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CLARITY OF THE SPOKEN IN THE UNIVERSITY CLASSROOMS

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Abstract

This paper evaluates the clarity of the spoken languages in university classrooms of the Department of Technical Physics of the Faculty of Engineering of the University "La Sapienza" of Rome. Acoustic measures, according to the indications of the norm ISO 3382:1997, the sound pressure level values, the EDT values and the reverberation time values in octave band have given, further the energetic relationships between early/late reflections, and the central time values have given. The measured values have been compared with the law limits in the scholastic environments, imported by the German norm DIN 18041:2004-05 "Hörsamkeit in kleinen bis mittelgrossen Räumen" (Audibility in small spaces and of average greatness) and by the Italian standard DM 18/2/1975 (Ministerial Decret). The SGA-SSA (Society Switzerland of Acoustic) have an own directive founded on the same German standard. By the use of the software "Odeon B&K", the acoustic field and the values of the acoustic parameters of the classroom of the Department of Technical Physics have been calculated. The simulated values and the measured values in the same classroom have been compared.

INTRODUCTION: ACOUSTIC QUALITY IN SCHOLASTIC CLASSROOMS

The acoustic quality of a scholastic classroom is influenced by physical factors as the distance by the teacher, the reverberation time, the background noise making difficult the understanding teachers lessons. Several studies show as the intelligibility decreases if the distance students - teacher increases. If intelligibility is 95% at distance of two meters, it decreases to 50% at distance of ten meters. The listener perceives the sound as overlap of direct and reflected sonorous waves. In according to the World Health Organization (OMS) - but also in according to different laws - the reverberation time of the scholastic classrooms has to be inclusive within the interval of 0,6 and 0,8 seconds. Background noise is mainly due to the external noise; it reduces the intelligibility, through:

- the auditory masking word, that is the inability to distinguish a sound in presence of a noise with the same level and frequency;
- the low attention level of the students.

Many Nations have established some acoustic standards for the scholastic environments, with particular attention to children handicap bearers. The new standards are based on the spoken student perception. Jack B. and Evans P.E., in 2004 on JEAcoustics [1] , the different standards for the acoustic quality of the classrooms for every Nation varying the background noise, the reverberation time and the acoustic building isolation, have published. In Italy the acoustic standard scholastic buildings are still fixed in the old D.M. of 18/12/1975 "Norme tecniche aggiornate relative all'edilizia scolastica, ivi compresi gli indici di funzionalità didattica, edilizia ed urbanistica, da osservarsi nella esecuzioni di opere di edilizia scolastica". The mentioned D.M.'75 considers the parameters to guarantee the minimal habitability conditions for the scholastic environments. For the acoustic section, it indicates an optimal reverberation time in function of the classroom volume varying with the frequency. The new Germany DIN 18041/2004 "Hörsamkeit in kleinen bis mittelgrossen Räumen", indicates the optimum reverberation time for the scholastic environments:

$$T = 0,32 * \log(V) - 0,17 \qquad [s] \qquad (1)$$

where T is the optimal reverberation time mediated between octave bands at 500Hz and 1kHz and calculated on the occupied room volume (V [m^3]). In fig.1 the optimal reverberation time for various activities are represented.

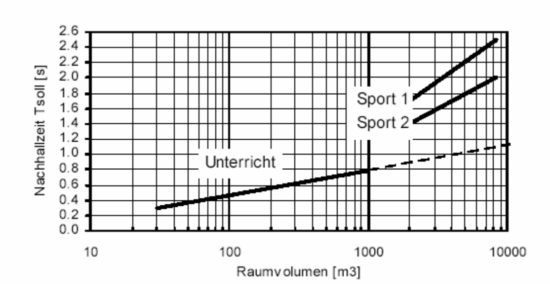

Figure 1-DIN18041:2004 optimal reverberation time, for the octave bands 500Hz and 1000 Hz, in function of the occupied room volume.

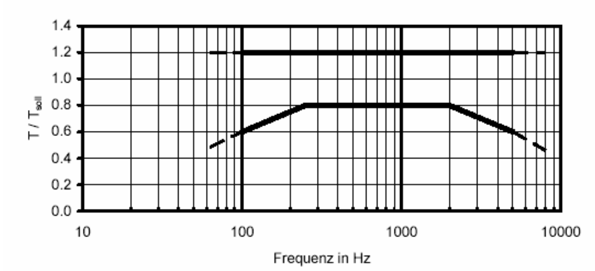

Figure 2 -DIN 18041:2004 tolerance band fir the recommended reverberation time as function of the frequency: T reverberation time - T_{ot} optimal recommended reverberation time of fig.1.

For unoccupied room, the reverberation time should not exceed the recommended values more than 0,2 sec. For volume rooms until 250 m^3 and with use spoken lessons, the optimal reverberation time should be until 20% low the curve of Fig. 2 in the interval frequencies within 250 Hz and 2 kHz. In the DIN 18041/2004 the admissible background noise levels, for different use of the room, are brought back. (tab.1). The minimum requirements of the C50, intelligibility CIS, STI and % ALcons index are given in tab.2 in function of the room size.

Tab.1- DIN 18041/2004 admissible background noise levels

Schalltechnische Anforderungen an die Raumnutzung	Störgeräusch-pegel L_{NA} dB	Eignung[a] für eine Entfernung: Sprecher – Hörer		Eignung[a] für Personen mit Hörverlusten	Eignung[a] für die Wahrnehmung schwieriger oder-fremdsprachiger Texte
		mittlere [b c]	grössere [b]		
I (mindest)	≤ 40 (laut)	+	-	-	-
II (mittlere)	≤ 35 (mittel)	+	o	o	o
III (hohe)	≤ 30 (leise)	+	+	+	+

[a]) "+" geeignet, "o" bedingt geeignet, "-" nicht geeignet
[b]) Für eine mittlere Entfernung zwischen Sprecher und Hörer kann üblicherweise ein Abstand von 5 m bis 8 m, für grössere Entfernungen > 8 m, angenommen werden.
[c]) Auch geeignet für geringere Entfernungen zwischen Sprecher und Hörer bis etwa 5 m.

Tab.2-DIN18041/2004 optimal values of the C50 indexes, of the intelligibility, of the STI and of the% ALcons index are brought back.

Raumtyp	Deutlichkeitsmass C_{50}	Common Intelligibili-ty Scale *CIS*	Speech Trans-mission Index *STI*	Articulation Loss of Consonants Al_{cons}
Kleines Auditorium, Hörsaal, Unterrichts-raum	≥ 0 dB	≥ 0,75	≥ 0,56	< 8 %
Sport- und Schwimmhallen mit Publikum	≥ -2 dB	≥ 0,70	≥ 0,50	< 12 %

DATA ANALYSIS

Oral speech transmission in six classrooms of the Engineering Faculty of the University "La Sapienza" of Rome have been calculated. The study is done by the impulse response to a logarithmic sweep signal in according to the indications of the norm ISO 3382 of 1997 " Misura del tempo di riverberazione in stanze con riferimento ad altri parametri acustici". Obtained the measured impulse response, the following parameters have been calculated by the Dirac software of B&K:

- Early Decay Time: EDT;
- Reverberation Time: T30; in all the classrooms the relationship signal/noise is greater than 45 dB, the T30 can be considered the reverberation time that must be compared with reverberation time values of the Italian and German norms;
- Central Time: Ts;
- Clarity Index :C50;
- definition Index: D50;
- Speech Transmission Index:

- STI for a male and female voice;
- Articulation Loss of Consonants: % ALcons

The obtained T30, C50 and STI values for every classroom have been compared with the optimal values of the DIN18041/2004 " Hörsamkeit in kleinen bis mittelgrossen Räumen " and with the optimal reverberation time of the D.M. 18/12/75. In the classroom an excitation signal is generated by the software DIRAC B&K, amplified by a Amplifier Type 2716 B&K and envoyed to OmniPower Sound Source type 4296 of the B&K. The recorded signal by a microphone receiver has been send to the pc. The amplifier system source is regulated for a midium pressure level of 75 dBA. The sonorous source has been placed in proximity of the blackboard at height 1,7 m, in the usual position of the teacher; the microphone/receiver is positioned in the center room at height 1,3 m. In the tab.3 the measured acoustic parameters values are reported for each analyzed occupied classroom.

Tab.3 -Measured acoustic parameters for every classroom.

	Classroom 1 $V=738m^3$ $S=190m^2$ $A^{a}_{(500H)}=28,42m^2$ $\alpha^{b}=0.26$		**Classroom 10** $V=229m^3$ $S=65m^2$ $A^{a}_{(500H)}=41m^2$ $\alpha^{b}=0.17$		**Classroom 11** $V=448m^3$ $S=140m^2$ $A^{a}_{(500H)}=90,73m^2$ $\alpha^{b}=0.22$		**Classroom 7** $V=316m^3$ $S=105m^2$ $A^{a}_{(500H)}=25,28m^2$ $\alpha^{b}=0.07$		**Classroom 8** $V=376m^3$ $S=125,44m^2$ $A^{a}_{(500H)}=37,44m^2$ $\alpha^{b}=0.09$		**Classroom 5** $V=269,57m^3$ $S=99,84m^2$ $A^{a}_{(500H)}=59,93m^2$ $\alpha^{b}=0.19$	
	Wall and ceiling are covered by fono-absorbent material		Ceiling is covered by fono-absorbent material		Ceiling is covered by fono-absorbent material		Classroom is lacking of fono-absorbent material		Classroom is lacking of fono-absorbent material		Ceiling is covered by fono-absorbent material	
	500Hz	1KHz	500Hz	1KHz	500Hz	1KHz	500Hz	1KHz	500Hz	1KHz	500Hz	1KHz
EDT (s)	1,03	1,26	0,87	0,68	0,83	0,75	1,81	1,45	2,05	1,63	0,73	0,49
T30 (s)	0,92	1,0	0,89	0,8	0,79	0,85	2,0	4,4	1,73	1,5	0,72	0,49
Ts (ms)	83	74,3	66,1	55,7	76,4	73,8	129,9	111,8	163,2	121,9	51	36
C50 (dB)	1,89	2,81	5,14	6,18	2,37	3,2	-0,81	0,34	-1,84	-0,66	5,24	9,34
D50 (%)	0,44	0,49	0,55	0,63	0,4	0,46	0,37	0,35	0,26	0,34	0,61	0,76
STI_{female}(%)	0,62		0,7		0,66		0,52		0,48		0,74	
% AI_{consf}	5,9		3,9		4,8		10,3		12,5		3	
STI_{male}(%)	0,61		0,69		0,66		0,51		0,48		0,74	
% AI_{consf}	6,2		4		4,9		10,6		12,9		3,1	

[a] A: fono-absorbent unit number

[b] α: medium absorption coefficient

Tab.4 - Comparison measured and calculated reverberation time values, as DM 18/12/1975 and as DIN 18041:2004.

	Reverberation time DM 18/12/1975		Reverberation time DIN 18041:2004	T30 calculated values processed by software Dirac	
	500Hz	1000Hz	500Hz-1000Hz	500Hz	1000Hz
AULA 1	1,03	0,91	0,83	0,98	0,88
AULA 10	0,97	0,85	0,78	0,89	0,8
AULA 11	1,09	0,96	0,87	0,95	0,95
AULA 7	1,03	0,96	0,83	2,0	1,4

AULA 8	1,06	0,96	0,85	1,73	1,5
AULA 5	1	0,88	0,8	0,72	0,49

The results show that the classrooms n°7 and n°8 need an acoustic correction. The classrooms are too much reverberant, the C50 and ALcons% values are out side of the DIN 18041/2004 limits

DIDACTIC CLASSROOM ACOUSTIC ANALYSIS

The volume of the classroom is 331 m^3 and the size is 9,50 x 9,00 (m^2), with a ceiling covered with fono-absorbent panels. The fono-absorbent units of the classroom at 500Hz are 50,40m^2. The study has been carried out by experimental measures, processed by the Dirac software and the numerical simulation. Planning the absorption coefficients of the covering surfaces, the simulate values are calibrated on the experimental values by measured impulse response. The difference between the experimental and the simulate values, for the same source and receiver position, have been compared (tab.5).

ODEON SOFTWARE

Odeon 6.0, B&K is a software for the acoustics confined spaces. The algorithm is based on the hybrid method: Source Imagine and Ray-Tracing. Geometry room are imported like cad 3Dface, file.DFX, or constructed, with a parametric language, through the software Odeon. The materials are defined through an absorption coefficient in the range frequencies 63Hz – 8 kHz and with a scattering coefficient. The material bookcase can be extended. The sonorous source can be defined as point, linear and superficial and defined with a directivity diagram, gain, equalization and delay; it's possible to reproduce the real sonorous source: like musical instruments, oratories, loudspeakers, small noise sources. It must be defined the position and the direction of the sonorous source.

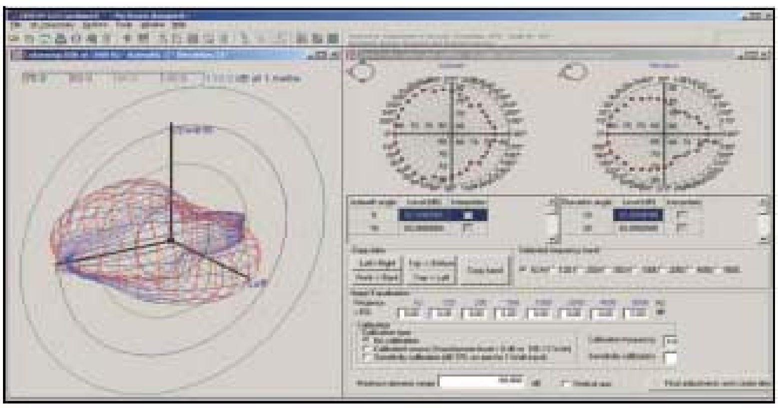

Figure 3-Directivity source characterization

The decay curves are determined with two methods: the Quick Estimate, based on statistics analysis and the Global Estimate based on the hybrid method: image Source and Ray-Tracing. This method adds to the first part of the impulse response, calculated more or less determinist, a late sonorous coda obtained by statistical relations. The Quick Estimate derives the reverberation time by the Sabin, Eyring and Arau-Pachades statistics formulas, and permits to know the reverberation time varying the absorbent surfaces distribution.

ODEON RESULTS

The geometry 3D of the furnished room is showed in fig.4.

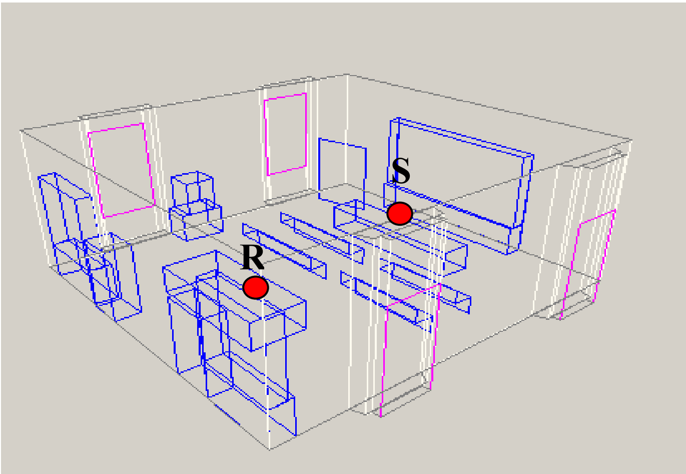

Figure 4 -Furnished didactic classroom

The file. Dxf, imported in Odeon, shows the source at height 1,70m and the receiver at height 1,20, in the same positions of the measurements. The omni-directional source power level is 80dB. With the 3D Investigate Ray Tracing key it has been verified the set up characteristics, after we have calculate Global Estimate. The check allows to set up correctly the excitation signal length to avoid the calculation error. If the length signal is smaller than 60% of the reverberation time, some indexes (as the T30) cannot be calculated, because the dynamic range of the impulse response is smaller than 30 dB. It is necessary that the excitation signal length is comparable to the reverberation time

The simulated acoustic parameters values with software ODEON have been compared with the experimental values derived by impulse response measured.

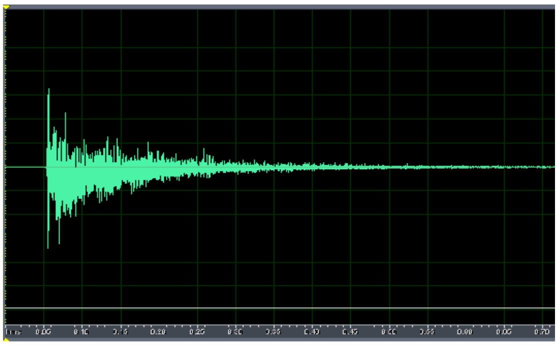

Figure 5.a -Simulate Impulse Response with software Odeon 6.0

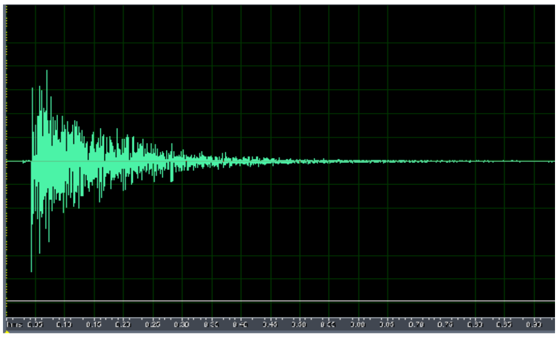

Figure 5.b -Measured Impulse Response with software Dirac

Tabella5- Comparison between simulated and calculated acoustic parameters in the didactic classroom of the Department of Technical Physics.

Didactic Classroom			EDT	T30	Ts	C50	D50	STI $_{female}$(%)	% AI_{consf}	STI $_{male}$(%)	AI_{consf}
ceiling is covered by fono-absorbent material **V** =331**m^3** **S= 89,91 m^2** **$A^{a}_{(500H)}$=50,4 m^2** **α^{b}= 0,17**	*DIRAC*	500Hz	1,02	0,98	74	4,3	0,44	0,67	4,5	0,66	4,7
		1kHz	0,8	0,88	63,7	4,14	0,54				
	ODEON	500Hz	1	1,05	68	3,94	0,54	0,62		0,62	
		1kHz	0,91	0,97	61,61	4,66	0,57				

[a] A: fono-absorbent unit number

[b] α: medium absorption coefficient

In table 5 the comparison between the calculated and simulated acoustic parameters in the didactic classroom and the relative refuse percentage, at the frequency of 500Hz and 1kHz are showed. The measured and the simulated values are similar.

Tab.6 -Comparison between the calculated and simulated values of reverberation time and those recommended by norm: DM 18/12/1975 and DIN 18041:2004.

	Reverberation time DM 18/12/1975		Reverberation time DIN 18041:2004	T30 Simulated values with software ODEON		T30 Calculated values processed by software Dirac	
	500Hz	1000Hz	500Hz-1000Hz	500Hz	1000Hz	500Hz	1000Hz
Didactic Classroom	1,03	0,91	0,83	1,05	0,97	0,98	0,88

In the tab.6 are showed the comparison between the measured and simulated values of reverberation time and the recommended reverberation time of DM 18/12/1975 and DIN 18041/2004. The classroom is excessively reverberant, the values reenter instead in the ranges proposed by the Italian norm.

CONCLUSIONS

The classroom acoustic behaviour is considered "good" in the classroom n°5, it can be considered "acceptable" in the nn° 1,10,11 and in the didactic classroom, and it is not "good" in the classrooms nn° 7, 8. In both the classrooms, n°7 and n°8 fonoabsorbent treatments are not present.

The German norm imposes more restrictive limits for the reverberation time in comparison to the Italian norm; moreover in the DIN 18041/2004 is brought back the C50, STI and %ALcons admissible limit values, particularly indicates to estimate the intelligibility spoken. As far as the Italian norm on such theme a review with the introduction of other parameters has attended. These parameters can better define the acoustic quality in the classrooms.

REFERENCES

[1] Jack B, Evans P.E., "Acoustical Standards for Classroom Design Comparison of International Standards and Low Frequancy Criteria", JEAcoustics 2004
[2] DM 18/12/1975 Norme tecniche aggiornate relative all'edilizia scolastica, ivi compresi gli indici di funzionalità didattica, edilizia ed urbanistica, da osservarsi nella esecuzioni di opere di edilizia scolastica.
[3] DIN 18041:2004 Hörsamkeit in kleinen bis mittelgrossen Räumen.
[4] ISO 3382 del 1997 Misura del tempo di riverberazione in stanze con riferimento ad altri parametri acustici.
[5] H.G.Schonwalder, J.Berndt, F.Strover, G.Tiesle, "Larm in Bildunsstatten – Ursachen und Minderung",Dortmund – Berlin Dresden 2004.