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A FIELD SURVEY OF ACOUSTIC CONDITIONS IN PRIMARY AND KINDER SCHOOL CANTEENS

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ABSTRACT

Canteens usually have critical acoustic conditions resulting from the need to maximize the number of occupants while minimizing volume. Thus, in the absence of specific sound absorbing treatments, very high sound pressure levels are usually observed resulting in significant impairment of communication (with increased vocal effort of speakers and reduced speech intelligibility), and dangerously high exposure levels for workers. The present paper reports acoustic measurements carried out in a nursery school canteen having a volume of 211 m^3 and seating about 50 children, and two primary school canteens having volumes of 650 m^3 (seating 126 children) and 367 m^3 (seating 107 children). Reverberation time was measured in each room as well as sound pressure levels during peak occupation (averaged over 15 minutes intervals), resulting in $L_{eq,A}$ spanning between 83 dB (in the nursery school) and 89 dB in the primary school with the smallest volume.

Keywords: *acoustic comfort, primary schools, vocal effort, intelligibility, room acoustics*

1. INTRODUCTION

The role of room acoustics in schools and teaching spaces has been largely investigated in the recent years, leading to important results both in terms of research [1–5] and practical regulations. In Italy, in particular, after the publication of design guidelines for schools [6] a specific National Standard has been recently issued [7] and its use is now mandatory in consequence of national laws for new buildings. School canteens, although being partly included in such regulations, are usually less investigated in the scientific literature, certainly because they are used for shorter time intervals and they do not affect teaching (and learning) processes. However, it is indubitable that they play an important social role, as students may more easily talk and interact among them, while having often significant impacts on workers attending the students activities.
The literature on the acoustics of restaurants, canteens and eating spaces has received important contributions that pointed out the role of background noise control and room acoustics to limit Lombard effect [8–12], also leading to the definition of more specific criteria to explain and assess the acoustic requirements of such spaces [13]. However, information about primary or nursery school canteens is limited (some data can be found in [5]), despite the higher sensitivity to noise of the users and the smaller dimensions compared to ordinary eating premises.
The present paper reports the results of acoustic measurements carried out in selected spaces where the number of occupants was very high compared to the volume and critical conditions were found for booth pupils and workers.

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2. METHODS

2.1 Case studies

Three canteens located in Bari were investigated, one belonging to the nursery school "Simpatiche canaglie" (N1) attended by 1 to 5 years old pupils, and two belonging to two different primary schools "Gandhi" (P1) and "Iqbal Masih" (P2). The first one (Fig. 1) has a floor surface area of 78.5 m^2, a net height of 2.7 m, and an overall volume of 212 m^3. The number of pupils that can be seated is 50, resulting in a volume per capita of 4.24 m^3/pers. Walls and ceilings are plastered and no other furniture apart from

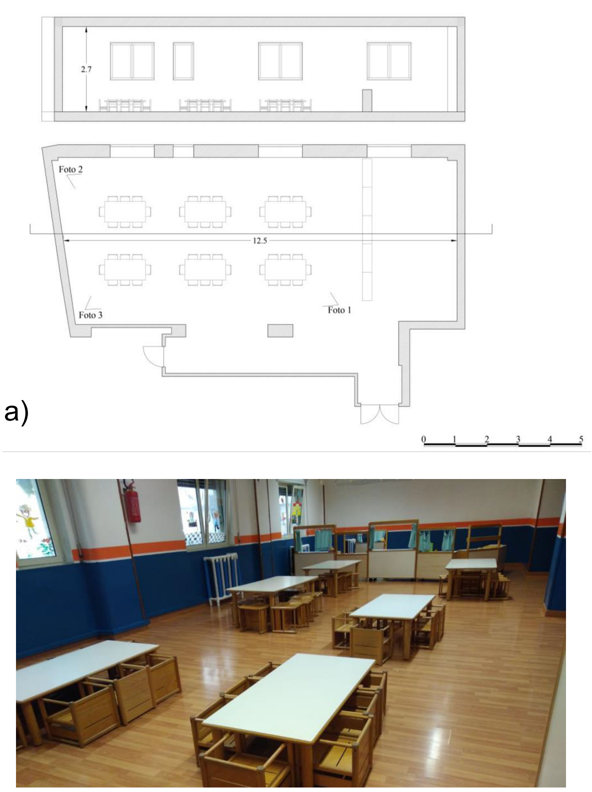

Figure 1. Plan, cross section and interior view of nursery school canteen (N1).

Figure 2. Plan, cross section and interior view of the canteen in primary school Gandhi (P1).

small tables and seats is in the room. Floor is made of laminated wood.

The second canteen (P1) is a simple rectangular room (Fig. 2) having a floor surface of 243 m^2, a net height of 2.7 m, and a volume of 656 m^3. The maximum capacity is 150 pupils, resulting in a volume per capita of 4.37 m^3/pers. Even in this case walls and ceiling are plastered and the floor is finished in ceramic tiles. No furniture, carpets or curtains are in the room apart from tables and seats.

The third canteen (P2) is an L-shaped room (Fig. 3), having a floor surface of 136 m^2, a net height of 2.7 m, and a volume of 367 m^2. The maximum number of seated occupants is 107, resulting in a volume per capita of 3.43 m^3/pers. Walls and ceiling are finished in plaster, and the floor is finished in hard polished stone. No furniture is in the room.

2.2 Measurement protocol

Two different sets of measurements were carried out in each room. First, room acoustic measurements were carried out under unoccupied conditions, measuring impulse responses according to ISO 3382-2 [14]. All the specifications prescribed for "precision" method were used apart from the source typology. In fact, to apply this method the sound source should comply with directivity limits set by ISO 3382-1 [15], while in the present case balloon bursts were used to excite the rooms. As the major limitation resulting from using balloons is related to difficult to control directivity pattern, particularly at low frequen-

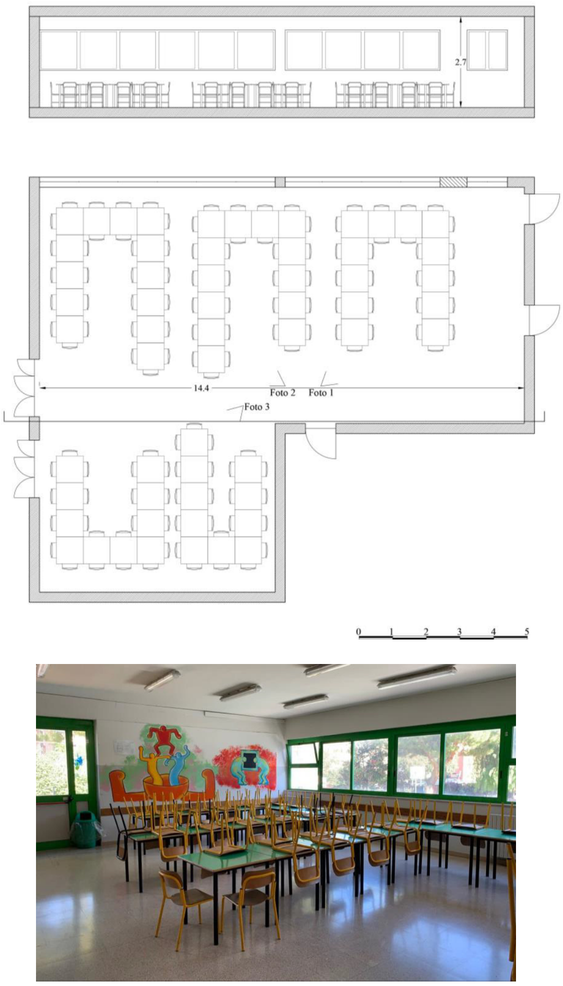

Figure 3. Plan, cross section and interior view of the canteen in primary school Iqbal (P2).

cies, for each source-receiver combination two impulse responses were recorded, taking care to carefully randomize the point of impact at every burst so to limit repeatability issues due to directionality. In any case, as the measurements were aimed at determining the reverberation time, directivity issues were not considered to be a problem. Impulse responses were recorded using a pair of omnidirectional microphones (Soundman OKM II), worn by one of the authors and connected to a Tascam DR08 portable recorder. Post processing and acoustical parameters calculations were made using Matlab scripts. Reverberation time was calculated with reference to a 20 dB decay to en-

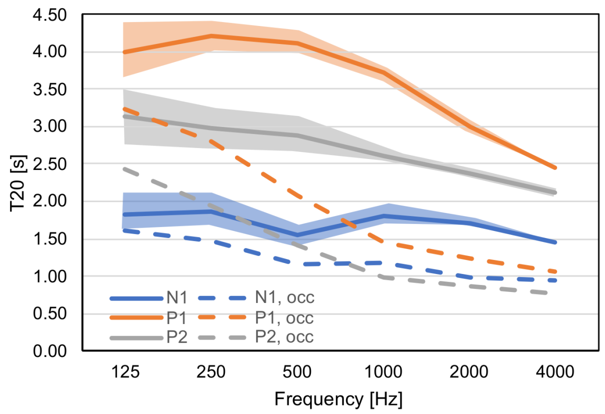

Figure 4. Reverberation time (T_{20}) as a function of frequency in the three canteens surveyed, measured under unoccupied conditions (–) and predicted under full occupancy (- -). Shaded areas represent standard deviations for measured values.

sure that proper signal-to-noise ratio was available across the whole frequency range of interest. In each space at least two source positions were used and three receiver positions.
The second set of measurements was carried out under fully occupied conditions when lunch was served. In this case a calibrated 01dB SOLO sound level meter equipped with a GRAS 40AR random incidence microphone was used. The sound level meter was mounted on a tripod during the measurements, in a central position located at at least 2 m from any direct sound source. Measurements covered the whole lunch time, arranged in 15 minutes recording sessions, covering (where possible) two consecutive shifts including entrance, eating, exiting phases. One-third octave bands levels (mean, minimum and maximum), statistical levels, and overall A-weighted level were determined.

3. RESULTS

3.1 Reverberation times

Measured reverberation times (T_{20}) showed quite different values among the surveyed canteens (Fig. 4), basically as a consequence of their volumes. In fact, P1 showed the longest T_{20}, followed by P2, and N1. Some scattering in the measured values appeared, as expected, in the lowest frequency bands, but the variations were generally small. Calculating the mean absorption coefficient, by taking into account actual volume and total surface area, returned a value varying between 0.04 and 0.05 for P1 and P2, and slightly higher, equal to 0.07, for N1, possibly because of the different seats and tables (Fig. 1).

Taking into account the procedures explained in UNI 11532-2 standard [7] it was possible to compare the measured values against the optimal values suggested for category A6.5, for which it is recommended that:

$$A/V \geq [1.47 + 4.69 \cdot \log(h/1)]^{-1} \quad (1)$$

where h is the room height and this calculation needs to be performed for all the octaves from 250 Hz to 2000 Hz. Considering the height of 2.7 m, for all the rooms the limiting A/V ratio should be greater that 0.287. Taking into account the measured T_{20} and the volume of each canteen, the average ratio among the octaves is 0.09 for N1, 0.04 for P1, and 0.06 for P2. Thus, it is largely below the desired value, as recommended by the standard, suggesting that a significant amount of sound absorbing treatments would be needed.

Based on the measured T_{20} values and on the volume of each room, it was possible to calculate, using the methods proposed by Rindel [13], the acoustic capacity of each space, resulting in 6.3, 8.4, and 6.7 persons, respectively for N1, P1, and P2. As the acoustic capacity is defined as the maximum number of persons in a room allowing sufficient quality of verbal communication in a distance of 1 m, such values confirm that the spaces are far from being suitable for use by the expected number of pupils.

Using the equivalent absorption per person given in the standard [7], it was also possible to calculate the predicted values of the reverberation time under fully occupied conditions. These values were calculated assuming an ideally diffuse sound field, but given the lack of scattering elements on the walls and on the ceiling, and the concentration of absorbing elements only on the floor, it is likely that non-diffuse behavior may take place and longer reverberation times would be observed in practice. However, they may offer some interesting points to explain the sound pressure levels measured under occupied conditions.

3.2 Sound pressure levels

With reference to sound pressure measurements, Fig. 5 shows the time histories for the three selected spaces. It can be observed that, during lunch time, the short L_{eq} (calculated with reference to a 2 s time interval) varies within a relatively narrow range (about 10 dB) in all the cases. Only in the N1 case a larger variation is observed, with a maximum (around 90 dB(A)) at the very beginning (pupils entering the space and taking place), and a slight decrease around 70 dB(A) toward the end of the lunch time when the first classes started to exit the space. In the primary schools the levels remained more stable around 80 and 90 dB(A) in P1, and around 85 and 95 dB(A) in P2. The averaged $L_{eq,A}$ over the entire measurement period were 83 dB(A), 85 dB(A), and 89 dB(A), respectively for N1, P1, and P2. The maxima observed in the three cases were 93.4 dB(A), 95.9 dB(A), and 99.5 dB(A) respectively. As expected, the loudest levels were found in the P2 case, where the volume per capita was the lowest compared to the others that were basically similar. The lowest T_{20} values observed in P2 were not enough to compensate for the lowest volume.

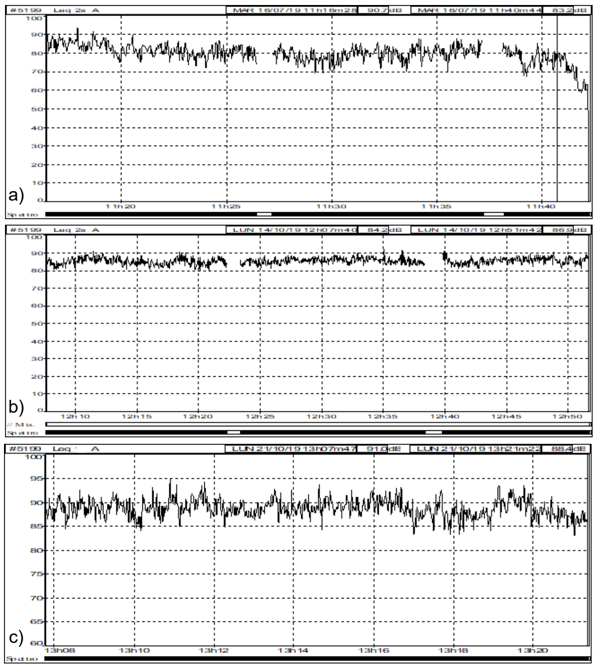

Figure 5. Time histories recorded in the three surveyed canteens: a) N1, b) P1, and c) P2.

In terms of spectrum, Fig. 6 shows that the three average spectra were relatively similar and overlapped, with a significant rise between 200 Hz and 5 kHz, clearly related to the specific characteristics of the voices of the small

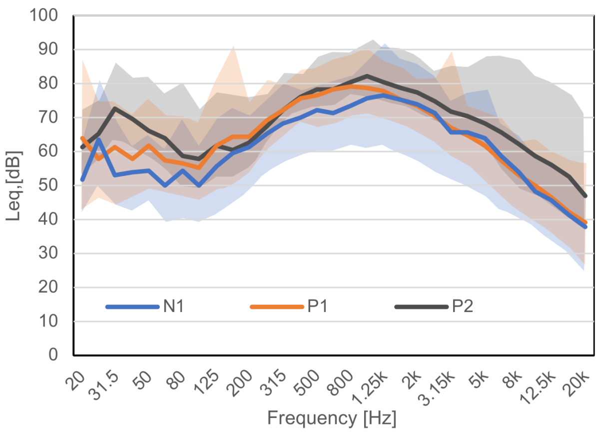

Figure 6. One-third octave band spectrum calculated over the entire measurement time in the three surveyed canteens (shaded areas represent minimum-maximum range).

occupants. In case of P2 it was observed that maxima exceeded 80 dB up to 12.5 kHz, while in the other cases a steeper fall was observed. This was realistically related to the much compact arrangement of tables and, as already stated, the lower volume per capita. In terms of minima, it is worth noting that N1 showed the lowest values, likely as a consequence of the reduction of the occupants during the last part of the measurement period. In fact, the shape of the spectrum remained similar, with the voice-related peak appearing in the 200 Hz - 5 kHz range. Despite exposure time is relatively limited, the observed values may represent a serious issue for pupils and workers. Similar values were only found in one case by Cotana $et al.$ [5] in the canteen with the highest occupancy.

3.3 Discussion

The observed results clearly raise some concerns about exposure limits for both children and school workers that operate in canteens. According to World Health Organization [16] the maximum daily exposure level to prevent hearing loss is set to 70 dB(A), resulting from a weekly exposure of 80 dB(A) for a maximum of 40 hours. For sensitive listeners like children, such limit is further reduced by 5 dB [17], Thus, the weekly sound allowance for children exposed to 83 dB(A) is reached after 6 hours 24 minutes, which reduce to 1 hour and 36 minutes if the level raises to 89 dB(A). For adults, the weekly limit with the latter level is reached after 5 hours exposure. Consequently, While for the nursery school (N1) the situation seemed not critical (also considering that the lunch time for each class is about 30 minutes), for primary schools (P1, and especially P2), some sort of corrective action is needed to reduce risks of hearing damage. In addition, under these critical conditions, the possibility to communicate (and consequently the social value of eating together) was severely impaired and apart from subjects seated closely, conversation was impossible and many children remained isolated. Observation during the measurements also showed that some of the pupils were protecting their ears with hands when they were not eating.

4. CONCLUSIONS

The paper investigated the acoustical conditions in three canteens located in a nursery school and in two primary schools. In all of them, the combination of reduced volume, high occupation density, and long reverberation time, caused sound pressure level to become dramatically high during lunch time. The averaged $L_{eq,A}$ over the entire measurement period were 83 dB(A), 85 dB(A), and 89 dB(A), respectively for N1, P1, and P2. Corrective actions are needed to minimize health risks and improve intelligibility and social role of the space.

5. ACKNOWLEDGMENTS

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