The acoustic correction of classrooms in historical buildings with numerical simulation

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Introduction

Often the classrooms are located in historical buildings, where for aesthetic and historical reasons it is difficult to install sound-absorbing panels for acoustic corrections; the classrooms are not regular in shape and the ceilings are not level [1], [2]. To improve the acoustic characteristics of the classrooms, sound-absorbing materials must be installed in an appropriate manner, but with non fixed structures, as they are historical buildings. Odeon, a compliant software for architectural acoustics was used to identify the type of material to be used, and where to find the geometrical position of the most effective location of acoustic correction. To produce a case study, classrooms situated in the Faculty of Architecture of the Seconda Università di Napoli (SUN) were selected. The classrooms were all located in the historic building, each irregularly shaped and had vaulted ceilings, the walls were smooth as they were plastered[3]. For each classroom measurements were taken on acoustic characteristic as the reverberation time (T30), the Definition (D50) and the Speech Transmission Index (STI). With the aid of the Odeon software, the programmed has tried to find the location where to install the panels to reduce reverberation time and improve the acoustics characteristic, preserving aesthetics and following historic preservation instructions. The results of the acoustic measurements for the classrooms and the relative acoustic correction of varying positions of the sound-absorbing panel are demonstrated.

Building history

The Faculty of Architecture of the Second University of Naples (SUN) is located in an ancient building in, Aversa near the city of Caserta. The building, called San Lorenzo ad Septimum, was built in the X century as Benedictine monastery; in the XV century the building was expanded. In 1807 the monastery was closed and a school for young boys was set up. Since 1990 the Faculty of Architecture in located here, with 13 classrooms and other rooms are for the administrative offices. Figure 1 shows the cloister on two levels with arches and columns, while the Figure 2 shows the monastery plant.

Acoustic measurements

For each classroom acoustic measurements were carried out using an omnidirectional spherical source fed with an MLS signal, the impulse responses were detected, and analysed the acoustic parameters for speech understanding. The sound source was placed in each classroom, in the teacher's position (height 1.6), and the microphones measurement were in different points in the classrooms at typical ear height (height 1.2 m), to obtain an average value of the acoustic properties. The acoustic parameters were measured in according to EN – ISO 3382, with a microphone measurement GRAS 40 AR endowed with the preamplifier 01 dB PRE 12 H connected with a laptop PC through the interface 01 dB Symphonie, the omnidirectional sound source was feed by a MLS signals.

Figure 1. Faculty of Architecture. The cloister on two levels with arches and columns.

Figure 2. Monastery plant.

Six university classrooms were used to gather the data as Table 1 demonstrates [4]. For each classroom used, the volume, the average height and the base area are all measured and demonstrated in the table. Figure 3 shows a university classroom during acoustic measurement recording, with the omnidirectional sound source and the microphone. The measurements were carried out after school hours or on school holidays to minimize the influence of school activities on the acoustic measurements. During the acoustic measurements, the background noise was LeqA = 40 dBA

Table.1

Number	classroom	Volume m^3	Average height, m	Base area, m^2
1	T4	275	5.5	50
2	T5	2517	12.1	208
3	P3	416	5.4	77
4	P4	1166	5.4	216
5	S2	626	4.6	136
6	S3	1850	7.2	257

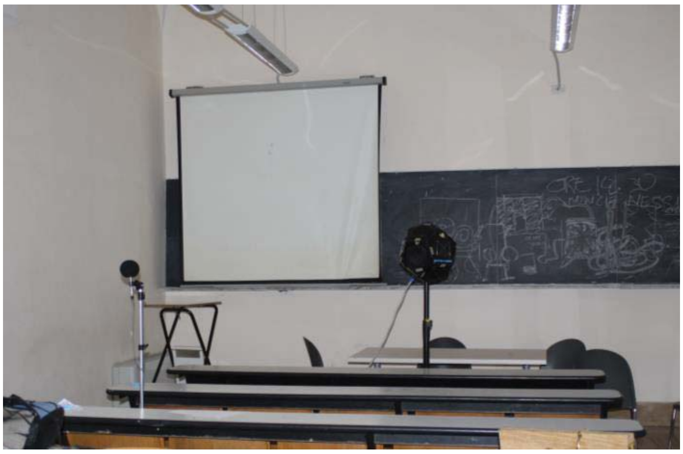

Figure 3. Acoustic measurements in a university classroom.

Virtual models by Odeon software

CAD software was used to draw up virtual acoustic simulation of the classrooms, and materials with absorption and scattering coefficients were assigned to each surface. The scattering coefficient is not frequency dependent which is due to the material properties and also due to the geometrical properties of the surface; so the desks and chairs were simulated as flat planes, with a scattering coefficient of 0.5 for the unoccupied condition [5]. With the Odeon software, the classrooms virtual models are calibrated on the T30 measured values. We are interested to know the effects of the insertion of absorbent materials in the classrooms on speech understanding, we analyse the relative noise indicators: D50 and STI. For each classroom we have a different value of area of absorbent material that correspond to the surface of vertical wall behind the teacher's position. For each classroom the Figures 4-6-8-10-12 show the values of T_{30} measured and the corresponding calculated (by Odeon software) T_{30} values obtained by the calibration of the virtual model; and the calculated values of T_{30} (by Odeon software) after the acoustic correction when, a surface of sound-absorbing material is inserted in the classroom to the vertical wall behind the teacher's position, or when the same equivalent area, of sound-absorbing material, is inserted below the ceiling. The equivalent area of sound-absorbing material changes for each classroom because the vertical wall is different from classroom, to classroom.

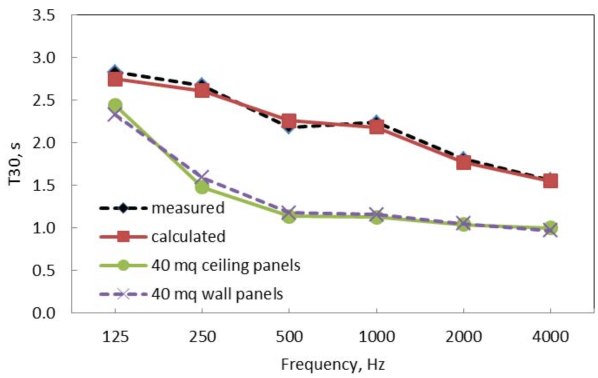

Figure 4. Classroom P3, values of T30 (measured, calculated, with 40 m^2 of absorbent material on walls, and with 40 m^2 of absorbent material under ceiling).

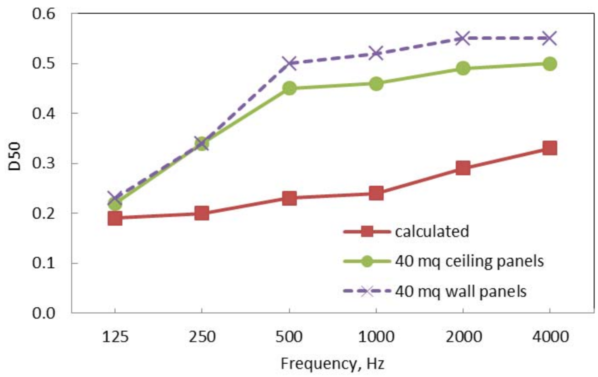

Figure 5. Classroom P3, values of D50 (calculated, absorbent material on walls, and with absorbent material under ceiling).

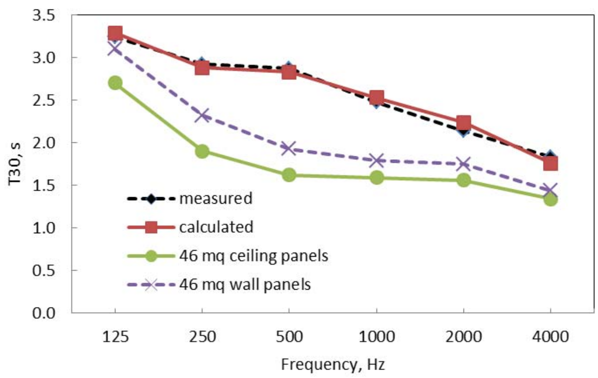

Figure 6. Classroom P4, values of T30 (measured, calculated, with 46 m^2 absorbent material on walls, and with 46 m^2 absorbent material under ceiling).

The Figures 5-7-9-11-13 show the values of D_{50} calculated (by Odeon software) when the walls of the classroom are smooth; and the values of D_{50} calculated, when a surface of sound-absorbing material is inserted in the classroom to the vertical wall behind the teacher's position, or when the same equivalent area, of sound-absorbing material, is inserted below the ceiling.

Table 2 - STI Value.

bad	poor	fair	good	excellent
0 - 0.3	0.3 - 0.45	0.45 - 0.6	0.6 - 0.75	0.75 - 1

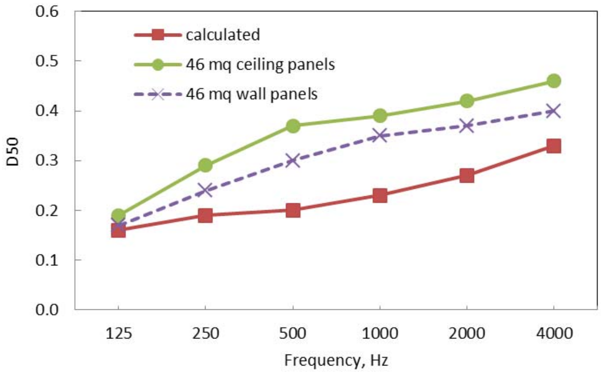

Figure 7. Classroom P4, values of D50 (calculated, absorbent material on walls, and with absorbent material under ceiling).

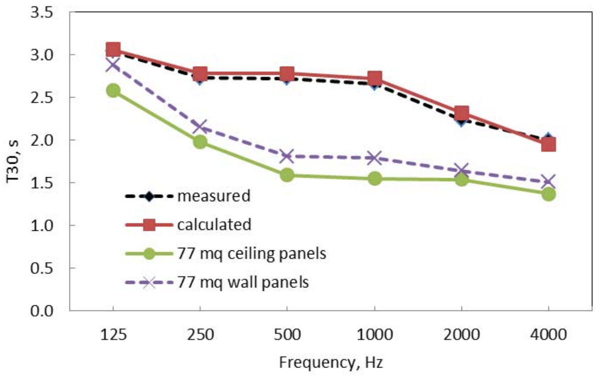

Figure 8. Classroom S3, values of T30 (measured, calculated, with 77 m^2 absorbent material on walls, and with 77 m^2 absorbent material under ceiling).

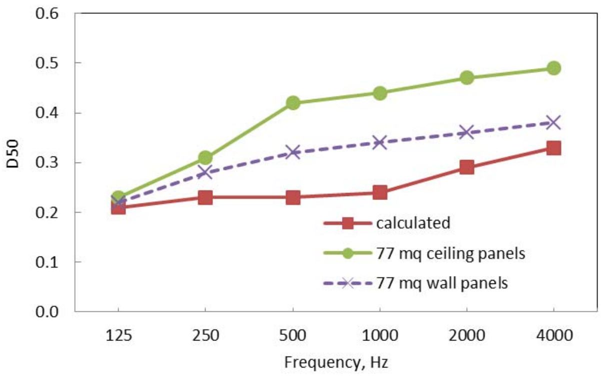

Figure 9. Classroom S3, values of D50 (calculated, absorbent material on walls, and with absorbent material under ceiling).

The Table 2 shows the STI values in numerical range from bad to excellent, while Table 3 shows the STI values: the first column is the classrooms; the second column is the STI values measured by MLS; the third column are the STI theoretical values when the classrooms walls are smooth; the fourth column are the STI theoretical values when the absorbent material has been inserted in vertical wall behind the teacher's position; the fifth column are the STI theoretical values when the same absorbent material area has been inserted below the ceiling.

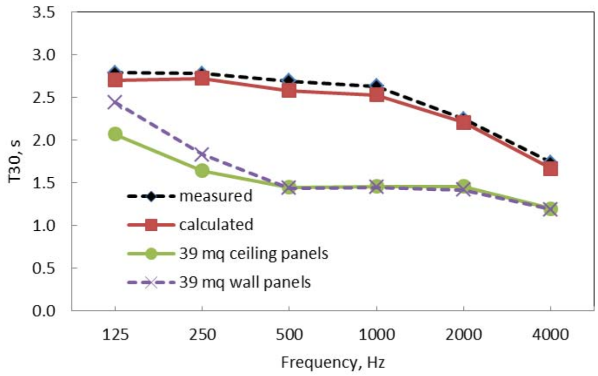

Figure 10. Classroom S2, values of T30 (measured, calculated, with 39 m^2 absorbent material on walls, and with 39 m^2 absorbent material under ceiling).

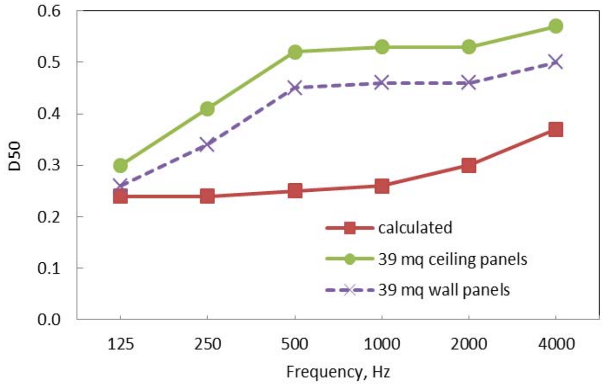

Figure 11. Classroom S2, values of D50 (calculated, absorbent material on walls, and with absorbent material under ceiling).

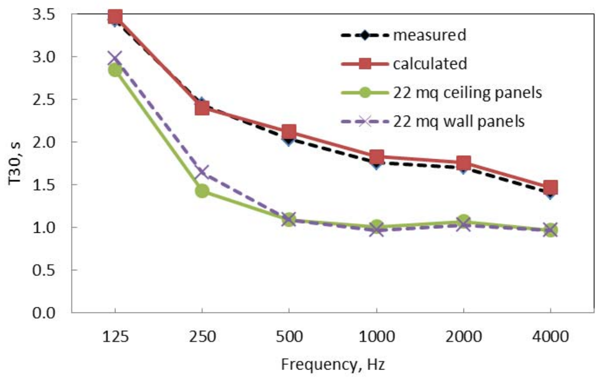

Figure 12. Classroom T4, values of T30 (measured, calculated, with 22 m^2 absorbent material on walls, and with 22 m^2 absorbent material under ceiling).

Conclusions

The classrooms in historical buildings don't have good acoustics (T_{30} measured at 1 kHz is over 1.0 s), and these classrooms need acoustic corrections. From the results of the

Odeon simulations, we can say that correction doesn't exist only in one geometrical position when installing the absorbent material to increase good classroom acoustics, but that for each classroom we must try to better position and install the absorbent materials. Using a software for architectural acoustics we can obtain useful information for each classroom geometry, and about the position on where to install the absorbent material to have the best acoustic performance.

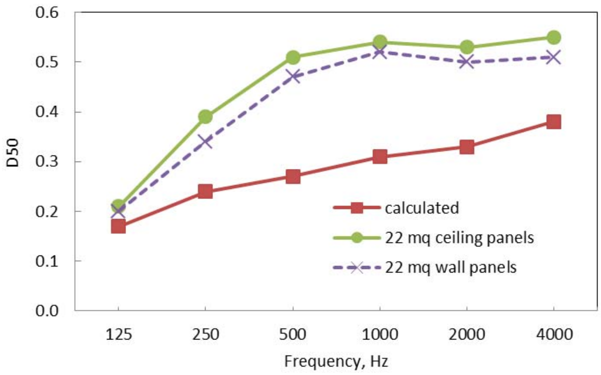

Figure 13. Classroom T4, values of D50 (calculated, absorbent material on walls, and with absorbent material under ceiling).

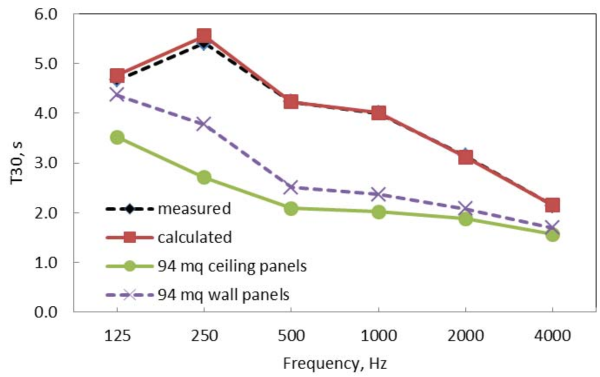

Figure 14. Classroom T5, values of T30 (measured, calculated, with 94 m^2 absorbent material on walls, and with 94 m^2 absorbent material under ceiling).

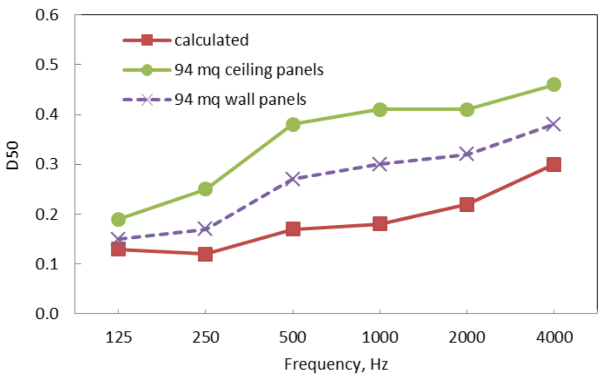

Figure 15. Classroom T5, values of D50 (calculated, absorbent material on walls, and with absorbent material under ceiling).

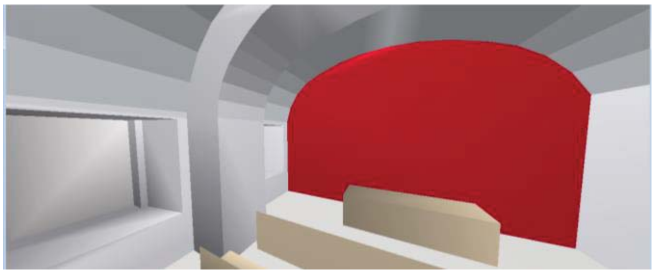

Figure 16. Classroom render by Odeon software, with absorbent panels (red surface) behind the teacher position.

Table 3. STI measured and theoretical values.

Classroom	measured	theoretical	walls	ceiling
T4	0.34	0.45	0.55	0.56
T5	0.38	0.36	0.48	0.42
P3	0.48	0.43	0.56	0.54
P4	0.47	0.42	0.51	0.47
S2	0.47	0.44	0.53	0.59
S3	0.46	0.42	0.51	0.47

Figure 17. Classroom render by Odeon software, with absorbent panels under the ceiling.

References

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