Knauf room acoustics | 03/2006

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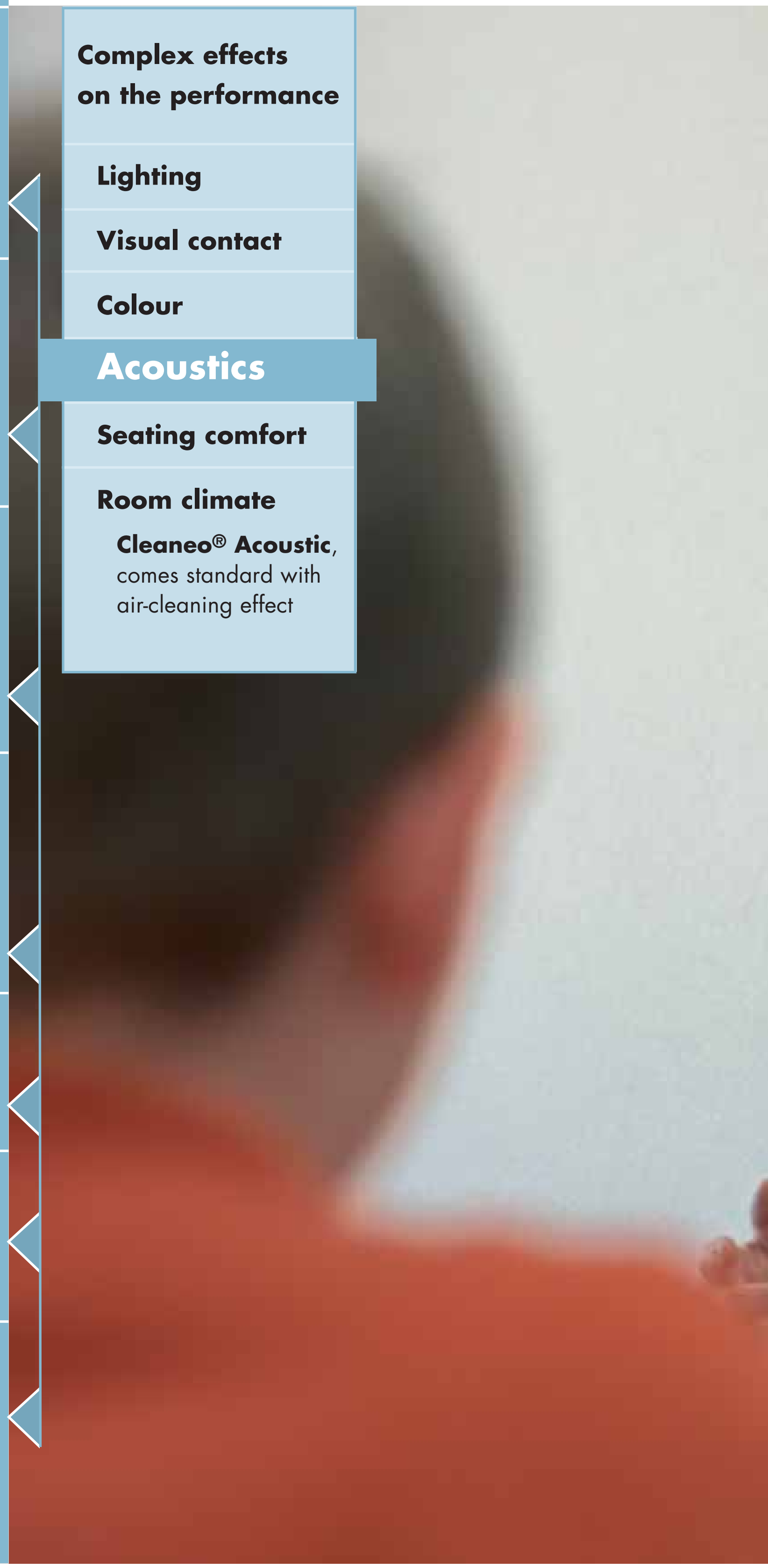
Comes standard with air-cleaning effect



Complex effects on the performance

- **Lighting**
- **Visual contact**
- **Colour**
- **Acoustics**
- **Seating comfort**
- **Room climate**
  - **Cleaneo® Acoustic**, comes standard with air-cleaning effect

DIN 18 041 for classrooms up to 250 m³

Poor room acoustics cannot be compensated by any other factors influencing the students' performance. Here, professional design capabilities directly effect the room's usability. In this bulletin we explain acoustical correlations, present design criteria and methods based on DIN 18041 and offer workable dimensioning tables for classrooms up to 250 m³.

Speaking volume

In general, a teacher is able to continuously speak twice as loud as the ambient background noise as long as this stays below about 45 dB (A).

Measured at a distance of one metre, the A-rated sound pressure level for a person speaking in a classroom:

relaxed voice	54 dB(A)
normal voice	60 dB(A)
raised voice	66 dB(A)
loud voice	72 dB(A)

However, when the background noise level reaches 50 dB(A) due to structural deficiencies or disturbances, the teacher is exposed to an extremely high and unacceptable physical strain – even if only temporarily.

This affects performance

- There is no getting used to background sounds
- Noise impacts the receiving and processing of the teaching content
- The ability to concentrate of both students and teacher is hampered
- The students' performance drops

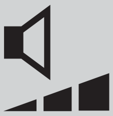
Desired signal and **interfering signal**

Besides the desired signal (speech), there is also the interfering signal (background sounds). For students to acoustically understand the teacher, he or she has to speak at least twice as loud as the background noise for listeners with normal hearing (a 10 dB difference in sound pressure level); and three to four times as loud for hearing impaired (a difference in sound pressure level of 15 - 20 dB).

Clarity improving

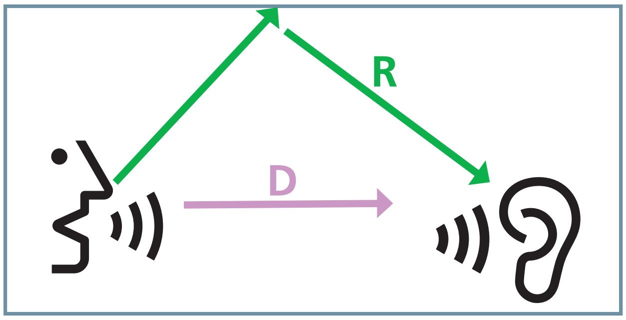
Direct sound D and acoustic reflections R with a difference in travel distance of the sound beams of up to 17 m (travel time difference of up to 50 ms)

Here, the unit ms denotes milliseconds



Example:

Assuming an average speaker-to-listener distance of 2 m at about 1.5 m above the floor and a ceiling height of 3.5 m, the travel distance of the direct sound D = 2 m while that of the acoustic reflections via the ceiling is R = 4.5 m, i.e. the difference in travel distance comes to (4.5 – 2) m = 2.5 m. With an acoustic velocity of some 340 metre per second, the **travel time difference is about 7 ms**, i.e., the acoustic reflection via the ceiling **improves the clarity** in this room.



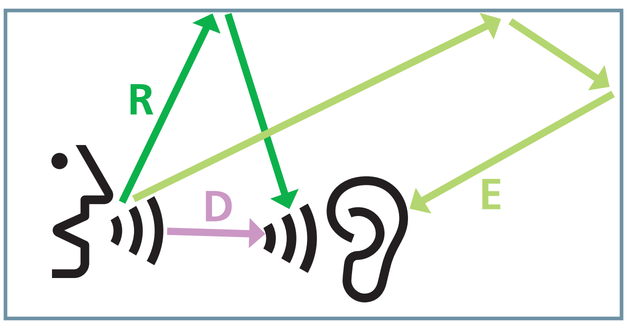
Clarity degrading

Acoustic reflections R with a difference in travel distance of the sound beams of more than 17 m (travel time difference greater than 50 ms)

Echo E with a difference in travel distance of the sound beams of more than 34 m (travel time difference greater than 100 ms)

Example:

Ceiling reflection: Assuming, once again, an average speaker-to-listener distance of 2 m at about 1.5 m above the floor and a ceiling height of 12 m, the travel distance of the acoustic reflections via the ceiling is now R = 21 m, i.e. the difference in travel distance equals (21 – 2) m = 19 m. With an acoustic velocity of 340 metre per second, the travel time difference comes to about 56 ms, i.e. the acoustic reflection via the ceiling degrades the clarity in this room.

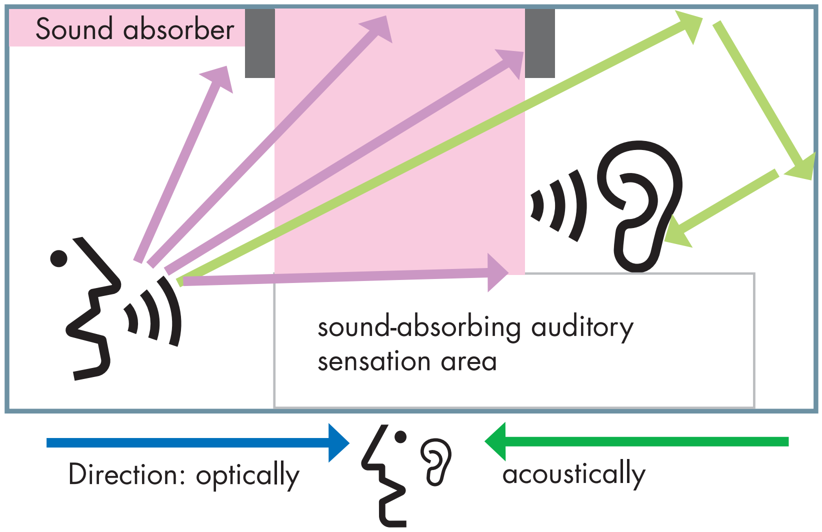


Echo: Again assuming an average speaker-to-listener distance of 2 m at about 1.5 m above the floor, this time for a room with a length of 24 m and a ceiling at 3.5 m, the travel distance of the acoustic reflections via the ceiling and the rear wall is E = 45 m, i.e. the difference in travel distance comes to (45 – 2) m = 43 m. With an acoustic velocity of 340 metre per second, the travel time difference comes to about 127 ms, i.e. the acoustic reflection via the ceiling is quite disturbing and degrades the clarity in this room considerably.

The cause: The average length of a spoken syllable is about 100 ms, the distance between syllables for continuous text about 200 ms. The acoustic reflection of corresponding loudness and a travel time difference of 127 ms arrives precisely in the pause between two syllable and thus affects the speech significantly.

Influencing factor **sound field structure**

Crucial for the clarity of speech is the difference in travel distance of direct sound and the acoustic reflections. A travel time difference of under 50 ms has a positive effect whereas a difference greater than 50 ms degrades clarity.



A detrimental effect in classrooms, for example, is a strong reduction of the initial sound energy from the direction of the speaker by protruding components (beams) or a continuously sound-absorbing suspended ceiling. In this case the listener locates the source of sound for instance in the direction of a high-energy side wall or back wall reflection.

Influencing factor **directivity orientation**

If the direction where the speaker is visible (optically perceivable) does not correspond with the direction from which he or she is heard (acoustically perceivable), it becomes difficult to concentrate on grasping the presented content.

The relevant frequency range of the reverberation time for speech is 100-5000 Hz.

Special requirements for the hearing impaired

For children with a slight hearing impairment, the reverberation time for the frequency range at 125 Hz should be as short as possible (T < 0.6 s).

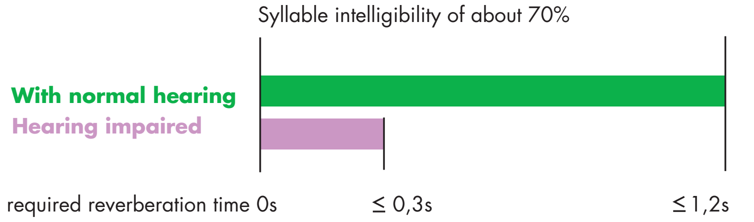
Hearing-impaired individuals require an even shorter reverberation time in the room in order to achieve the same level of speech intelligibility (specifically that of syllables) as listeners of normal hearing.

No quietening down in the rear seats

Classrooms from about 10 m in length with little or no sound absorbing materials typically offer only insufficient speech intelligibility in the rear seat rows.

Noise begets noise

Along with an increasing reverberation time, the expected level of behaviour-based noise in the background also rises. In contrast, people in a quiet surrounding (short reverberation time) will even behave quieter.



Example:
A high level of syllable intelligibility of about 70 % require, under certain conditions, to reduce the reverberation time in the room from 1.2 s for listeners of normal hearing to 0.3 s for those with a hearing impairment.

Influencing factor **reverberation time**

The reverberation time is a room acoustics criterion that designates the "acoustic decaying" of a room after the sources of sound have been shut off. In general, the speech intelligibility drops with increasing reverberation time. In reverberating rooms (e.g. in school corridors), a speaker is much more difficult to understand than in office rooms. The target level for the reverberation time is determined by the required syllable intelligibility.

Classroom acoustics **design procedures**

The required acoustic measures for classrooms and rooms used in a similar fashion are defined in accordance with the DIN 18041 to ensure the acoustic quality over “medium to larger distances” (rooms of group A) according to the procedure explained above:

1. Determining the rooms‘ primary use
2. Determining the room volume
3. Defining the required value for the reverberation time T_{req}
4. Determining the acceptable frequency-dependent tolerance range of the target reverberation time, see page 08
5. Defining the required acoustical absorption measures, see page 09-11
6. Arrangement of the required sound absorbers, see page 12-13

1. Determining the rooms‘ primary use

Depending on the purpose of the room, the following categories are defined according to DIN 18041:

Rooms of category U:
Classroom (except for music lessons), classrooms for music lessons with audio-visual presentations, group rooms in kindergartens and day-care centres

Rooms of category H:
Classroom (except for music lessons), group rooms in kindergartens and day-care centres mainly with a room volume of up to 250 m^3 for:

- individuals with impaired hearing
- communicating in a language that is not their native tongue
- communicating with individuals who speak German as a foreign language
- communication with individuals who require improved speech intelligibility for some other reason

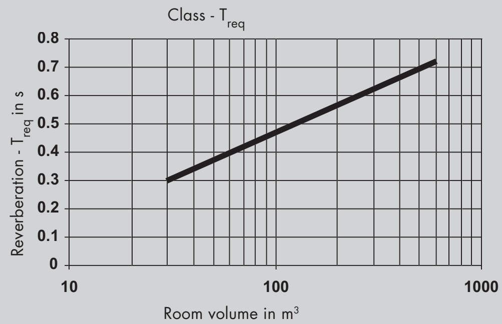
Rooms of category M
Rooms for music lessons including actively playing music and singing.

2. Determining the room volume

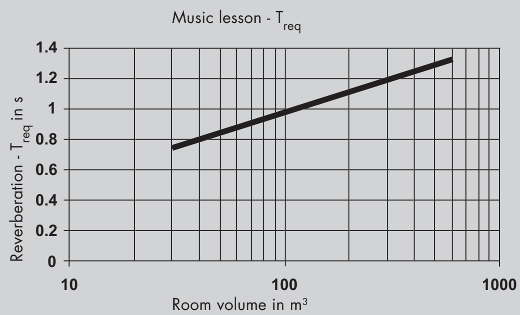
3. Defining the required value of the reverberation time T_{req}

Depending on the room’s volume and type of use (classrooms), DIN 18041:2004-05 “Acoustic quality in small to medium-sized rooms” states required values T_{req} for the reverberation time. The required values for the specified types of use, with the room being occupied, can be read from the charts below.

Category U and H:



Category M:

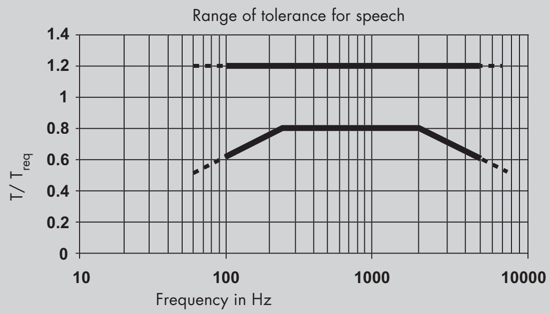


Our room acoustics calculator – www.knauf.de/raumakustikrechner – is available for a detailed computation of steps 2 to 5.
After entering the data regarding the room’s primary use, dimensions, types of surfaces and the level of occupation, the program will provide suggestions for absorber areas.

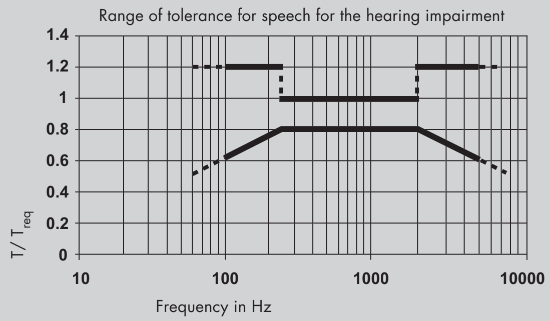
4. Determining the acceptable frequency-dependent tolerance range of the target reverberation time

Based on the required value T_{req}, the acceptable frequency-dependent tolerance range and frequency dependence of the target reverberation time T for said rooms of categories U, H and M is to be assigned by the charts below. Reference values below 100 Hz and above 5000 Hz are displayed as dashed lines.

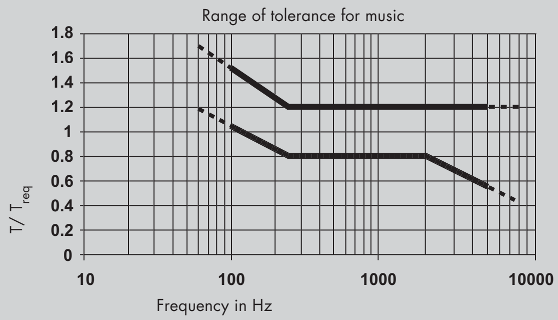
Category U

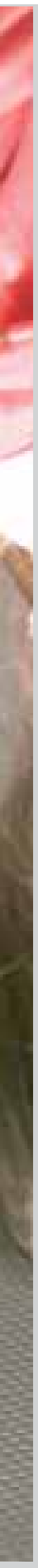


Category H



Category M





5. Defining the required acoustical absorption measures

5.1. General calculation method for classrooms

The required frequency-dependent equivalent sound absorption area A_{req} is calculated based on the target reverberation time generally for room uses of categories U, H, M depending on room volume according to equation (1). The relevant frequency range for classrooms acoustics lies between 100 Hz and 5000 Hz. The required materials for realising the equivalent sound absorption area A_{req} is calculated according to equation (2).

Equation (1)

$$A_{req} = 0.163 \cdot \frac{V}{T}$$

Equation (2)

$$A_{req} = \sum_{i=1}^{n} \alpha_i \cdot S_i + \sum_{j=1}^{k} A_j$$

V total room volume in m^3
T reverberation time in s
A_{req} required equivalent sound absorption area in m^2
α_i sound absorption coefficient of the area S_i to be installed
S_i area to be installed with coefficient sound absorption α_i
A_j equivalent sound absorption area of non-laminary,
materials, objects (e.g. chairs) and persons within the room in m^2

5.2. Simplified procedure for rooms used as classrooms, categories U and H up to 250 m³

Here, a simplified assessment of the required equivalent sound absorption area is possible using the rated sound absorption coefficient α_w. Guideline values for the additionally required sound absorption area S depending on α_w are listed in the following for categories U (table 1) and H (table 2). It is assumed that the rooms have sound-reflecting furnishings and equipment as is usual for their type of use (non-padded seating, little or no sound-absorbing flooring such as linoleum or needle felt, no curtain elements) and are occupied (according to the building authority approval standard values) – the tolerance range is also considered.

Since the regarded frequency range covers only the octave mid-frequency between 250 Hz and 4000 Hz, an additional frequency-dependent calculation for the octave mid-frequency 125 Hz is recommended. (See example 1, page 14)

> Note:
> The sound absorption coefficient α is basically the ratio of the sound energy not reflected by a surface to the incidental sound energy. Sound absorption properties of materials are always determined by measuring the sound absorption coefficient for diffuse sound incidence α_s in a reverberation test room acc. to DIN EN 20354.
> The practical sound absorption coefficient α_p (octave band) is converted from the measured sound absorption coefficient α_s.
> The rated sound absorption coefficient α_w (single value) is detected by comparison with the reference curve of α_p.
> For reasons of convenience, the frequency-dependent calculation of the required sound absorption area should be done using the α_p as this is given in more current planning documents.

Calculation the acoustical absorption requirements

The calculation of the frequency-dependent equivalent sound absorption area (A_{erf}) is done for all types of room use (categories U, H, M) according to equation 1. For smaller classrooms (up to 250 m^3) categories U and H can be calculated using the simplified procedure. For this, the rated degree of sound absorption coefficient α_w is used.

Category U

Rated sound absorption coefficient α_w	Guideline values for the required area to be installed in m² with room volume in m³					
	30	70	100	150	200	250
1.00	8.. 12	11.. 17	14.. 20	19.. 29	25.. 37	27.. 41
0.85	9.. 14	13.. 20	16.. 24	23.. 34	29.. 44	32.. 48
0.80	10.. 15	14.. 21	17.. 26	24.. 36	31.. 47	34.. 51
0.75	11.. 16	15.. 22	18.. 27	26.. 38	33.. 50	36.. 54
0.70	11.. 17	16.. 24	19.. 29	27.. 41	35.. 53	39.. 58
0.65	12.. 18	17.. 26	21.. 31	30.. 44	38.. 57	42.. 63
0.60	13.. 20	19.. 28	23.. 34	32.. 48	42.. 62	45.. 68
0.55	15.. 22	21.. 31	26.. 37	35.. 53	46.. 68	50.. 75
0.50	16.. 24	22.. 34	28.. 40	38.. 58	50.. 74	54.. 82
0.45	18.. 27	25.. 38	31..45	42.. 64	56..82	60.. 91

Table (1)

Category H

Rated sound absorption coefficient α_w	Guideline values for the required area to be installed m² with room volume in m³					
	30	70	100	150	200	250
1. 00	10.. 12	14.. 17	17.. 20	23.. 29	30.. 37	33.. 41
0.85	11.. 14	16.. 20	19.. 24	27.. 34	35.. 44	38.. 48
0.80	12.. 15	17.. 21	21.. 26	29.. 36	38.. 47	41.. 51
0.75	13.. 16	18.. 22	22.. 27	30.. 38	40.. 50	43.. 54
0.70	14.. 17	19.. 24	23.. 29	33.. 41	42.. 53	46.. 58
0.65	14.. 18	21.. 26	25.. 31	35.. 44	46.. 57	50.. 63
0.60	16.. 20	22.. 28	27.. 34	38.. 48	50.. 62	54.. 68
0.55	18.. 22	25.. 31	31.. 37	42.. 52	55.. 68	60.. 75
0.50	20.. 24	28.. 34	34.. 40	46.. 58	60.. 74	66.. 82
0.45	22.. 27	31.. 38	38.. 45	51.. 64	67.. 82	73.. 91

Table (2)

5.3 Calculation method for functional, class-related rooms.

For rooms functionally related to the classrooms (technical shops, break hall, school refectory, hallways) the following guideline values apply according to DIN 18041 as to the free wall and ceiling areas to be lined with materials of a rated sound absorption coefficient α_w as a multiple of the room's floor area per usual ceiling height of, on average, 2.5m (table 3).

Type of room	Factors to determine the required area S to be installed in m² for materials of rated sound absorption coefficient α_w														
	1.00	**0.95**	**0.90**	**0.85**	**0.80**	**0.75**	**0.70**	**0.65**	**0.60**	**0.55**	**0.50**	**0.45**	**0.40**	**0.35**	**0.30**
Technical shop	0.9		1.0	1.1		1.2	1.3	1.4	1.5	1.6	1.8	2.0			
Break hall, school refectory of more than 50 m² floor area	0.5		0.6			0.7		0.8		0.9	1.0	1.1	1.3	1.4	1.7
Staircases, hallways, exhibition foyers	0.2				0.3					0.4			0.5	0.6	0.7

Table (3) Guideline values for the wall and ceiling areas to be covered with materials of a rated sound absorption coefficient α_w as a multiple of the room's floor area per usual ceiling height of, on average, 2.5m for rooms related to the classrooms

Due to the partially limited frequency spectrum of the noise level in such rooms, the requirements regarding the frequency-dependent degree of sound absorption of areas to be installed can be modified.

Staircases and hallways in particular are to be equipped with sound absorbers effective in the octave mid-frequency range of 500 Hz to 2000 Hz.

In technical shop rooms, the octave bands' noise spectrum of the functional/technical equipment must be considered – aside from the spectrum of 500 Hz to 2000 Hz – as it determines the sound pressure level. In break halls, the importance of speech with an octave-band mid-frequency of 250 Hz to 2000 Hz should constitute the basis for the dimensioning of the sound absorbers to be installed.

6. Arrangement of the required sound absorbers

The principle design of measures of room acoustics in classrooms is essentially based on their purpose. Influencing factors of the type of class, such as frontal instruction, learning in groups, partner lessons and disengaged learning, are to be considered should they be the preferred manner of use. Generally the typical configuration parameters are considered, such as:

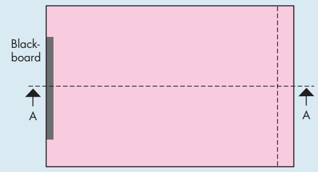
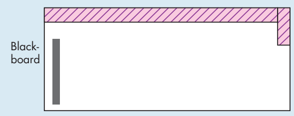
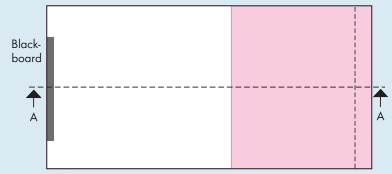
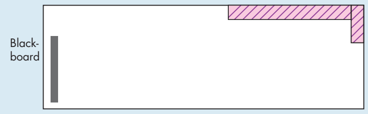
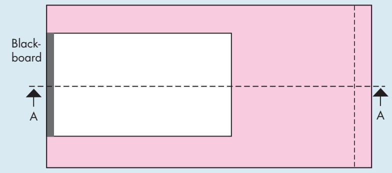
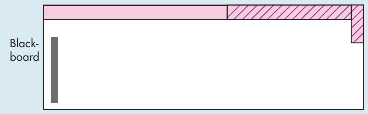
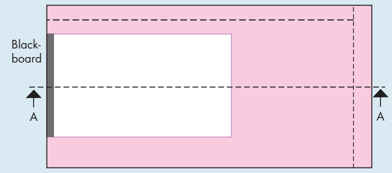
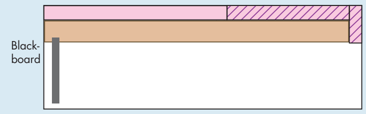
- occupied room with about 80 % of the maximum seating capacity
- minor sound-absorbing configuration of the room, such as non-padded seating, little or no sound-absorbing flooring (linoleum, needle felt)
- sound-reflecting equipment (cabinets, shelves, blackout systems)
- ribbon windows on the exterior facade with about 2m height
- interior room parting walls such as stud partitions or flexible furrings

The following basic arrangement options V1 to V2 for sound absorbers with a preferred effectiveness in the medium and high frequency range apply to the ceiling area and a generally arranged sound-absorbing cladding of the upper rear wall surface (for a specified blackboard position); respectively for the upper front wall

The procedural design method for directional classes should be

- initially, the smallest arrangement area required is assumed for the sound absorbers combined with a sound-absorbing rear wall and adjacent ceiling bands Option V 2.1
- should this area be insufficient, then covering the ceiling – for rooms up to 250 m^3 – entirely with absorbers, along with the rear wall, is acceptable; this arrangement can also be used for rooms without a distinct primary direction use Option V 1
- furthermore, the ceiling can also be covered in U-shape, possibly with an area section of a longitudinal wall as well Option V 2.2 and V 2.3

In all other rooms, such as technical shops, break halls and school refectories, hallways and staircases, the sound-absorbing materials are to be arranged primarily on the available ceiling and wall surfaces.

Arrangement of the sound absorbers on the ceiling	Alternative		View
Entire area (only up to 250 m³)	V 1	Ceiling Layout	
		Longitudinal section A-A	
Adjacent to the rear wall	V 2.1	Ceiling Layout	
		Longitudinal section A-A	
U-shape Ceiling Layout	V 2.2	Ceiling Layout	
		Longitudinal section A-A	
U-shape Ceiling Layout and area section of Longitudinal wall	V 2.3	Ceiling Layout	
		Longitudinal section A-A	

Example 1:
Calculation of classroom

1. Initial parameters

Classroom with standard equipment and normal occupancy

Spatial geometry:

Depth:	6.0 m
Length:	8.0 m
Height:	3.0 m
Floor area:	48.0 m^2
Volume:	144.0 m^3

Use:

Classroom, category U according to DIN 18041 directional classes

2. Assessment

Assessment can be done using the simplified procedure as V_{ex} = 144,0 $m^3 \leq 250\ m^3$.

Calculating the additionally required sound-absorbing area according to table 1

Selected absorber:

Knauf Cleaneo Acoustic Board design 15/30 R with standard fleece + mineral wool, suspension height 200 mm according to Knauf Technical Data Sheet D12:

α_w = 0.65 (LM)

α_{p125} = 0.55

Note:

In order to determine the additionally required absorption area, the least favourable value of α_{p125} = 0.55 is assumed so that a separate verification of the frequency range 125 Hz can be omitted

Additionally required absorption area according to table 1:

Note:

interpolation acceptable

S_{req} = 26 to 37 m^2 for

V = 100 m^3

S_{req} = 35 to 53 m^2 for

V = 150 m^3

==> for 144 m^3 = 34 to 51 m^2

(on average 42 m^2)

Defining the absorption area / arranging the absorbers

Fully covered ceiling surface allowing for band of non-perforated gypsum boards (for compensatory tolerance of 30 cm) combined with a partial lining of the rear wall (Option V 1)

Ceiling area:	5.40 x 7.40 = 40 m^2
Rear wall (upper third):	6.0 x 1.0 = 6 m^2
	46 m^2 > 42 m^2

Calculation example

Determining the acceptable absorption areas in classrooms using the simplified procedure

Example 2:
Assessment of break hall

1. Initial parameters

Break hall with standard equipment

Spatial geometry:

Depth:	6.0 m
Length:	10.0 m
Height:	3.0 m
Floor area:	60.0 m^2
Volume:	180.0 m^3

Use: Break hall

2. Assessment

Calculating the additional sound absorption surface:

Selected absorber

Knauf Cleaneo Acoustic Board design 12/25 R with standard fleece + mineral wool, suspension height 60 mm according to Knauf Technical Data Sheet D12:

α_w = 0.70 (M)

additionally required absorption surface according to table 3 for α_w = 0.70 -> multiplier 0.7 for ceiling height of 2.5 m required surface for ceiling height of 3.0 m:

S_{req} =
(multiplier from table 3) x floor area x (ceiling height / 2.5 m)

$S_{req} = 0.7 \times 60\ m^2 \times (3.0/2.5) = 51\ m^2$

Arrangement of the absorbers

Ceiling coverage (about 85 %) combined with reflecting surfaces (smooth gypsum boards without perforation) possibly with lighting installation

Knauf Cleaneo® Acoustic Board Types

Standard Circular Perforation R
Standard Square Perforation Q
Alternating Circular Perforation R
Random Perforation PLUS R
Block Perforation
Block-slotts "Slotline"

Cleaneo® Acoustic, the new system for acoustic ceilings, improves the ambient air considerably. Cleaneo Acoustic works twenty-four-seven and requires no sunlight. Conclusive air-cleaning effects with Cleaneo Acoustic.

Now standard for all Knauf Aperture Boards

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I would like more information – please send

______ (qty.) Knauf Technical Data Sheet Cleaneo Acoustic Ceilings D12

______ (qty.) Knauf Technical Data Sheet Cleaneo Acoustic K761

☐ I have a concrete object. Please arrange a visit by your system consultant.

For date arrangement contact:

____

Name ________________

Company ________________

Street address ________________

Postal code/city ________________

Fax ________________

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Sakret Bausysteme
Dry Mortars for New
Projects and Renovations