PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

The new Italian standard UNI 11532 on acoustics for schools

Arianna ASTOLFI[1]; Linda PARATI[2]; Dario D'ORAZIO[3]; Massimo GARAI[3]

[1] Department of Energy, Politecnico di Torino, Turin, Italy

[2] Acustica Parati & Co., Crema, Italy

[3] School of Engineering and Architecture, University of Bologna, Italy

ABSTRACT

In Italy, the new UNI 11532 standard introduces requirements for acoustic comfort in different building typologies such as schools, offices and hospitals. In March 2018 the UNI 11532 - Part 1 "General requirements" was published, which includes the main descriptors related to noise, room acoustics and speech intelligibility to be considered for the design and verification phases. The drafting of Part 2, dedicated to schools, is now completed. This standard is voluntary for private constructions, but mandatory in the public sphere following the issue of the Ministerial Decree "Minimum Environmental Criteria (Criteri Ambientali Minimi or "CAM") for the awarding of design and construction services for new construction, renovation and maintenance of public buildings", dated 11 October 2017. The Decree explicitly refers to the UNI 11532 standard for the requirements to be guaranteed in public procurement. The underlying principles and criteria of the new standard in the case of schools, as well as comparisons with other standards in Europe, will be presented and discussed in this work.

Keywords: Classroom acoustics, Italian standard, Acoustic comfort, Speech intelligibility

1. INTRODUCTION

At the beginning of 2017 a new regulation has been issued in Italy for public buildings, making, for the first time, a distinction between public and private ones. It is the Ministerial Decree "Minimum Environmental Criteria (Criteri Ambientali Minimi or "CAM") for the awarding of design and construction services for new construction, renovation and maintenance of public buildings", dated 11 October 2017.

The new regulation goes more deeply into details distinguishing sound insulation and acoustical comfort and recalling technical standards, whose contents become compulsory. This standard is voluntary for private constructions, but mandatory in the public sphere.

Specifically, it explicitly refers to the Technical Standards UNI 11367 "Acoustic classification of buildings units – Evaluation procedure and in situ measurements" [1] for sound insulation and to the UNI 11532 "Internal acoustical characteristics of confined spaces" for acoustical comfort.

Just after the publications of the new CAM regulation in 2017, it was immediately clear for the experts at the Italian standardization body that the T.S. UNI 11532:2014 needed to be reviewed for better complying with the new regulation expectations. Moreover, the public tenders are based on the C.A.M.; this means that their contents must be explicit, that is i) clear goals, ii) specific predicting methods and iii) practical verification methods.

Due to the requirements listed above, the review transformed the original standard into a package of standards. Part 1 (published in 2018) is devoted to general issues, while part 2 (expected to be published in October 2019) is intended for schools, where the main goal is to achieve a good speech intelligibility. The end users will be teachers (vocal effort reduced) and students (attention encouraged).

The main indices to be verified are Reverberation Time (RT) and STI (Speech Transmission Index),

[1] arianna.astolfi@polito.it
[2] l.parati@acusticaparati.it
[3] dario.dorazio@unibo.it, massimo.garai@unibo.it

but in order to achieve the goals, background noise level must be also considered. The suitable values for RT are those listed in the DIN 18041:2016 [2], while for STI they have been referred to the UNI technical committee experience.

Background noise is a complicate issue in educational buildings. Basically, it can be defined as “all the other signals (noise) different from the one of interest”. In literature few information is given, such as the Student Activity Noise [3]; basically, background noise is due to environmental noise (external noise), students’ behavior, and noise from service equipment.

Background noise is one of the most important factors affecting speech intelligibility. As a matter of fact, STI depends on the signal to noise ratio (SNR). Here is the main point: the new UNI 11532 standard will be the reference document for public tenders, being cited in the CAM decree, and thus everything in it must be clear, predictable and measurable. On the other hand, service equipment and environmental noise are the only predictable aspects of background noise, while activity noise is neglected at the design and verification phases.

What seems to be the best way to solve the problem is to consider the teacher's vocal effort as *Normal* based on ANSI 3.5 [4], i.e. having L_{Aeq} equal to 60 dB(A) at 1 m, for rooms below 250 m^3, increased up to *Raised*, i.e. 70 dB(A) , for rooms above 250 m^3, with and without amplification systems; then, the room is designed so that, thanks to the optimal values of reverberation time and sound pressure level from service equipment (i.e. HVAC systems) and outdoor noise, a STI value suitable for special hearing or communication needs can be expected.

2. REQUIREMENTS

In relation to the activities the room is designed for, interventions are defined and, in cascade, the limit values, which already include the measurement uncertainty.

2.1 Identification of the environment in relation to its use

Table 1 shows the categories of the school environments in relation to their use covered by the UNI 11532 Part 2 Standard, with the objectives to be reached according to the activity carried out inside the rooms. Table 2 shows the detailed description of use for the categories from A1 to A5.

Table 1 – Categories of the school environments in relation to the use

Category	Activity	Interventions
A1	Music	Objective achieved with integrated design of geometries, furnishings, control of residual noise
A2	Speech/Conference rooms	
A3	Teaching/Speech communication/Convention rooms/Interaction rooms	
A4	Teaching/Speech communication, Special rooms included	
A5	Sport	
A6	Areas and spaces not intended for learning and libraries	Objective achieved with sound absorption and control of residual noise

2.2 Reference values for sound insulation and noise from service equipment

Reference values for the following acoustic descriptors are shown in UNI 11367, and correspond to the values identified as “superior performance”:

- weighted apparent sound reduction index, R'_w;
- weighted standardized sound level difference of a façade, $D_{2m,nT,w}$;
- weighted standardized sound level difference $D_{nT,;}$
- weighted normalized impact sound pressure level in field, L'_{nw};
- equivalent A-weighted sound pressure level in a room due to the sound produced by

continuously operating equipment or machinery in the building (e.g HVAC systems), installed out of the room under consideration, standardized to a reference reverberation time, L_{ic};

- A-weighted maximum sound pressure level in a room due to the sound produced by non-continuously operating equipment or machinery in the building, (e.g. waste water flow, lifts etc.), installed out of the room under consideration, standardized to a reference reverberation time, L_{id}.

Table 2 – Detailed description of use for the categories from A1 to A5

Detailed description of use				
Category		Description of use	Qualitative objective	Examples
A1		Music Mostly musical performances	Good acoustics for non-amplified music; limited speech comprehension	Music teaching rooms with live playing of music and singing
A2		Speech/Conferences Speech presentations where there is a frontal speaker	High grade of speech intelligibility	Classrooms, lecture theatres
A3	A3.1	Class A2 environments for people who have hearing impairment or non-native speakers or special classrooms	High degree of speech intelligibility even for people with hearing impairment or non-native speakers or with language differences	Classrooms, lecture theatres
	A3.2	Speech Communication with the simultaneous presence of several people speaking in the classroom	High degree of speech intelligibility even with multiple speakers simultaneously	Classrooms, classrooms for interviews, classrooms for seminars, classrooms for study or work groups, laboratories, administrative offices, teachers' rooms and similar
A4		More people talking in the room (like Category A3.2) and intended for people with special needs (special classrooms) Excluding special classrooms with volume over 500 m^3, or for musical activities	High degree of speech intelligibility with multiple speakers simultaneously, and for people with hearing impairment or non-native speakers or with language differences	Classrooms, classrooms for interviews, classrooms for seminars, classrooms for study or work groups, laboratories, administrative offices, teachers' rooms and similar. Rooms for videoconferences
A5		Sports: swimming pools and gyms and similar	Speech communication possible but at short distances	Pool and gyms for use as sports environments in general

2.3 Reference values for STI

This descriptor applies to the categories A1, A2, A3 and A4 in Table 1 and Table 2. For environments smaller than 250 m^3 as an alternative to STI the descriptor C_{50} can be used. The reference values for STI in furnished and unoccupied environments are shown in Table 3. These values refer to the arithmetic average of the measured values in the measurement positions as shown in Figure 1 and Table 5.

For STI and C_{50} measurements, a sound source with a directivity approximating that of a human speaker should be used, in compliance with ITU RECOMMENDATION P.58 [5], or ITU-T P.51 -compliant speakers [6].

Table 3 – Reference values for STI

	V< 250 m^3	V≥ 250 m^3
Without amplification system or with system off	≥ 0.55 with source output at 1 m on axis equal to 60 dB(A).	≥ 0.50 with source output at 1 m on axis equal to 70 dB(A).
With amplification system	≥ 0.60 with source output as in normal conditions of operation of the amplification system	

2.4 Reference values for C_{50}

The C_{50} descriptor can be used as an alternative to STI for categories A1, A2, A3 and A4 exclusively for environments smaller than 250 m^3. For environments with V ≥ 250 m^3 only STI is applicable. The reference values for C_{50} are shown in Table 4. They refer to furnished and empty rooms. The limit values refer to the arithmetic average of the measured values in the measurement positions shown in Figure 1 and Table 5. The C_{50} values in each single measurement position are obtained as the arithmetic average of the measured values in the octave bands 500-1000-2000 Hz.

Table 4 – Reference values for C_{50}

	< 250 m^3
Without amplification system or with system off	≥ 2 dB

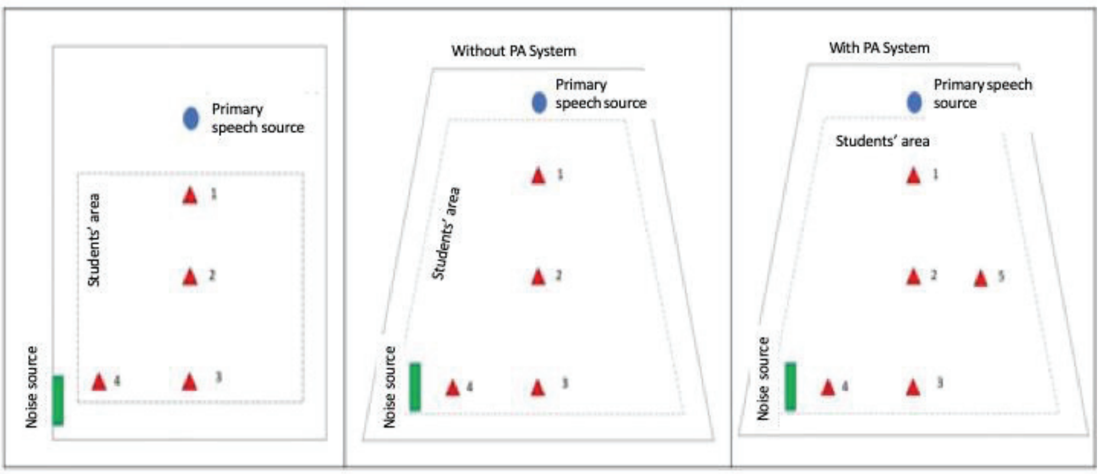

Figure 1 – Examples of measurement positions in classrooms with and without amplification system

Table 5 – Mandatory and optional measurement positions for speech intelligibility

	$V < 250\ m^3$		$V \geq 250\ m^3$	
	$STI - C_{50}$		STI	
	Without amplification system or with system off		Without amplification system or with system off	With amplification system
Positions	mandatory	optional	mandatory	mandatory
1		x	x	x
2	x		x	x
3		x	x	x
4	x		x	x
5				x

2.5 Reference values for reverberation time

The optimal reverberation time, T_{ott}, corresponding to a conventional room occupation of 80%, with the exception of category A5, is determined according to the specific room activity as a function of the room volume, according to the formulas shown in Table 6. Figure 2 shows the dependence of the optimal reverberation time from the volume, and Figure 3 shows the T_{ott} frequency dependence. Formulas and graphs derive from DIN 18041.

Table 6 – T_{ott} (s) calculation formulas for categories from A1 to A5

Category	80% occupied room	
A1	$T_{ott,A1} = (0.45\log V + 0.07)$	$30\ m^3 \leq V < 1000\ m^3$
A2	$T_{ott,A2} = (0.37\log V - 0.14)$	$50\ m^3 \leq V < 5000\ m^3$
A3	$T_{ott,A3} = (0.32\log V - 0.17)$	$30\ m^3 \leq V < 5000\ m^3$
A4	$T_{ott,A4} = (0.26\log V - 0.14)$	$30\ m^3 \leq V < 500\ m^3$
Category	Unoccupied room	
A5	$T_{ott,A5} = (0.75\log V - 1.00)$ $T_{ott,A5} = 2.00$	$200\ m^3 \leq V < 10000\ m^3$ $V \geq 10000\ m^3$

As said, for categories A1, A2, A3 and A4 the requirements for the reverberation time refer to the furnished and occupied state at 80% of the capacity. The conversion between the values in the occupied status to the values in the unoccupied but furnished state, as at the time of the verification, must be carried out in accordance with Eq. 1, in the octave bands between 125 Hz and 4000 Hz:

$$T_{inocc} = \frac{T_{occ}}{1 - T_{occ}\frac{\Delta A_{pers}}{0.16V}} \quad (1)$$

where:

T_{occ} is the optimal reverberation time for the room occupied at 80%, in s;

T_{inocc} is the optimal reverberation time for the unoccupied, furnished room, in s;

V is the volume of the room, in m^3;

ΔA_{pers} is the area of equivalent absorption of persons, in m^2.

For the category A5 only the octave bands between 250 Hz and 2000 Hz are considered. For the category A6, the reference values are always considered for furnished and unoccupied conditions and the optimal value of the reverberation time is a function of the equivalent absorption area, in m^2, and of the geometric characteristics of the environment (volume and height).

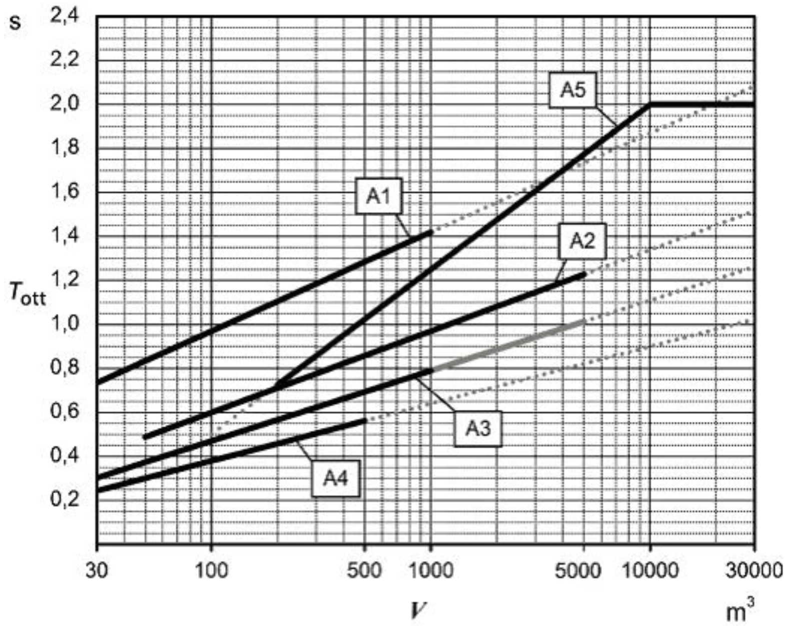

Figure 2 – Dependence of the optimal reverberation time T_{ott} from the volume and the mode of use

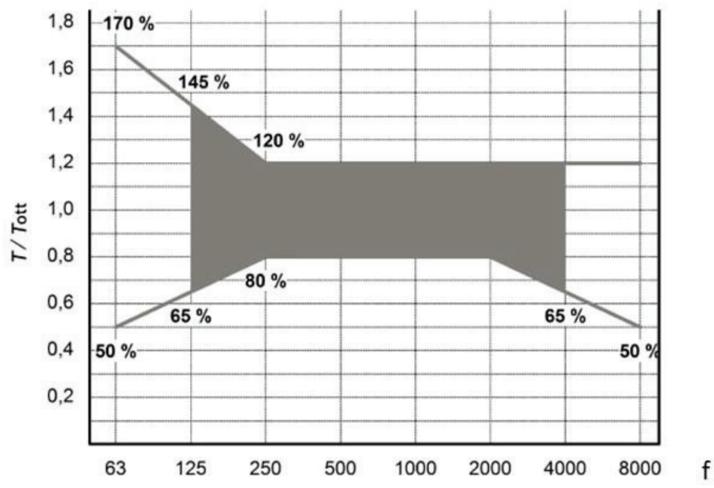

Figure 3 – Target range for T_{ott}, as a function of frequency for the categories from A1 to A4

Table 7 – Reference values for $L_{ic,int}$, NC and L_{amb}.

Mode of use	$L_{ic,int}$ dB(A)	NC	L_{amb} dB(A)
Classrooms and libraries with V < 250 m^3	≤ 34	≤ 25	≤ 38
Classrooms and libraries with V ≥ 250 m^3	≤ 38	≤ 30	≤ 41
Single office	≤ 35	≤ 25	≤ 38
Exhibition environments, rooms for studying	≤ 45	≤ 35	≤ 48
Gyms, swimming pools, administrative offices, laboratories, areas open to the public, canteens, corridors, reception / area	≤ 45	≤ 35	≤ 48

desk			

2.6 Reference values for noise from continuous operation systems inside the room

In UNI 11532-2, the noise due to continuous operation systems, i.e. from HVAC systems, is expressed by the descriptor $L_{ic,int,}$ which is defined as the energy spatial average of the $L_{pu,c}$ values obtained at the measurement positions shown in Figure 1. $L_{pu,c}$ is the equivalent A-weighted sound pressure level at a specific position in a room due to the sound produced by equipment or machinery installed in the room under consideration, standardized to a reference reverberation time. Alternatively, NC [7] limit values can be ensured. Table 7 shows the reference values for $L_{ic,int}$ and NC.

2.7 Reference values for environmental noise

The determination of the overall noise that occurs in the furnished and unoccupied room, is essential for a clear understanding of speech in the teacher-student relationship and of the speech among pupils. The overall noise level in an environment, L_{amb}, is determined by:

1. Noise due to sources outside the school (noise from vehicular or railway traffic, noise from commercial or industrial activities, etc.);
2. Noise from continuous operation systems serving the environment (mechanical ventilation systems, heating, cooling, vents, etc.).

The noise coming from continuously operating systems in the building, installed out of the room under consideration, is subject to compliance with UNI 11367. The environmental noise level in the room, L_{amb}, must comply with the limit values in Table 7.

3. PREDICTION AND VERIFICATION METHODS for STI, C_{50}, T, $L_{pu,c}$ and L_{amb}

3.1 Prediction methods

The prediction methods for STI, C_{50} and reverberation time are reported in UNI 11532-1.

The prediction methods for STI refers to CEI EN 60268-16 [8]. Two methods are available: (1) calculation based on a predicted direct field, combined with an exponential reverberant decay; statistically calculated reverberation times may be used here; (2) prediction based on a simulated impulse response of the system in the acoustic space. Predictions based on simulated impulse response offer a higher degree of precision. For the STI descriptor, the values obtained in the 4 kHz octave band will also be extended to the 8 kHz octave band if data are not available.

C_{50} can be determined as a function of the volume, V, of the reverberation time, T, and of the source-receiver distance, r, with the Barron & Lee theory [9], according the formula:

$$C50(r) = 10log\frac{\frac{100}{r^2}+\left(\frac{31200T}{V}\right)\left(1-e^{\frac{-0.691}{T}}\right)e^{\frac{-0.04r}{T}}}{e^{\frac{-0.04r}{T}}\left(\frac{31200T}{V}\right)\left(e^{\frac{-0.691}{T}}\right)} \qquad (2)$$

The prediction method for calculating the reverberation time is described in EN 12354-6, while for $L_{pu,c}$ the reference standard is the EN 12354-5.

The indoor sound pressure level due to noise sources outside the school, i.e. the residual noise level, is obtained from the external noise level, the sound insulation property of the façade and the reverberation time, according to Eq. (E.2) of EN 12354-3. L_{amb} is obtained from the logarithmic sum of the residual noise level and the noise due to continuous operation systems in the room, $L_{ic,int}$.

3.2 Verification methods

The verification method for STI is described in CEI EN 60268-16 [8], while for C_{50} and T in EN ISO 3382. The procedures and conditions for measuring the noise from HVAC systems for ordinary environments are described in UNI 8199 [10].

The measured values of each quantity, before being compared with the reference values, must be corrected with the measurement uncertainty as specified in the Standard. The comparison with the NC curves must be carried out as usual without considering the measurement uncertainty.

The assessment of the measurement uncertainty is based on the experimental approach in terms of repeatability and reproducibility, which leads to an evaluation of the typical uncertainty of a given measurement method based on inter-laboratory tests.

4. FINAL REMARKS

The new UNI 11532-2 builds on the previous experience in other European countries. For example, the classification of the different spaces in relation to their use and the determination of the optimal reverberation times are taken from DIN 18041 [2]. BB93 was a reference for many concepts and procedures and also gave input the for establishing some limit values, like the indoor ambient noise level. However, all this was fitted to the Italian situation. For example, UNI experts had to consider the case of a school building in the city center, exposed to high traffic noise levels, where windows cannot be opened, and thus mechanical ventilation systems are installed. Regarding equipment noise, there no single international standard covering all issues: limit values for both equipment external or internal to the room under consideration, calculation procedures to be used at design stage consistent with procedures for verification of the installed equipment etc. Therefore, prescriptions from national (e.g. UNI 8199) and international (e.g. EN 12354-6) standards were harmonized. It was considered that verifications must be done in empty rooms, because according to the law they can be used only after a positive verification, and thus an unambiguous link between the unoccupied and occupied conditions had to be specified. Limit values were specified considering that in Italy most classrooms lack of a PA system and many surfaces are not sound absorbing: linoleum or ceramic tiles on the floors, smooth wall for water cleaning etc. Last but not least, single parts of the standard are applicable to (partial) refurbishments of schools.

REFERENCES

[1] UNI 11367 (2010) "Acustica in edilizia - Classificazione acustica delle unità immobiliari - Procedura di valutazione e verifica in opera". ("Building acoustics - Acoustic classification of building units - Evaluation procedure and in situ measurements").
[2] DIN 18041 (2016). "Hörsamkeit in Räumen—Anforderungen Empfehlungen und Hinweise für die Planung" ("Acoustic quality in rooms—specifications and instructions for the room acoustic design") (German Institute for Standardisation, Berlin).
[3] Hodgson M, Rempel R, Kennedy S. Measurement and prediction of typical speech and background-noise levels in university classrooms during lectures. J. Acoust. Soc. Am. (1999); 105(1):226-233.
[4] ANSI/ASA S3.5-1997 (R2017). "Methods for Calculation of the Speech Intelligibility Index".
[5] ITU Recommendation P.58 (1994) "Head and torso simulator for telephonometry".
[6] ITU-T P.51 (1996), "Telephone transmission quality – Objective measuring apparatus – Artificial mouth".
[7] Schaffer ME. A Practical Guide to Noise and Vibration Control for HVAC Systems (SI), 2nd ed., ASHRAE, 2011.
[8] CEI EN 60268-16 (2012). "Sound system equipment Part 16: Objective rating of speech intelligibility by speech transmission index".
[9] Barron M, Lee L-J. Energy relations in concert auditoriums, J. Acoust. Soc. Am. (1988); 848(2):618-628.
[10] UNI 8199 (2016). "Acustica in edilizia - Collaudo acustico di impianti a servizio di unità immobiliari - Linee guida contrattuali e modalità di misurazione all'interno degli ambienti serviti." ("Building acoustics - Acoustic testing of service equipment in buildings - Contractual guidelines and measurement methods inside served buildings")