Proceedings of the International Symposium on Room Acoustics, ISRA 2010

29-31 August 2010, Melbourne, Australia

The acoustic design proposed for a church's transformation into auditoria

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PACS: 43.55.Fw; 43.55.Ka; 43.55.Nd

ABSTRACT

It is a common way in Europe to transform dismissed buildings into auditoria, especially for musical performances. In Italy there is a lack of concert halls specially designed for music, due to the historical tradition of Opera. Therefore, a strong request of concert halls requires converting more building than in foreign Countries. Among all, in Italy there are a large number of churches that cannot be used for their original purposes (i.e. messes or religious meetings) and due to economic reasons they require to be transformed into auditoria. In this paper an ancient church (which dates back to 16th Century) located in Imola (30 km far from Bologna), which is planned to be converted into Auditorium, is analyzed. The church is already utilized for musical performances but the acoustics requires to be improved. A measuring campaign was carried out by means of binaural and 3D microphones and omni-directional loudspeaker. The measurements were finalized to relate sound quality to different configuration of acoustical panels and sound source position in the stage. In the following step, an acoustic design was realized and proposed for the refurbishment of the church. The results of the measurements and of the simulation are presented.

INTRODUCTION

The church of San Domenico in Imola has a long and troubled history, as the adjoining couvent. The first construction in Gothic style was realised from 1280 to 1374. In 1636 a big lateral chapel, in Baroque style, was built. From 1702 to 1718 the inside of the church was interely refurbished in the actual morphology: single aisle and long presbytery covered by vaults, transept covered by a fake dome and lateral chapel.

There's a lot of churches in the centre of Imola and a few priest, so that church is often closed to public; sometimes it's used for musical performances. So isn't superfluous to think another destination for some of those buildings.

Planning to transform the church into auditoria, the acoustic should be improved without destroing the historic and artistic testimonies who are located inside of it.

THE HISTORY

The Dominican community settled his first conventual nucleus in the city of Imola since 1249 in the area were is situated the actual church, which was near an old chapel. In 1280 an earthquake damaged that chapel, so the monks built another church in correspondence of the actual church, from the apse to the actual transept. At the same time the convent was enlarged because of the increasing of the number of monks. The church was soon too small for the church-going people, and therefore in 1303 Pope Benedict XI allowed to enlarge the church, which was completed until the actual front (Figure 1) in 1374. In that period the church was divided for an internal pier in two parts, one for the monks and the other for the church-going people.

Figure 1. The main portal of the church (XIV century)

After that and until 1638 only the convent was enlarged and refurbished. In that year the pier who divided the two churches and some small lateral chapels to allow the construction of a big chapel aside the transept with an elliptical dome, in Baroque style, was pulled down. Afterwards, from 1702 to 1718 the inside of the church was interely refurbished in Baroque style.

After Napoleonic invasion (1797), the convent was used as barrack, jail, artisan workshop, so was partly pulled down and rebuilt; today, after a further refurbishment, it's the town seet of the museum and picture gallery.

Figure 2. The inside of the church (1718)

Differently from the convent, the church was abandoned and restored, but it didn't change from 1718 until now (figure 2).

ACTUAL ACOUSTICAL QUALITY

Experimental measurements

The acoustical quality of the church was measured by the following instruments:

- an equalised and omni-directional loudspeaker
- a dummy head (Neumann)
- a Soundfield microphone (MK V)
- a Personal Computer linked to loudspeaker and receivers.

Figure 3. Image of the measurement instruments used within San Domenico in 2008

The measurements were conducted by means of a logarithmic sine sweep, ranging between 40 Hz to 20 KHz. The signals acquired by the microphones were stored in a 20 bits 96 kHz sample rate soundboard (Layla), and then post processed in the laboratory.

To represent carefully tha acoustic behaviour, the loudspeaker was located in two different positions (the transept and the presbytery) aside the median apse to avoid focal effects. In that way yhe loudspeaker simulates the real performers' positions. The microphones were located in 32 positions within the church's aisle, which will be bounded to the public.

Starting from IRs measured by the Soundfield microphone and the dummy head, the most important acoustical parameters (T20, EDT, C50, C80, D50, G, IACC, LF, etc.) were calculated.

Spatial distribution of acoustical parameters

The measurement of the acoustics in the church confirmed the opinion of the people that played and listened in the church of San Domenico.

The reverberation time resulted quite high, mainly at low frequencies. Consequently, many other parameters related with RT resulted quite high. The Clarity (C80), the Center Time (CT), te Definition (D), all them results quite high. The Speech Transmission Index (STI) and RApid Speech Transmission Index (RaSTI) resulted limited. Rhe average value of RaSTI was less than 0,5 therefore the voice intellegibiliy is limited.

Table 1. Values of acoustic parameters measured

Hz	63	125	250	500	1000	2000	4000
T20	6.3	5.9	5.6	5.00	4.6	4.0	3.0
EDT	7.5	6.9	6.4	5.6	5.0	4.0	2.7
C50	11.5	11.1	10.8	10.2	9.7	8.8	7.1
C80	8.6	8.1	7.8	7.1	6.6	5.6	3.8
D50	6.6	7.2	7.7	8.7	9.6	11.6	16.2
Ts	522	478	445	384	345	284	202
G	10.2	9.8	9.4	8.6	8.1	7.3	5.8
RaSTI		0.37	0.38	0.41	0.43	0.47	0.55

Most of the acoustic parameters resulted varying noticeable between the transept and the aisle because of the fake vault above the transept, and had an asymmetrical trend because of the lateral chapel. The chapel, moreover, has behaviour of a big resonator who gives back to a delayed reverberation tail, in spite of the intelligibility and all the acoustic quality of the church.

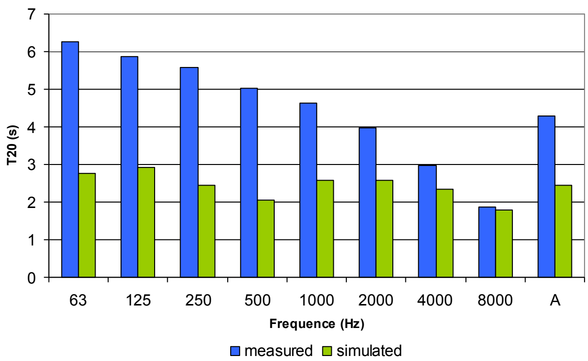

Figure 4. Reverberation time (T20) measured and calculated

ACOUSTIC DESIGN

The interventations of the church refurbishment into auditoria were proposed in function of acoustic quality, safety rules and protection of the architectonic value of the building. All the interventations were designed as possibly not invasive and reversible.

Stage platform

It was designed into the transept a wood's stage platform. Thinked as extension of the presbytery staircase, the new stage can host about 50 musician performers in an area of 80 m². Rised from the floor, the new stage is also sighter from the public, and the wood can better absorpe the sound.

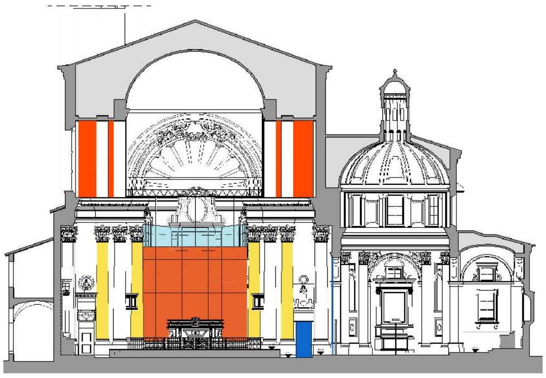

Figure 5. Auditoria design: internal section through the lateral chapel; the acoustic shell is represented in orange (paited wood panels) and azure (transparent plastic panels)

Rise public stand

It was designed in the back of the aisle a rise public's stand, wich position and dimensions are depending on safety exits, on minimum breadth for the lateral passages and on the necessity to maximise the pit-stalls number (264). This stand can also improve the stage view and host below, near the center, a box office and a wardrobe. This kind of structure allowed a hall volume reduction and a sound absorpion using materials like fitted carpet, parquet flooring, velvet and stuffed pit-stalls, wood and plastic panels. In the fore of the aisle was settled another 142 pit-stalls for the public, and 4 reserved places for people with phisic handicaps. Totally the designed auditoria can host 410 people.

Acoustic shell

It was built an acoustic shell over the stage. To improve the acoustic from the musicians perspective (and help their performance), the surfaces near the stage should can reflect on the stage part of the sound energy produced. The other part of the energy can be directioned toward the public. The acoustic shell is made of panels placed on a metal structure hang from three reticular beams.

In this case, the acoustic shell is made only of panels back and over the stage, without obstructing the view of the sides of the presbytery, with a lot of Baroque decorations and stucco works. Moreover, to let see the decorations on the vault of the apse, over the stage are used transparent plastic panels, differently from the painted wood panels used in the other part of the acoustic shell. The shape design of the acoustic shell was impoved step by step with the design tridimensional model.

Acoustic panels, tissue covering and hangings

To reduce the reverberation time, are used some measure technically simples, not invasives, reversibles and not so expensives who gave an essential help.

Was used some acoustic panels composed in two plywood on 5 mm thick and an interspace on 50mm filled with a glass wool. Those panels were introduced on the internal surface of some vaults and on the enw wall of the aisle, to prevent echo effect from the end of the hall. Acoustic panels can absorpe a big sound energy, reducing the reverberation time, for medium and low frequencies.

Moreover are introduced heavy courtains to screen the windows (very reflecting for medium and hight frequencies) and close the minor spaces, fistly the Baroque lateral chapel. In that way the acoustic rays can't go into the minor spaces and late go out on the hall. The heavy courtain absorpes a lot of energy at the hight frequencies. This kind of intervention has also an important architectonic value, as re-interpretation of the tradition that saw the churches with decorative curtains setted up for the important feasts.

To reduce the reverberation time for hight frequencies, some pilasters are been covered with heavy fabric in the same colour to hiding the intervention.

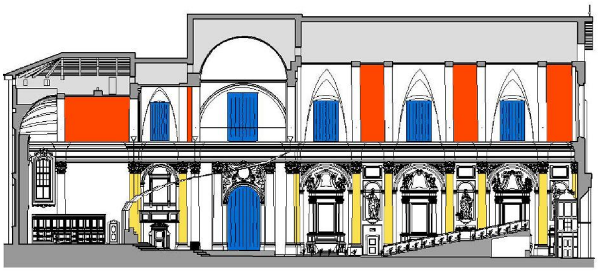

Figure 6. Auditoria design: are represented the stage platform, the acoustic shell profile and the rise public stand; are represented also acoustic panels (in red), tissue coverings (in jellow), and hangings positions (in blue)

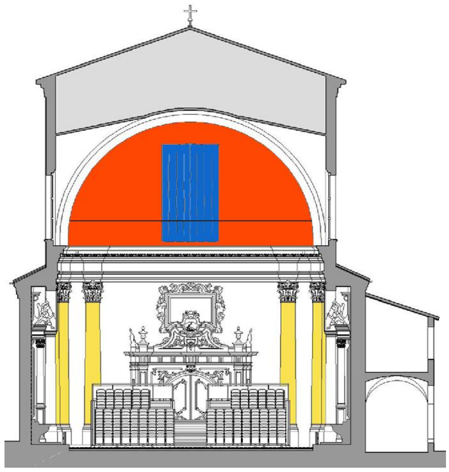

Figure 7. Auditoria design: Acoustic panels (in red), tissue coverings (in jellow), and hangings (in blue);

RESULTS

The new absorbing surfaces, the reflecting panels and the closing of the lateral chapel allow a significant reduction of reverberation time of about 2 s, and a bigger reduction for low frequencies. The reflecting panels enhance strength at long distances from stage.

Table 2. Values of acoustic parameters in the auditoria configuration

Hz	63	125	250	500	1000	2000	4000
T20	2.8	2.9	2.4	2.0	2.6	2.6	2.3
EDT	2.5	2.7	2.2	1.8	2.3	2.3	2.1
C50	6.1	6.5	5.7	4.8	5.9	6.0	5.5
C80	3.7	4.0	3.2	2.1	3.4	3.4	2.9
D50	19.5	18.4	21.0	24.9	20.6	20.2	22.0
Ts	187	199	168	140	175	175	161
G	6.8	6.6	5.8	4.8	5.7	5.7	5.3
RaSTI		0.54	0.58	0.63	0.57	0.57	0.59

The values of some acoustic parameters in designed configuration are reported in table 2.

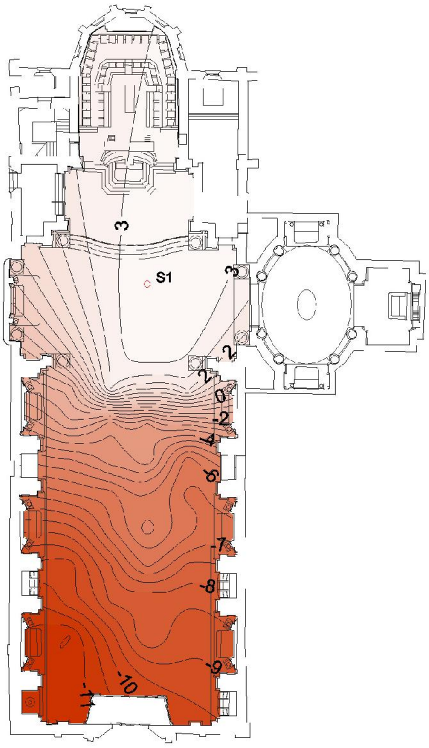

Figure 8. Spatial distribution of C50 before the design

3D auralisation

A tridimensional model of the church was prepared with the exact positions of loudspeakers and microphones. The model was calibrated by means of an iterative changing of the sound absorption coefficients of all the material inside the church; in that way the acoustical parameters achieved from the theoric model corresponded to the measured parameters.

CONCLUSIONS

Tha acoustic design allowed a significant improvement of most acoustic parameters, but they are still far from the optimal parameters of a auditoria designed on purpose. In spite of that, for a refurbishment design, the acoustic of the hall results are good.

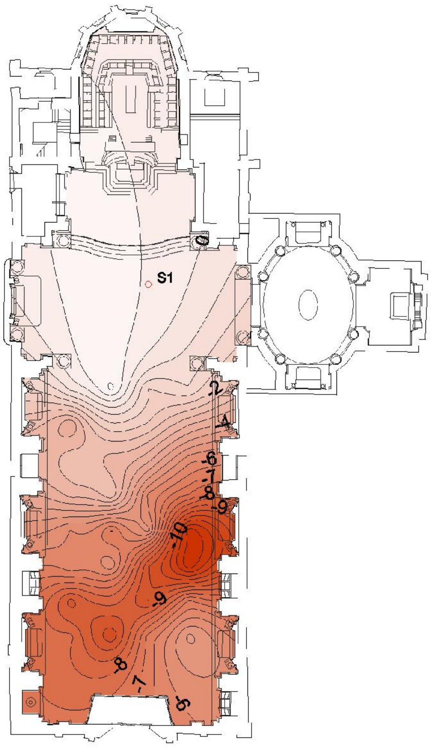

Figure 9. Spatial distribution of C50 after the design

In that way the church owner and the city autorities has a new opportunity to think another possible use for that precious building: a new and fascinating auditorium.

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