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THE ITALIAN STANDARD ON CLASSROOM ACOUSTICS UNI 11532-2:2020 EXPLAINED THROUGH CASE STUDIES

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ABSTRACT

The UNI 11532-2:2020 is the Italian standard on acoustic environments in schools, comprised of classrooms and ancillary locals, like libraries, school gyms and canteens. Two years after its release, this talk is aimed to present some early results based on case studies, both design simulations and in-situ measurements. Indeed, on the one hand, the UNI 11532-2:2020 takes care of active classrooms asking consultants to consider the acoustic absorption of occupancy to reach the target range of reverberation time in a wide frequency range. It is shown how mixing material typologies becomes crucial to achieve these targets. On the other hand, adequate intelligibility is needed in unoccupied conditions, too. It is shown how the requirements could be reached in small and large environments. A selection of case studies – a primary school classroom, a library, and a university lecture hall - aims to show some design solutions to reach the targets required by UNI 11532-2:2020.

Keywords: *classroom, UNI 11532, intelligibility*

1. INTRODUCTION

Italian Standard UNI, 11532-2:2020 on classroom acoustics, was written by a Working Group including technicians, academic researchers, and people from industries, and it is mandatory for all new public buildings [1]. For Classrooms and Lecture Halls, both RT and Intelligibility (C_{50}, STI) targets are defined. The RT target was intended in occupied conditions, following German Standard DIN 18041 [2]. Procedures are less rigorous for environments like nurseries or libraries: a minimum equivalent absorbing area is required to minimise the Lombard effect.

Astolfi et al. previously showed an overview of Italian Standard UNI 11532-2 [3].

The present work is aimed to show some effects of this new standard on the acoustic design of a classroom and lecture hall.

2. UNI 11532-2:2020 REVERBERATION CRITERIA

The following table (Table 1) shows the criteria collected in UNI 11532-2:2020 [1].

Table 1. Italian Standard UNI 11532-2:2020: Overview of mandatory criteria

Categories		Reverberation			Intelligibility		
			Criterion	range		Criterion	range
A1	music	Occupied conditions	T	**Validated in each octave band** in the range 125-4000 Hz	Unoccupied conditions	--	
A2	Large auditoria		T			STI	125-8000 Hz
A3	**Classroom** V < 250 m³ V < 8800 ft³		T			C_{50}	Averaged over 500-1k-2kHz
A3	**Lecture halls** V> 250 m³ V > 8800 ft³		T			STI	125-8000 Hz
A5	Gyms	Unoccupied conditions	T				
A6.2	Changing room, etc..		A/V	Validated in each octave band in the range 250-2000 Hz		--	--
A6.3	Library		A/V			--	--
A6.4	Canteen		A/V			--	--
A6.5	Nursery		A/V			--	--

The optimal value of Reverberation Time T_{ott} depends on Volume (V); its target window is shown in Figure 1. The role of occupancy in classrooms was demonstrated in many studies [4].

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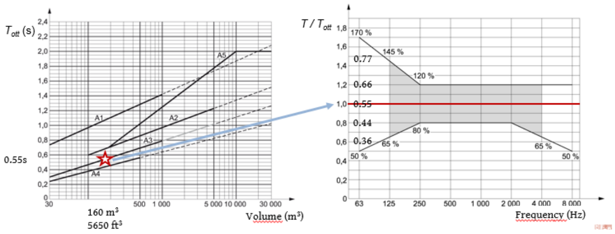

Figure 1. RT – Target window.

The Reverberation Time is described with a predictive model, calculated with the Eqn. (1)

$$T_{opt} = 0{,}16 \frac{V}{\sum_i S_i \alpha_i + \sum_j A_{j,obj} + \mathbf{0.8} \boldsymbol{N\Delta A_{occupancy}}} \qquad (1)$$

Where:

- $\sum_i S_i \alpha_i$: Absorption of boundary surfaces: walls, ceiling, floor, and windows.
- $\sum_j A_{j,obj}$: Equivalent absorption area of objects like seats, desks and benches.
- $0.8N\Delta A_{occupancy}$: Increasing absorption due to the occupancy (80% the full occupancy).

The target window (see Figure 1) values provide a well-balanced sound-energy distribution over all the audience [5]. It is also essential to consider teachers' vocal and students' listening efficiency [6].
According to Italian Building Code (CAM) [7], measurements must match with predicted values within the target window. On the one hand, sound diffusion is needed to reach a good match between predicted RT and measured RT; on the other hand, is required to increase speech intelligibility [8,9]. Measurements must be done in unoccupied but furnished conditions, and the shape of the measured RT is close to the one reported in Figure 2.

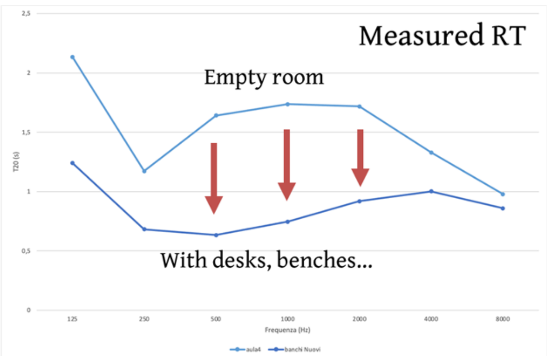

Figure 2. Measured RT.

3. CASE STUDY 1: CLASSROOM

3.1 Ceiling design

The presented case study is a newly built classroom in a secondary school with a volume of 160 m³ (5650 ft³) and 25 students. The configuration of the classroom is the one shown in Figure 3.

Figure 3. Classroom case study for the ceiling design (Brancati School, Pesaro, Italy).

In the design phase, the first thing to do is to calculate the Reverberation time in unoccupied conditions, with the Eqn. (2)

$$T_{unocc} = \frac{0.16\,V}{\frac{0.16\,V}{T_{opt}} - 0.8N\Delta A_{occupancy}} \quad (s) \qquad (2)$$

The increase in equivalent absorption area, the value $\Delta A_{occupancy}$ depends on the students' age and the seats' material, varying for each octave band object of interest, as reported in the following table (Table 2).

Table 2. $\Delta A_{occupancy}$ For each octave band, the student's age and seat's material.

	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Man setting of wooden chair	0,15	0,30	0,40	0,45	0,55	0,55
Man sitting on upholstered armchair	0,05	0,05	0,05	0,10	0,10	0,15
Secondary-school student sitting at the desk	0,10	0,15	0,35	0,50	0,50	0,55
Primary-school student sitting at the desk	0,05	0,10	0,20	0,35	0,40	0,45

According to the target window (see Fig. 1), for a classroom of 160 m^{3,} the optimal value of reverberation time – in occupied condition - T_{ott} is equal to 0.55s. The corresponding (see eq. 2) reverberation time values in the unoccupied state T_{unocc} are those reported in Table 3.

Table 3. Reverberation Time results in unoccupied conditions | Classroom.

	T_{opt}	T_{unocc}					
		125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Wooden seats and desks	**0.55**	0.60	0.61	0.67	0.72	0.72	0.72

Table 3 shows that the recommended Reverberation Time values in unoccupied conditions increase with frequency. Therefore, acoustic materials on the ceiling should perform well at low frequencies and low absorption at mid-high frequencies to reach Reverberation Time targets. According to UNI 11532-2 [1] recommendations and considering frontal instruction (teaching activities take place from the front of the classroom), the best configuration of the sound absorption materials is the one reported in Figure 4. Remembering that the room may be adapted to alternative approaches is crucial.

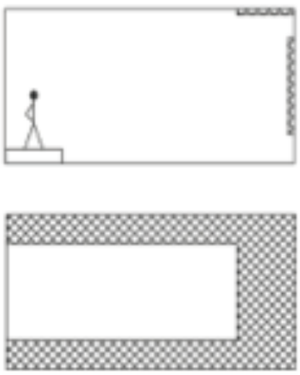

Figure 4. Suggested configuration of sound absorption materials in classrooms.

In this situation, the ceiling moves from a homogeneous and single material configuration (whole surface covered with rock wool modules at high density) to an inhomogeneous materials mix (ceiling covered with rock wool modules at high density and perforated gypsum board). (Figure 5)

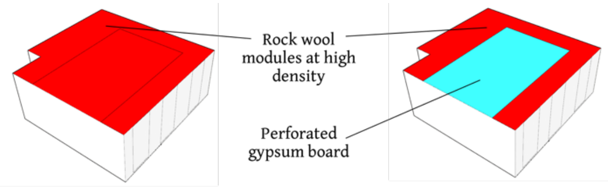

Figure 5. From homogeneous to inhomogeneous ceiling.

3.2 Results

Highlighting and analysing the advantages that could be found using the material mix on the ceiling can be done by checking and comparing the predicted values with the measured ones.
They are comparing results shown in Figs. 6 and 7, an inhomogeneous ceiling obtained by mixing acoustic materials better matches predictive formulae and measured values.

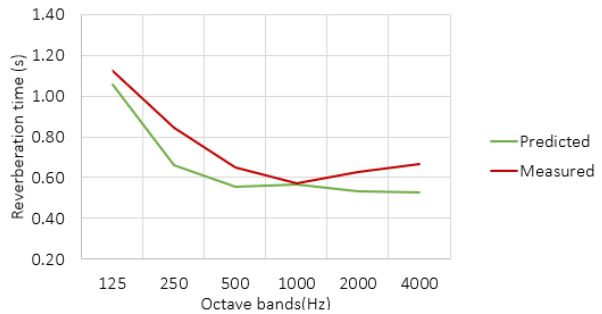

Figure 6. Homogeneous ceiling: comparison between predicted and measured RT.

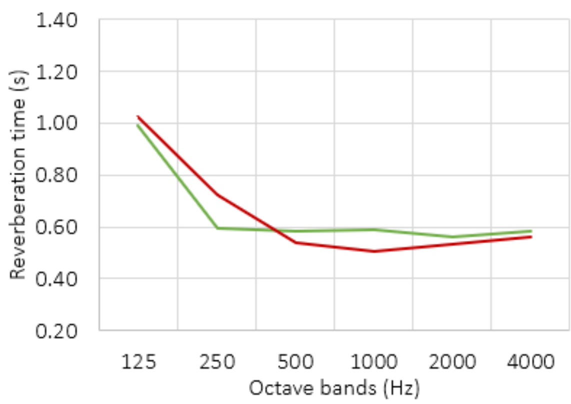

Figure 7. Inhomogeneous ceiling: comparison between predicted and measured RT.

Each material used in the inhomogeneous ceiling gives different contributions in sound absorption for each octave band from 125 Hz to 4000 Hz. To highlight this, pie plots of Figure 8 are shown in the octave band of 500 Hz and 2000 Hz.

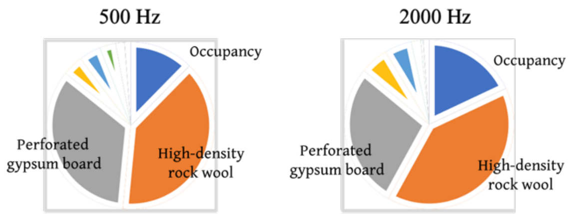

Figure 8. Pie plots with all relevant contributions regarding sound absorption at 500Hz and 2000Hz.

4. CASE STUDY 2: LECTURE HALL

The second case study is a lecture hall of the University of Bologna, with a volume of 1200 m^3 and 260 seats available (see Figure 9).

Figure 9. Lecture hall (University of Bologna, Bologna, Italy).

As before, the Reverberation Time in unoccupied conditions is calculated with the Eqn. 2 and each octave band. The obtained results are reported in the following table (Table 4).

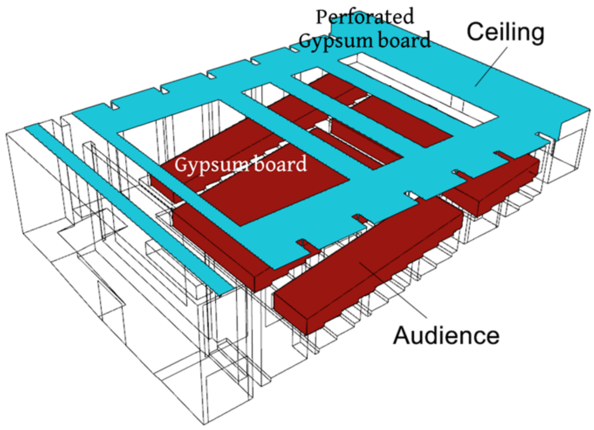

Figure 10. Lecture hall ceiling configuration.

Table 4. Reverberation Time results in unoccupied conditions | Lecture Hall.

	T_{ott}	T_{unocc}					
		125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Wooden seats	**0.82**	0.95	1.12	1.27	1.37	1.60	1.60
Upholstered seats	**0.82**	0.85	0.85	0.85	0.90	0.90	0.95

The mixed ceiling configuration is set as in Figure 10. Plotting the values obtained for the Reverberation Time in unoccupied condition and then adding for each octave band occupancy, it is clear that the Reverberation Time curve falls inside the range described by the RT - Target window.

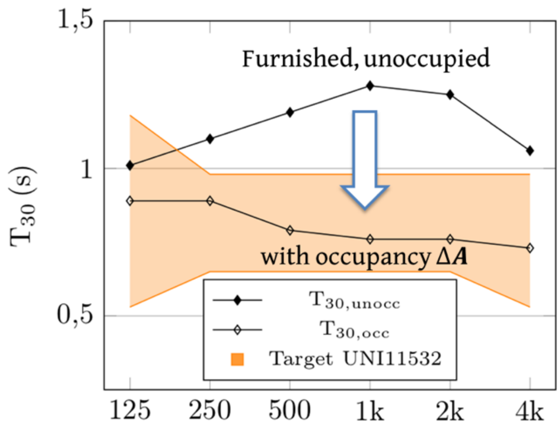

Figure 11. Lecture hall: measured values of RT in unoccupied conditions and correction through occupancy factor.

Let's note that, in this case, ceilings' acoustic design should focus on mid-low frequencies.

5. CONCLUSIONS

Italian Standard on classroom acoustics UNI 11532-2:2020 [1] was explained through case studies. The Reverberation Time target window depends on volume and considers occupancy absorption too. According to Italian Building Code, RT targets must be reached for every octave band in the 125-4000 Hz range and must be validated in the design process and measurements. Sound diffusion is needed, and measurements must be done in unoccupied but furnished conditions.
The occupancy absorption is negligible for classrooms (V=150-250 m3), and RT targets vary according to many Local Standards (in the presented case study T_{opt}=0.55s for V=160 m^3). The acoustic design should be focused on ceilings because they can contribute to sound diffusion, and a mix of materials (e.g. perforated gypsum board and rock-wool modules) allows to reach RT targets both for mid-low and mid-high frequencies.
For the Lecture hall (V>250 m^3), the Reverberation Time targets at high frequencies are reached by occupancy absorption, and the acoustic design of ceilings should be focused on mid-low frequencies [9].

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