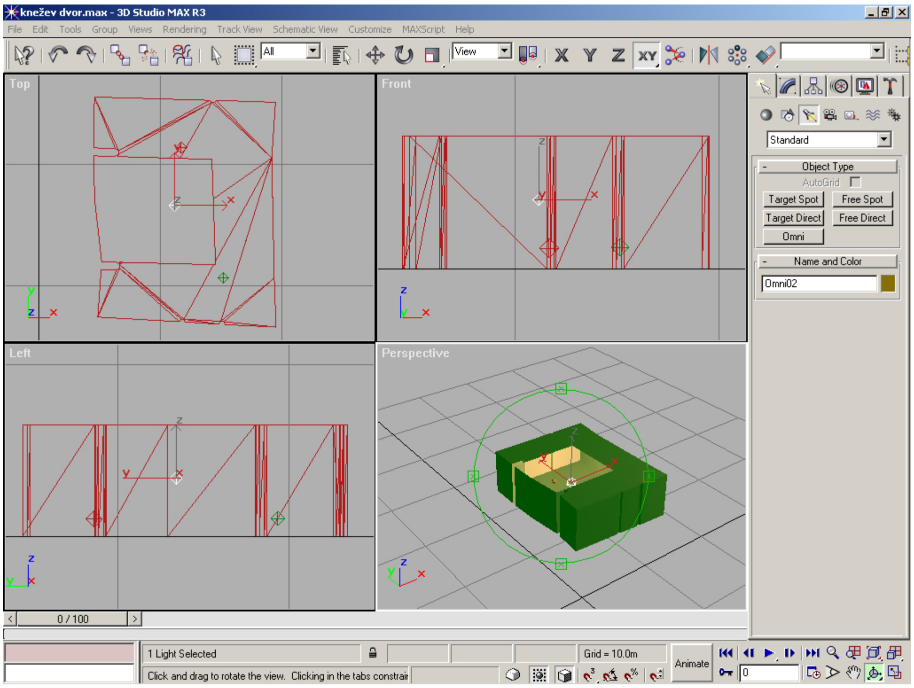

Fig. 5. The simulation model, three views and 3D model.

The results of the simulation are shown in fig. 6. The simulation was made for 250, 1000, 4000 Hz and it shows that at every frequency a different patter of the SPL distribution occurs. The SPL levels are shown in shades of grey (lighter means higher SPL).

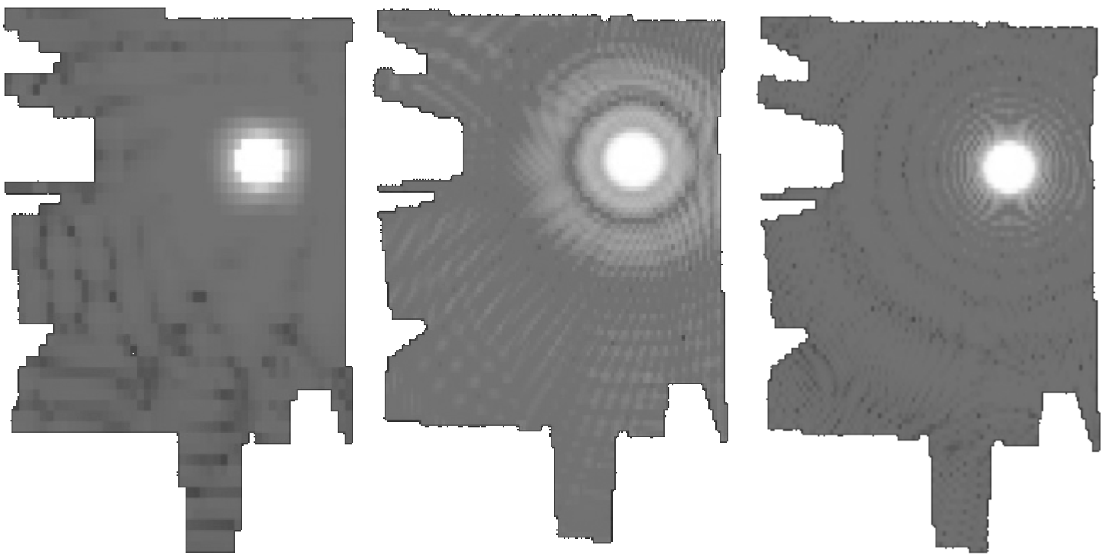

Fig. 6. SPL distribution for frequencies: 250, 1000 and 4000 Hz (left to rigt).

<u>ETC measurements</u>

ETC measurements were made on characteristic spots in the atrium to investigate the reflective behavior of the walls and floors and to measure ALCons, Rasti, C and D parameters, [3]. The measuring positions are marked on fig. 1 (M1 – M6). Measuring positions M1, M2 and M6 are on the ground floor of the atrium, and M3, M4 and M5 on the second floor (the marked spots

present their projection on the ground floor). The sound source was always positioned in front of the fountain which is the usual place for musicians (marked with "S").
Some typical problems of the acoustic of the building can be seen in fig. 7. Both measuring positions were on the floor of the atrium, M1 is an "ideal" listening position far away from any wall. Nevertheless, there is a strong, close reflection after the direct sound from the ground which is highly undesired. An even worse situation is shown on the right ETC because M2 is near the left wall and the near reflection is almost the same size as the direct sound.

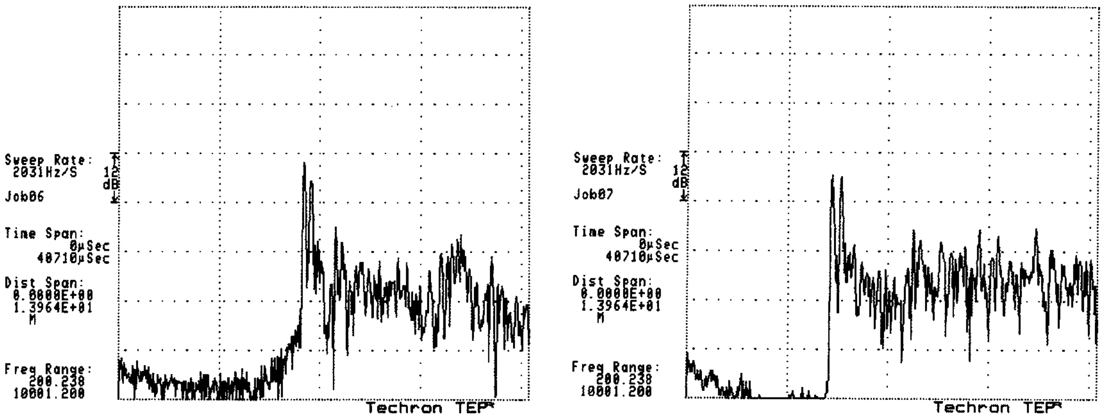

Fig. 7. Left - ETC on M1, Right - ETC on M2.

Fig. 8 presents two ETC curves measured on the first floor of the atrium (fig. 1). M3 is measured for a standing position next to the balcony. There are of course strong reflection from the surrounding walls that are unavoidable, but the direct sound is much bigger then the rest of the reflections. Measuring position M4 shown on the right represents a listener sitting near to the back wall of the balcony. It is an acoustically very bad situation with numerous strong reflections.

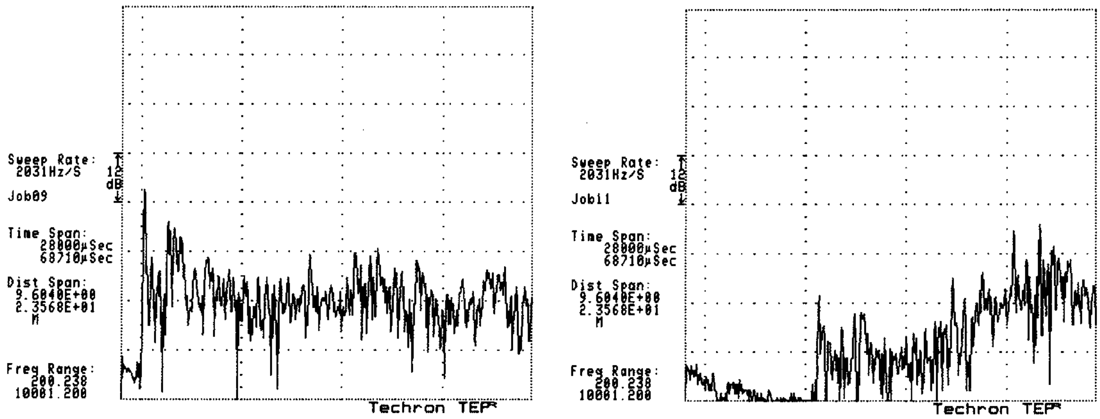

Fig. 8. Left - ETC on M3, Right - ETC on M4.

Some interesting information can be obtained from fig. 9. M5 represents a sitting listener of the first floor near to M4. The ETC curve shows the lack of the direct sound and very strong early reflections. 3D TDS (Time Delay Spectrometry) curve on the right shows the decay of sound with time. At higher frequencies sound energy decays much quicker because of the absorption in the air and the absorption of the walls and floor (although small). At lower frequencies, this decay is much smaller. Therefore, the results of the intelligibility are bad, as well as the C and D parameters, table I.
Fig. 10 shows a much better situation. The measuring position M6 is on the ground of the atrium, the direct to reverberant energy is not so bad and the acoustic parameters measured on this spot (table I) show that this position gives a better listening impression. Nevertheless, a strong comb filter effect can be seen on the 3D TDS diagram because of a strong early reflection (ETC curve). This is not the case with M5.

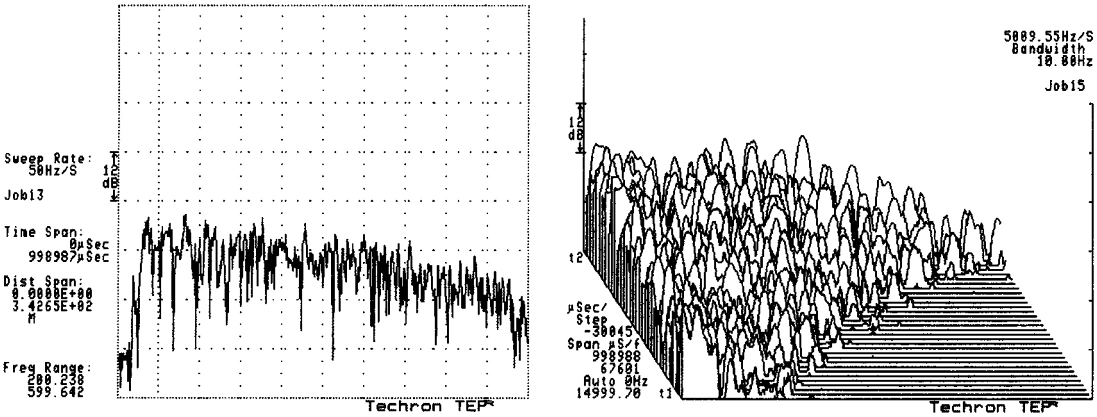

Fig 9 Left - ETC on M5, time window changed, Right - 3D TDS of M4.

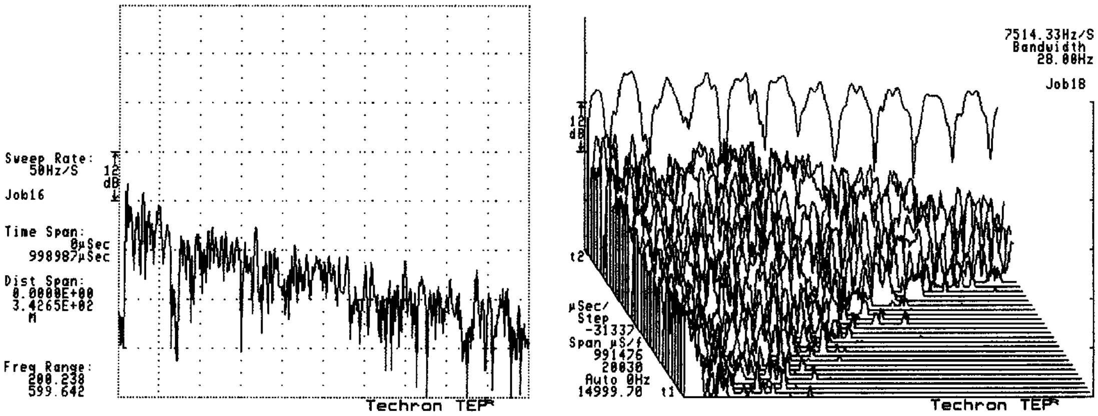

Fig. 10. Left - ETC on M6, time window changed, Right - 3D TDS of M6.

Table I Acoustic parameters of two characteristic measuring positions.

Position	AlCons	Rasti	C	D
M5	18,68%	0,408 poor	-7,07 dB	-7,85 dB
M6	5,89%	0,621 good	2,86 dB	-1,81 dB

CONCLUSION

This paper gives several conclusions. The best listening positions correspond to a good direct to reverberant energy ratio. Positions in the atrium near strong reflective surfaces have low intelligibility, the sound image is blurred and there cannot be a correct localization of the orchestra instruments. The simulation has showed that places nearer to the walls have much more interference which was also observed with the ETC curves.

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