Acoustic climate inside a canteen and mitigation solutions

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The acoustic environment inside a canteen is an important feature to guarantee speech intelligibility and speech privacy, as well as to reduce the exposure levels. Unfortunately this aspect is not always properly taken into account as others, like cleanliness. This paper describes the case-study of the canteen at the National Agency for Environmental Protection (APAT), having a capacity of 220 seats. The acoustic environment has been characterized by measuring the main acoustic descriptors for speech intelligibility (Reverberation Time, STI, C80 and D50) and evaluating the noise exposure levels for the users. The comparison of the results with the recommended values showed a bad situation, especially in the speech frequency range, which requires acoustic corrections to improve the quality of the acoustic environment. To identify these corrections a numerical model of room acoustics, implemented on a commercial software, has been used to evaluate the effects produced by different corrections. The proposed correction improves the acoustic performances up to a good level, without modifying the structural parts and existing walls. Moreover, the solution allows to maintain the hall's usability without obstructing users mobility, screening natural lighting and reducing number of seats.

1 Introduction

Speech intelligibility within confined spaces is a very important feature to guarantee, because it allows to achieve acoustic comfort. In the present paper, the canteen at the National Agency for Environmental Protection (APAT), situated in Rome (Italy), has been investigated in order to assess its acoustic quality.

Measurement campaigns have been carried out to define the indoor acoustic environment, evaluating the main acoustic descriptors for speech intelligibility – Reverberation Time T30, Speech Transmission Index STI, Clarity index C80 and Definition index D50 – in different points inside the canteen; comparison with the recommended values showed a bad situation.

A virtual model of room acoustics, implemented on the Bruel & Kjaer software "Odeon", has been used to propose mitigation solutions in order to reach the required acoustic performances.

2 Hall's description

The canteen is constituted by an irregular shaped room, reported in Fig. 1, having an area of 150 m^2 and a completely closed volume of 450 m^3. There are 53 formica-covered tables (about 220 seats); the plastic false ceiling is installed at 20 cm distance from the loft, and the linoleum floating floor is raised 30 cm above the concrete floor; both the walls and columns are formica-covered; the doors are metallic. There are also 2 windowed walls.

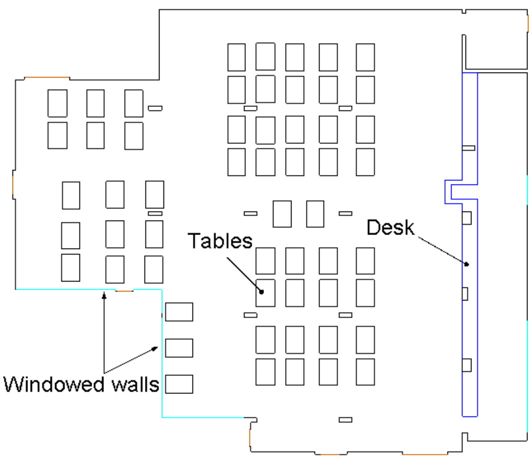


Fig.1 Canteen's plan

3 Measurement campaigns

3.1 Dosimetric measurements

Dosimetric measurements have been carried out inside the canteen when the biggest number of persons is present, between 13:00 and 14:00, in order to assess the user's daily exposure to noise.

Those measurements have been taken in 9 selected sites, reported in Fig. 2, for a period of about 30 minutes, depending on the effective lunch duration.

A portable sound level meter characterized by small dimensions (personal dosimeter) has been used, measuring the A-weighted equivalent sound pressure level (Leq) in the real user's positions. Acquisition time of 5 sec. and "Fast" time constant were set up.

Fig. 2 Dosimetric measurement positions

Measurements results showed Leq values higher than 80 dB(A) up to about 92 dB(A); Fig. 3 shows the Leq time history for the instance of the measurement position n. 2

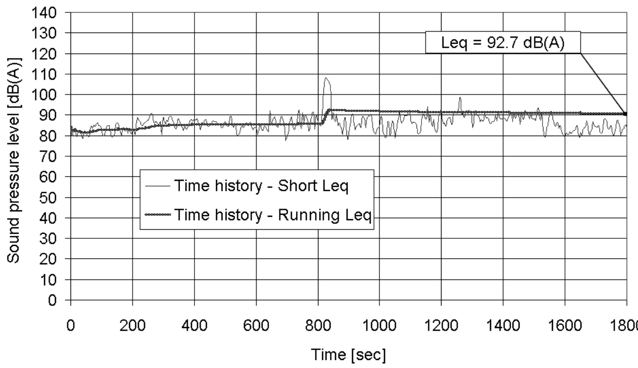


Fig. 3 Leq time history of the measurement position n. 2

In the range between 70 and 80 dB(A), the acoustic envirmonent is comparable to a situation of heavy traffic. Such values, referred to the short time of exposure to noise, do not present any risks, but can induce "annoyance" effects, considering the use of the specified ambient.

3.2 Acoustic descriptors measurement

The acoustic descriptors T30, C80, D50 and STI have been carried out by means of the Bruel & Kjaer "Dirac" system, in compliance with ISO 3382 [1].

The measurement system, schematized in Fig. 4, is composed by dodecahedral source, microphone, power amplificator and spectrum analyzer.

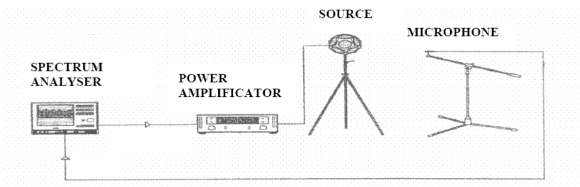


Fig. 4 Measurement system

To simulate the room impulse response, MLS, lin-sweep and e-sweep signals, generated by Dirac system, were amplified, emitted by the source and taken back by a microphone situated at 1.5 m height from the floor.

The acoustic measurements have been carried out with 2 different source positions, for each of them considering 5 microphone positions, as showed in Fig. 5.

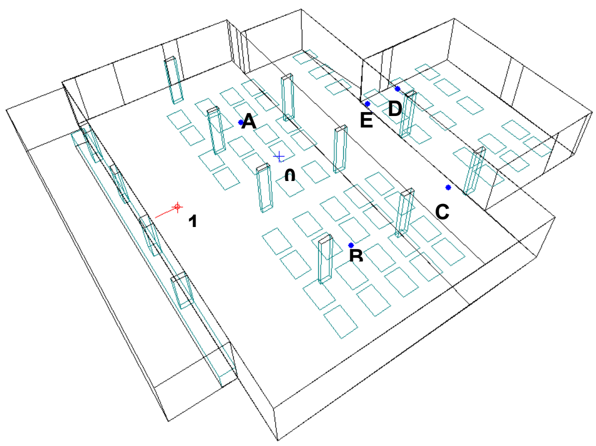


Fig. 5 Source (0-1) and microphone (A-E) positions

It is possible to evaluate the canteen's acoustic quality comparing the measured values with the optimal acoustic descriptors for speech intelligibility [2,3,4] reported in Table 1.

T30 (sec)	D50	C80 (dB)	STI
0.9	> 0.5	> 3	> 0.6

Table 1 Optimal acoustic range descriptors values

Fig. 6 summarizes the mean measured values of the descriptors related to the source and microphone positions considered.

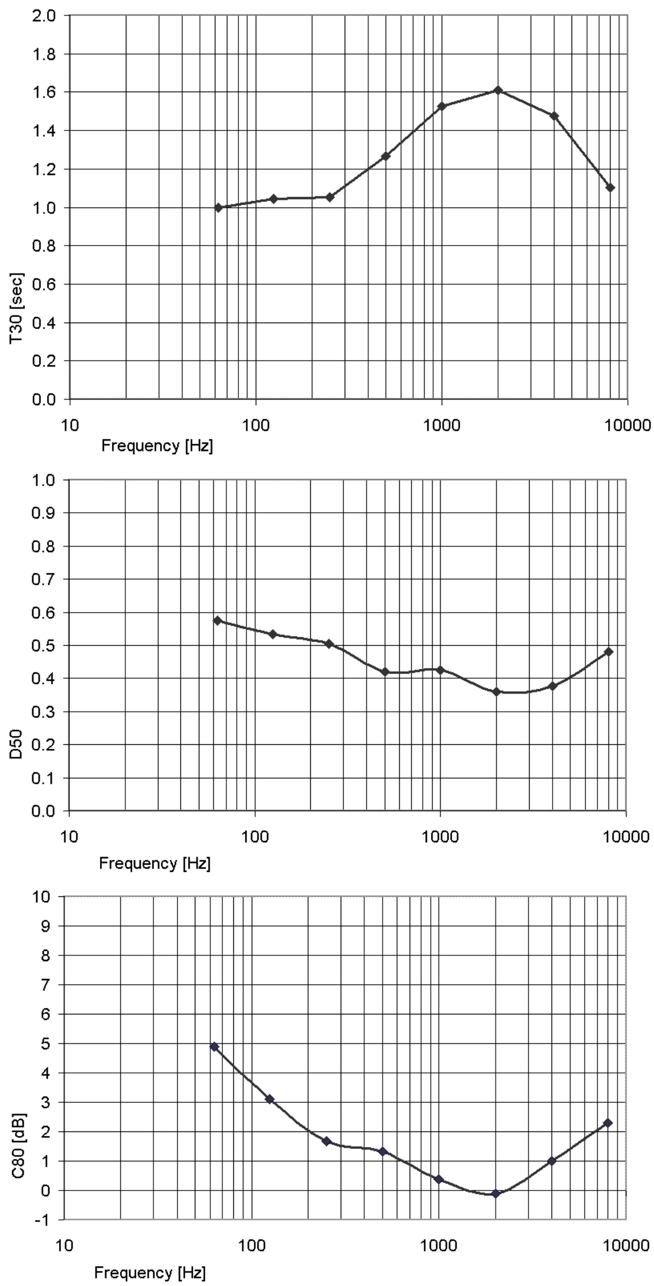


Fig. 6 Mean measured values

STI mean value related to the source position n. 1 is equal to 0.50, corresponding to "Fair" acoustic quality class.

It is interesting to note that T30 behaviour at low frequencies, presenting lower values than medium and high frequencies, is due to the floating floor's absorbing properties.

Such results show that it is necessary to improve hall's acoustic quality, especially in the speech frequency range comprised between 500 and 4000 Hz.

4 Numeric simulations

4.1 Model Calibration

The Bluer & Kjaer software "Odeon" simulates the room acoustics using image source method and ray tracing prediction algorithms [2].

Table 2 reports the absorbing coefficients of the materials inserted in the numeric model.

Frequency (Hz)							
63	125	250	500	1k	2k	4k	8k
Floor							
0.42	0.25	0.20	0.07	0.02	0.07	0.06	0.06
Ceiling							
0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Metallic surfaces							
0.59	0.59	0.59	0.81	0.64	0.26	0.17	0.17
Formica							
0.02	0.02	0.03	0.03	0.03	0.03	0.07	0.07
Glass							
0.18	0.18	0.06	0.04	0.03	0.02	0.02	0.02
Tables							
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Table 2 Materials acoustic properties adopted

Acoustic simulations have been carried out in the source position n. 1. To calibrate the model, the simulation results have been compared to the measured values, as showed in Table 3.

T30 (sec)	D50	C80 (dB)	STI
0.10	0.04	0.88	0.01

Table 3 Mean calibration results with source position n. 1

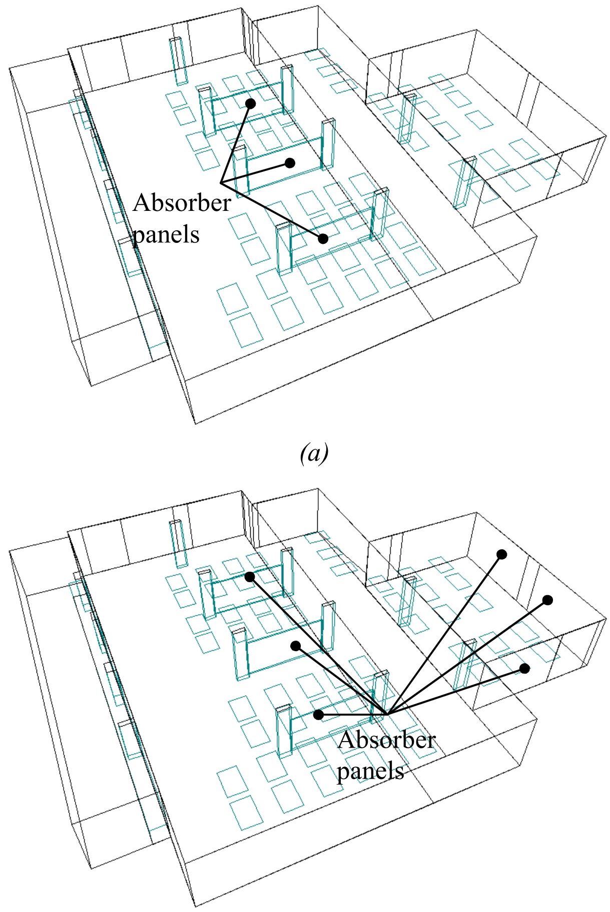
4.2 Proposed solutions

In order to improve acoustic quality, two solutions have been considered:

a) installing three absorber panels, each of them connected to two existing columns in order to guarantee a better static stability;

b) in addition to the previous, installing other absorber panels over some canteen's walls.

Fig. 7 shows the absorber panels in the two considered situations.



(a)

(b)

Fig. 7 Absorber panels layout in the acoustic corrections (a) and (b)

Table 4 reports the values of the absorbing coefficient α chosen for the absorber panels.

Frequency (Hz)							
63	125	250	500	1k	2k	4k	8k
0.15	0.15	0.55	0.80	0.90	0.85	0.80	0.80

Table 4 Panels absorbing coefficient α

After the simulations, the obtained acoustic descriptors for both the correction solutions have been analysed. Fig. 8 summarizes the mean simulated descriptors and the measured values.

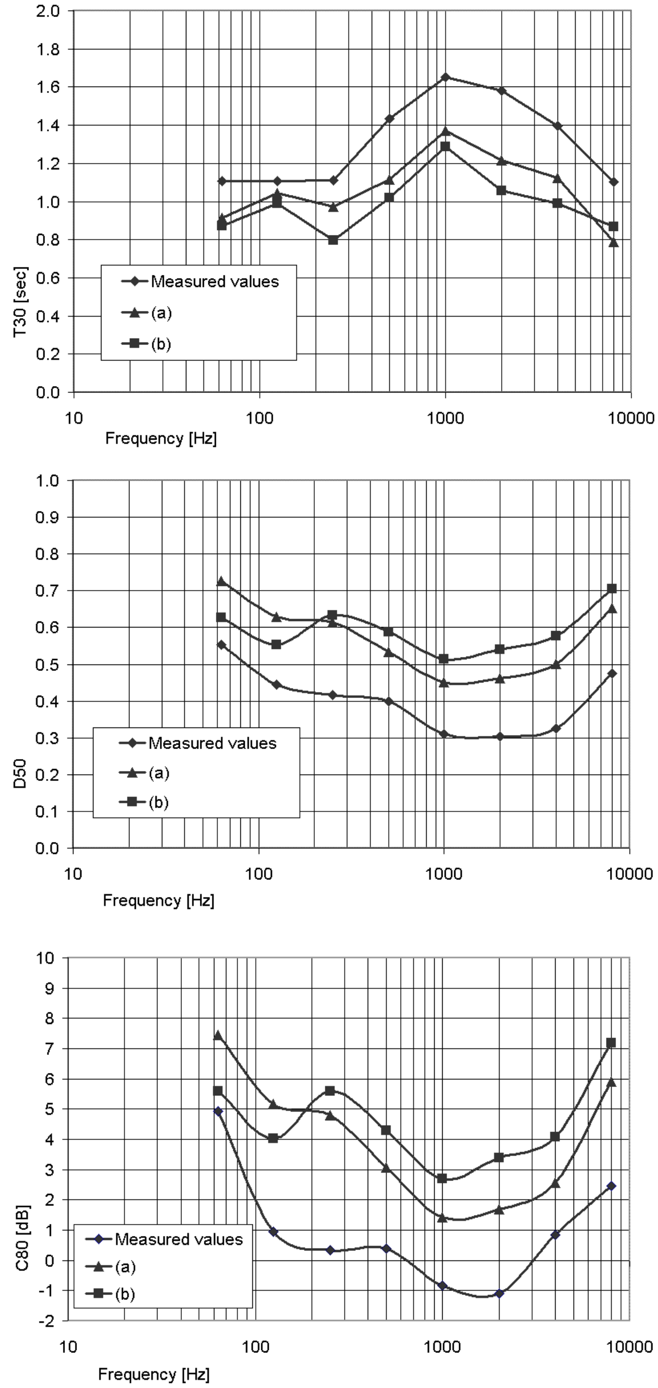


Fig. 8 Mean acoustic descriptors values measured and simulated with the acoustic correction (a) and (b), considering source position n. 1

STI mean value is improved from 0.50 up to 0.59 for the solution (a), maintaining the same “Fair” acoustic quality class, and up to 0.62 in the case (b) which allows to reach the “Good” category.

Although the quite improvement obtained in the case (a), nevertheless the optimal acoustic range values cannot be reached; such goal can be carried out, almost throughout the whole interesting frequency range, adopting the acoustic correction (b).

5 Conclusion

The acoustic quality of the canteen has been defined by measurement campaigns. Dosimetric measurements have been carried out in 9 measurement points, during lunch time, evaluating the acousitc envirnonment inside the canteen. The Leq values measured, always higher than 80 dB(A), can induce annoyance effects. Then the main acoustic descriptors – Reverberation Time, Clarity, Definition and STI indexes – has been investigated, turning out the need of acoustic correction to improve speech intelligibility.

The room acoustic parameters have been verified using a 3D numeric model implemented on a commercial software. Two acoustic corrections have been checked: the first, achieved with the introduction of three absorber panels, each of them installed between two existing columns, and the second, with other additional absorber panels installed over some canteen’s walls. The related acoustic descriptors have been calculated and then compared to the optimal values.

The simulation results have showed that the first solution allows to improve the general acoustic quality, but not to reach the optimal range values which can be obtained using the more complete acoustic correction.

Both the proposed solutions improve the acoustic performances, without modifying the structural parts and existing walls; moreover, it is possible to maintain the hall’s usability without obstructing users mobility, screening natural lighting and reducing number of seats.

References

[1] International Standard ISO 3382, “Acoustics – Measurement of the reverberation time of the rooms with reference to other acoustical descriptors” (1997)

[2] R. Spagnolo, “Manuale di acustica applicata” (2001)

[3] ISO TR 4870 “Acoustics – The construction and calibration of speech intelligibility tests” (1991)

[4] International Standard IEC 60268-16, “Objective rating of speech intelligibility by Speech Transmission Index” (1998)