Acoustical furniture – Measuring and modelling for 3D-simulation

Christian Nocke
Akustikbüro Oldenburg, Germany

Summary

In the standard DIN EN ISO 354 “Measurement of sound absorption in a reverberation room“ [1] a measuring procedure for sound absorption of non laminar single objects like furniture, lamps, movable walls and other objects is described with the result of an equivalent sound absorption area A_{obj}. Unfortunately, for usage in acoustical 3D simulation programs the sound absorption coefficient of an area is required, because usually objects are build up or modeled by laminar areas. A unified standard to convert the equivalent sound absorption A_{obj} to sound absorption coefficients for models of single objects does not exist so far. The new parameter is designated as α_{obj}, see also [2]. Its’ definition requires besides knowledge of the sound absorption area of the respective object, the definition of a simplified geometry of the object, which is referred to as an acoustical representation. Manufacturer and merchants of office-facilities have already started to describe acoustically effective products in assistance of the new parameter. In that way an efficient adoption from corresponding computer programs (like pcon-planner [3]) in 3D room acoustic simulations programs is enabled. In this article the procedure is presented and based on that examples of office planning are demonstrate

Introduction

One possibility to bring the necessary sound absorption in rooms, nowadays especially offices, may consist of fitting sound absorbing abilities to furnishings like furniture, movable walls, seats and lamps. In this article a procedure is presented, how sound absorption of corresponding non-laminar acoustic absorber can be described in order to use them in room acoustical 3D simulations.

From the in a reverberation room measured sound absorption area A_{obj} of a single object, a sound absorption coefficient for the in the simulation used elements is derived. With this to the surface of an object related sound absorption coefficient, single objects can also be considered in corresponding software programs. Furthermore with this parameter a comparison of several different single objects is possible, which was until now only indirectly possible by the absorption area A_{obj} .

Measurements in the reverberation room according to DIN EN ISO 354 at objects

To determine sound absorption the reverberation time is measured in an empty as well as in, with a test object equipped reverberation room.

The procedure is described normatively by DIN EN ISO 354 [1]. In the Standard conditions are situated for room volume *V*, “diffusivity” of the sound field, the test object, to be used measurement equipment and many further details.

Test objects are distinguished between laminar sound absorbers and individual sound absorbers. Laminar absorbers require a covered area of approximately 10 m² to 12 m². Several constructions are presented in detail in the normative Appendix B of DIN EN ISO 354 [1].

For individual sound absorber according to DIN EN ISO 354 [1] a corresponding detailed presentation of constructions is missing. Listed is: “Single objects (e.g. chairs, detached movable walls or people) have to be positioned for measurement in the same way, as it is common practice." It is pointed out, that test objects of individual sound absorbers have to consist out of at least three uniform objects. Provided that the test object consists of a single objects, it is to be measured in the reverberation room on at least three positions.

Equivalent absorption area A_T of test objects arises after requirements of DIN EN ISO 354 [1] out of the difference of reverberation rooms equivalent absorptions area with test objects A_2 and without A_1:

$$A_T = A_2 - A_1 \quad [m^2] \quad (1)$$

Subsequently, for laminar sound absorbers the area S covered by test objects can be used to calculate the sound absorption coefficient α_S:

$$\alpha_S = \frac{A_T}{S} \quad [--] \quad (2)$$

The index S is used, to point out the described procedure in the reverberation room.

For individual sound absorbers the equivalent sound absorption area of each object A_{obj} is to be specified. Therefore, the equivalent absorption area A_T is to be devided by the number of objects n, usually n = 3, accordingly applies:

$$A_{obj} = \frac{A_T}{n} \quad [m^2] \quad (3)$$

Results of measurements according to DIN EN ISO 354 [1] are given for laminar absorbers as absorption coefficient α_S and as absorption area of an object A_{obj}.

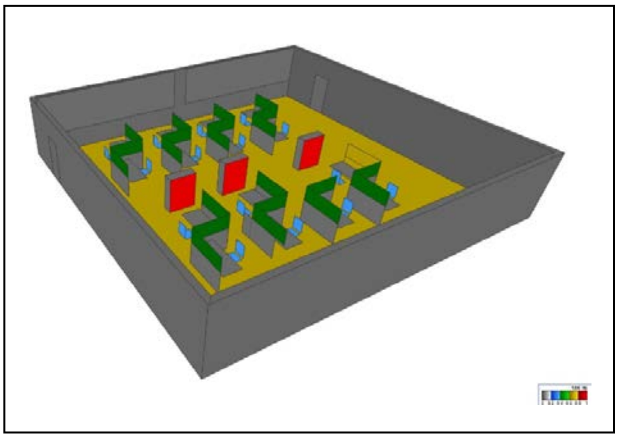
Unclear statements in DIN EN ISO 354 concerning objects

There is in the current version of DIN EN ISO 354 [1] the ambiguity of how to deal with objects such as movable walls, table tops, cabinets and other elements of furniture that quite allow the definition of a surface or reference surface S. At absorbers with two sonicated sides like movable walls or so called "Acoustic Sails", "Clouds" of other freeforms, DIN EN ISO 354 [1] does not contain any specific requirements as to how the reference surface S is to be determined. There is only the remark that, in the case of absorbers sonicated on both sides, the degree of sound absorption is the ratio between the equivalent sound absorption area of the test object and the area of the two sides of the test object [1, note 1 in point 3.9].

Absorption coefficient for single objects

As a rule, a direct input of the sound absorption area A_{obj} of individual objects in the relevant programs for 3D room acoustics simulation is not provided. All room boundary surfaces, but also the furnishings, are approximated in the three-dimensional computer simulation by elements of flat surfaces or cuboids, see room example in Figure 1.

Figure 1: Example of a three-dimensional room model for room acoustics simulation. Colors indicate the



absorption coefficient of the surfaces, here for 1000 Hz octave

In order to be able to consider the acoustic effect of individual objects within the meaning of DIN EN ISO 354, such as sound-absorbing movable walls, cabinets or "ceiling sails" in the 3D simulation, it is necessary to assign a value of the sound absorption coefficient to the surfaces of these objects in the computer model.
In this case, either a sound absorption coefficient α_{Obj} averaged over all surfaces of the object or the sound absorption coefficient for the individual surface components or components of the object α_{KA} can be specified. For both approaches, it is necessary to define a geometry that is simplified compared to real geometry for the acoustic model, referred to below as acoustic representation. In the following it is assumed that the absorption is considered in octave bandwidth. As described in ISO 11654 [2] [3], octave band values are determined by the arithmetic mean of each of the three one-third octaves in the octave.

Geometry in room acoustic simulation programs

All acoustically relevant furniture and other furnishing elements are to be created as a cuboid or a combination of several cuboids. Alternatively, each side of a cuboid can also be arranged as a single surface. The dimensions of the cuboid should be based on the actual dimensions of the objects represented (furniture, furnishings). However, the geometric extent should also be applied to flat or thin elements such as e.g. Tables, table tops or partitions, always at least 10 mm.

Often parts of a piece of furniture are equipped with acoustically effective or sound-absorbing materials, while other surfaces are rather reverberant. Examples are partition walls, which can be equipped with different types of panels or cabinets with only partially acoustically effective fronts and / or back walls. Therefore, it usually makes sense to construct the surface model of the acoustic representation in such a way that acoustically effective areas are separated from reverberant areas and independent areas are created in each case. These surfaces can then be assigned different materials with different values of the sound absorption coefficient. Alternatively, a cuboid can be modeled and the acoustically effective surface can be preset as an additional cuboid at the corresponding location.

Sound absorption coefficient α_{Obj}

The procedure described below is used if the individual object consists of materials with similar absorption properties (for example "sound reflecting" wood and metal cabinets) or if significant differences in the absorption properties can not be measured. For example, in a chair with upholstered seat and back and seat bottom and back of the back plastic, the different sound absorption coefficients of upholstery and plastic usually can not be determined separately. A measurement in the reverberation room supplies the sound absorption area A_{obj} in relation to the object. The average sound absorption coefficient α_{Obj} of all surfaces of the acoustic geometry exposed to the sound field is calculated as follows:

$$\alpha_{\mathrm{Obj}} = \frac{A_{Obj}}{S_E} \qquad [--] \qquad (4)$$

with S_E the total surface exposed to the sound field of the object in the acoustic representation.

Sound absorption coefficient $\alpha_{K\alpha}$ of different components of an object

Prerequisite for the determination of the sound absorption coefficient of a single (sound-absorbing) component K_α of the individual object is the interchangeability of this component. The determination of the sound absorption coefficient of the component K_α is based on a comparison of the sound absorption surface of the object $A_{Obj,\ K0}$ without the sound-absorbing component and the sound absorption surface $A_{Obj,\ K\alpha}$ with the sound-absorbing component. The sound absorption coefficient assigned to component K_α can then be determined as follows:

$$\alpha_{Obj,K\alpha} = \frac{A_{Obj,K\alpha} - A_{Obj,K0}}{S_{E,K}} + \alpha_{Obj,K0} \qquad [--] \qquad (5)$$

with the area $S_{E,\ K}$ of the swapped component of the individual object. Here, it is assumed that the area size of the exchanged component (non-absorbing or absorbing) remains the same. The sound absorption coefficient $\alpha_{Obj,\ K0}$ is determined from the equivalent sound absorption area A_{Obj} of the object without the sound-absorbing component.

Example cabinet with acoustic front

A schematic representation of a cabinet with acoustic front is shown in Figure 2. The dimensions of the cabinet are: width: 0,8 m, depth: 0,46 m, height: 1,09 m. This results in a total surface area of S_E = 3,11 m², the size of the acoustic front amounts to $S_{E,\ K\alpha}$ = 0,87 m². Figure 6 shows the sound absorption surfaces of the cabinet with and without acoustic front measured in the reverberation chamber on the left. The right graph shows the corresponding absorption coefficient for the components of the object. The absorbent front shows a significantly higher degree of absorption ($\alpha_{Obj,\ K\alpha}$) than the rest of the cabinet body ($\alpha_{Obj,\ K0}$).

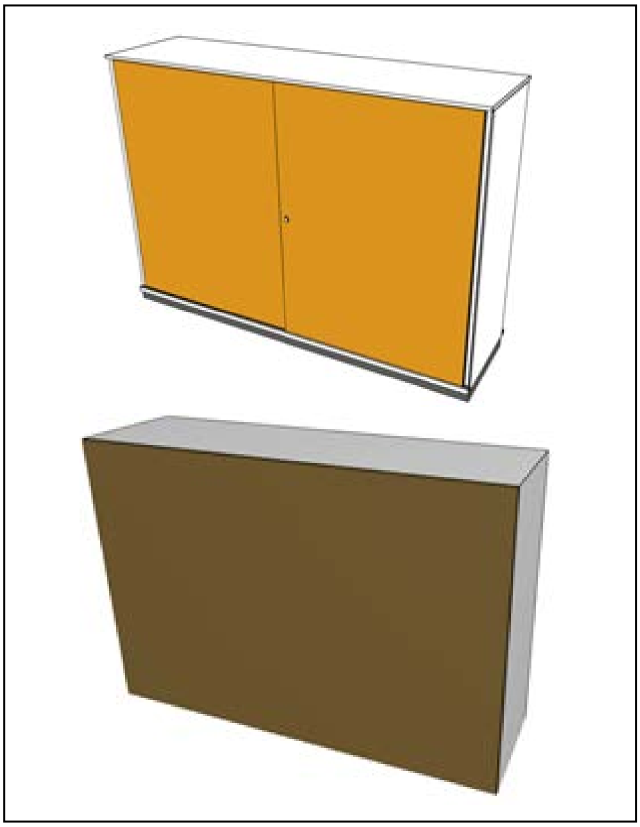


Figure 2: Cabinet with acoustic front (upper picture) and its acoustic representation (lower picture), consisting of a cuboid for the carcass and a 1 cm thin cuboid for the acoustic front on the front of the cabinet.

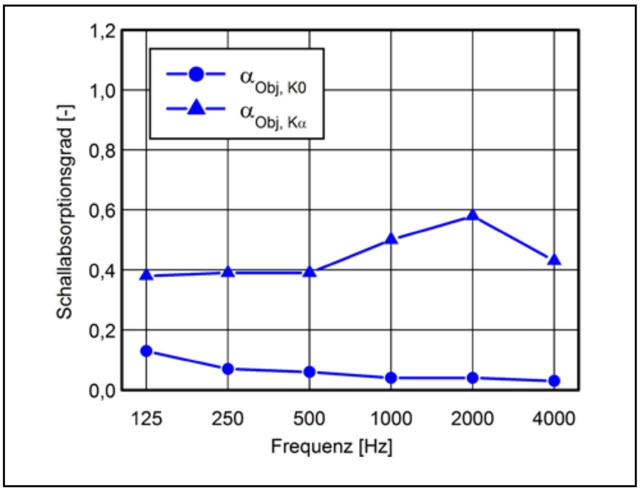
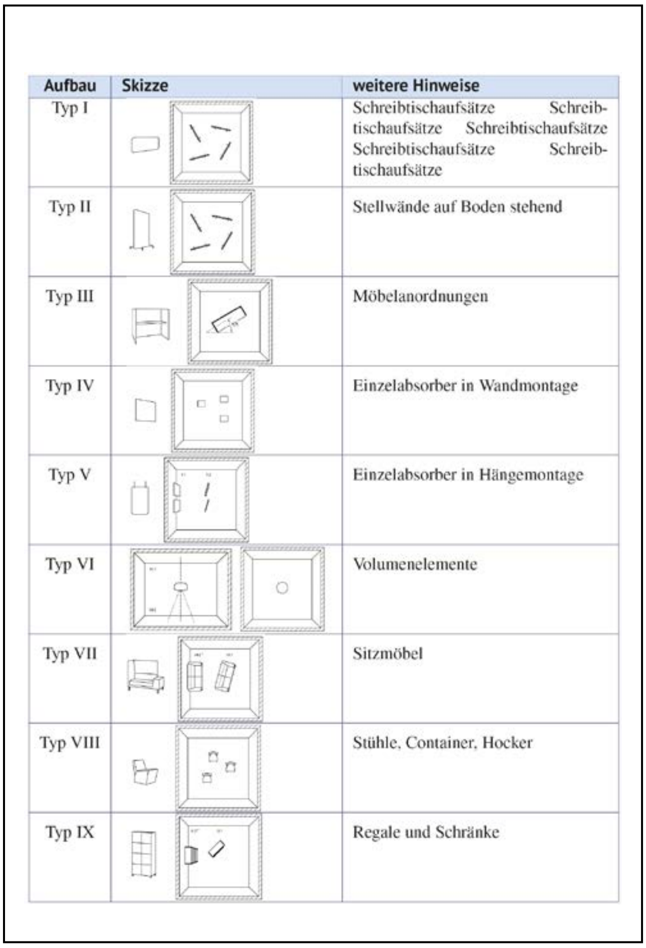


Figure 3: Sound absorption coefficient α_{Obj} for the cabinet from Figure 2

Normative implementation

In ISO / DIS 20189 [7], the new characteristic α_{Obj} is described normatively for the first time. In the normative Annex B to ISO / DIS 20189 [7] we demonstrate the application of α_{Obj} by means of various examples.

Also in ISO / DIS 20189 [7] clarification for the measurement of objects is described in the normative Annex E. In Figure 4, the corresponding structures are shown in the sketch of [7]. This clarification for the measurement of objects in the sense of DIN EN ISO 354 [1] will in future facilitate the description of acoustically effective objects, especially in the office environment.



Aufbau	Skizze	weitere Hinweise
Typ I		Schreibtischaufsätze Schreib-tischaufsätze Schreibtischaufsätze Schreibtischaufsätze Schreib-tischaufsätze
Typ II		Stellwände auf Boden stehend
Typ III		Möbelanordnungen
Typ IV		Einzelabsorber in Wandmontage
Typ V		Einzelabsorber in Hängemontage
Typ VI		Volumenelemente
Typ VII		Sitzmöbel
Typ VIII		Stühle, Container, Hocker
Typ IX		Regale und Schränke

Figure 4: Design types for test objects and examples according to normative Annex B of ISO / DIS 20189 [7]

Conclusion and outlook

The absorption coefficient α_{obj} or $\alpha_{Obj, K\alpha}$ proposed in this article has already been widely used in practice. Whenever 3D computer models are used for simulation for non-planar sound absorbers, such definition of simplified geometry and associated values for the object-related sound absorption coefficient is necessary. Manufacturers and distributors of office equipment have begun to describe acoustically effective products with the help of α_{obj} or α_{KA}, so as to allow an efficient adoption of corresponding computer programs for spatial planning [4] [5] in room acoustics simulation programs [6]. The normative implementation of this approach has been completed with ISO / DIS 20189 [7].

Acknowledgement

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