Steiner, Beat; Kilian, Michael; Haidn, Bernhard and Keck, Margret

Optical parameters for the assessment of floors in cattle housing

In addition to meeting requirements relating to animal welfare and process technology, floor materials must in future also comply with functions for emission reduction. In this issue emission-relevant optical parameters such as open and closed void volume and topographical depth were recorded by optical 3-D-surface measurement. Finely-textured surfaces such as a smoothed slatted floor had low volumes, whereas concrete profiled floors or a rubber mat with dish-shaped hollows gave high volumes. On commercial farms opposite effects were apparent: mastic asphalt got rougher and concrete got smoother due to the ageing effect. With a view to reducing ammonia emissions the aim should be to use surface textures with a low void volume.

Keywords
Floors, cattle, loose housing, emission, topography, surface texture

Abstract
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To date, floor surfaces have been assessed primarily in terms of animal behaviour and claw health. In addition to skid resistance, however, parameters allowing us to derive technical building measures for reducing ammonia emissions are essential for the assessment of new materials. The topography-measuring device developed at the Institute for Agricultural Engineering and Animal Husbandry of the Bavarian State Research Centre for Agriculture enables the three-dimensional photography of numerous surface features [1]. The aim of investigations at the Reckenholz-Tänikon ART Research Station was to evaluate emission-relevant parameters by means of topography measurement and to comparatively describe both standard and new materials, as well as to derive pointers on emission reduction.

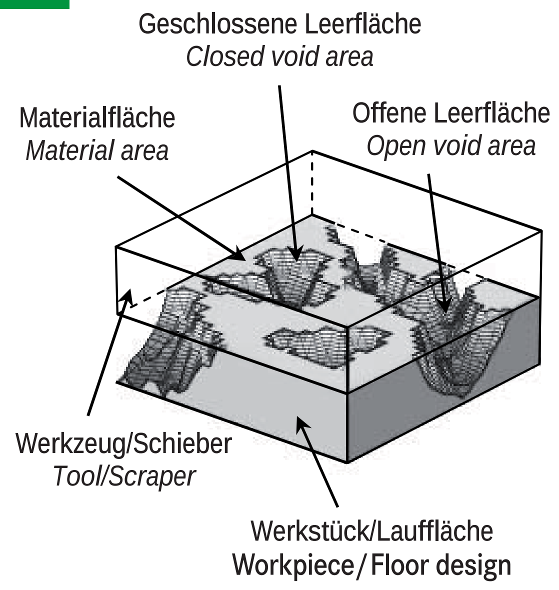
Description of technical surfaces

The theoretical foundation for the description of technical surfaces is the mechanical-rheological model of sheet-metal deformation developed by Sobis [2]. This model distinguishes between material surfaces, as well as between open and closed void areas (**figure 1**). The volumes on the surface are dependent on the number and size of the volume-forming areas and on the topography depth S_d. Unlike with the open void areas (at least one side open), with the void areas closed off on all sides, the faeces-urine mixture cannot drain away, as it is hemmed in.

Function-relevant parameters for floor surfaces

The assignment of function-relevant surface characteristics of the floors (**table 1**) was performed from the perspective of animal welfare and NH_3 emissions. Also of importance on the floors is the residual soiling on the surfaces or in the closed void areas after mechanical dung removal. The S_d affects volume parameters as well as facilitating the description of ani-

Fig. 1



Mechanical-rheological model according to Sobis [2], and [7]

Table 1

Assignment of function-relevant surface characteristics of floors

Tiergerechtheit *Animal welfare*	**NH_3-Emissionen** *NH_3 emissions*
Kanten/Grate/Punktbelastung *Edges/burrs/concentrated load*	Emissionsfläche und –volumen *Emission area and volume*
Abrasivität *Abrasiveness*	Drainierbarkeit *Drainability*
Verdrängungsraum *Displacement space*	Reinigungsfreundlichkeit *Ease of cleaning*
Rutschfestigkeit *Slip resistance*	Restverschmutzung *Residual soiling*

mal-welfare characteristics such as concentrated load and slip resistance.

Topography-measurement method

For the measurements of the present study, the topography-measuring device as described in Kilian [1] was used. Here, a scanner projects a laser line vertically onto the surface to be measured and a portion of the laser light is reflected from the object onto a detector. From this, the distance to the object is calculated according to the triangulation principle. A total of 16 different products were measured under laboratory conditions, and three flooring materials were measured under practical conditions. The following material categories were examined in the laboratory (**table 2**):

- Coatings with epoxy-resin sand
- Mastic asphalt
- Solid and perforated concrete
- Rubber mats.

In practice, the measurements were made on 18 farms with the materials mastic asphalt, solid concrete and perforated concrete. The floors of three farms in each case were categorised into the age classes of under three and over nine years of age. The materials in the laboratory were recorded at four measuring points in two lengthways and two crossways measurements each, in order to take account of any differences in surface texture resulting from the corresponding measuring direction. A measuring point consisted of three parallel measuring tracks of 186 × 10 mm each. The measurements on the commercial farms were carried out at ten measuring points per housing system in each case. All measurements were performed on as-new surfaces, or in practice on cleaned surfaces. Data were analysed with the surface software WinSAM. The open or closed void volumes were represented in each case as an average of six measurements.

Results

With regard to the emission volume in the form of the faeces-urine mixture, the two parameters open (V_{op}) and closed (V_{cl}) void volumes were summarised. For the as-new surfaces, average volumes of between 260 and 1,000 cm^3/m^2 were yielded (**figure 2**). Floor designs with fine-structured surfaces such as mortar coatings or a heavily-smoothed slatted floor (perforated concrete 1) had deep volumes. The highest values were for coarse-textured concrete profile floors, concrete-rubber granulate, and for rubber mat 1 with distinct dish-shaped hollows (**figure 3**). The proportion of V_{op} generally stood at under 10 % of the total volume. Rubber mat 1 constituted an exception, with a share of around 25 % (207 of 838 cm^3/m^2). For fine-textured surfaces, the topography depth S_d came to just 0.6 or 0.8 mm; for coarse textures such as granulated rubber and profile flooring, 2.8 or 2.4 mm.

The floors on the commercial farms showed significant differences from ageing effects [1] (**figure 4**). For mastic asphalt, the average volumes at under three years of age were 430, for those over nine years of age, 1810 cm^3/m^2. Solid concrete floors yielded volumes of around 750 (< 3 yrs.) and 610 (> 9 yrs.), perforated concrete floors of 310 and 210 cm^3/m^2, respectively. Slatted floors less than three years old exhibited topography depths of 0.7 mm, those over nine years old, 0.5 mm; the figures for solid concrete surfaces were 1.5 and 1.2 mm, respectively.

Ensuring drainability

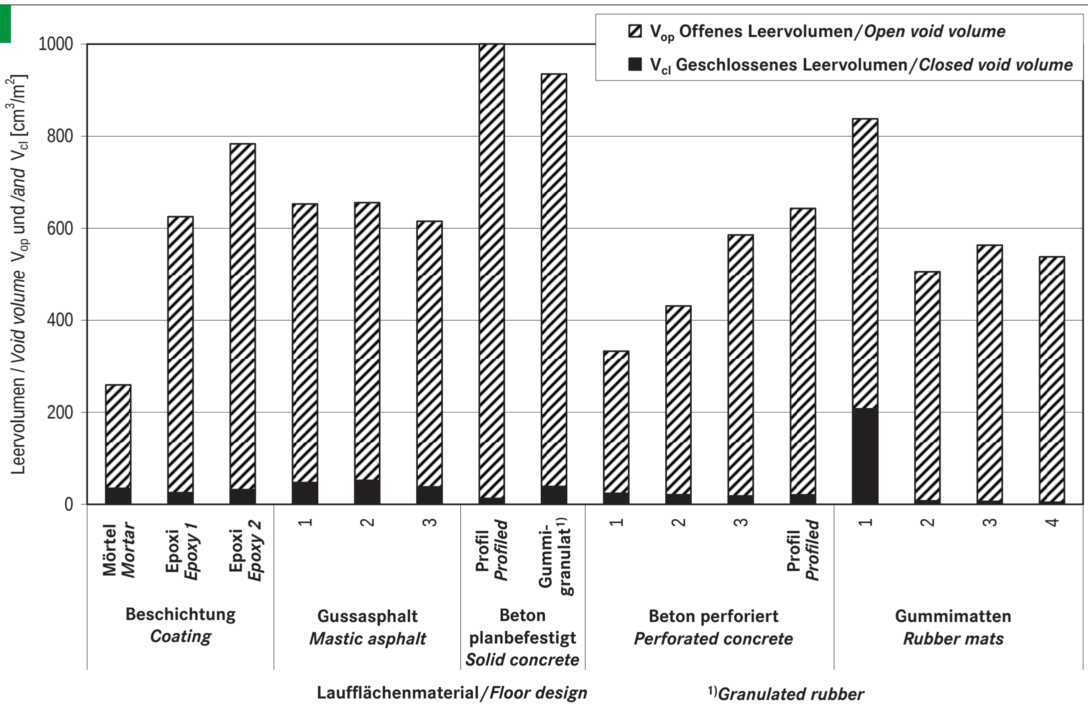
For a low emission volume, the sum of V_{cl} and V_{op} should be as low as possible. With a view to other function-relevant characteristics, however (**table 1**), a medium range should be sought. The rougher the flooring materials are, the more easily a microclimate develops that positively influences the urease-forming microflora (urease being the enzyme that splits urea into carbon dioxide and ammonia). Smooth, and hence fine-rough surfaces achieve low urease activity levels [3; 4; 5]. The worse

Table 2

Overview of flooring materials investigated and differences in design

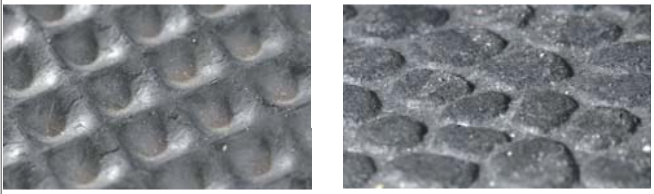
Bodenmaterial *Floor design*		Details zur Oberflächenbearbeitung *Details of surface treatment* Struktur/Körnung *Texture/Grain size*		
Beschichtung ***Coating***	Mörtel/*Mortar*	3-Komponenten-Mörtel *Mortar 3-components*		
	Epoxi/*Epoxy 1*	0.1-0.6 mm		
	Epoxi/*Epoxy 2*	0.7-1.2 mm		
Gussasphalt ***Mastic asphalt***	1	Quarzsand/*Silica sand* 1-1.7 mm		
	2	Quarzsand/*Silica sand* 1-2.2 mm		
	3	Rundsand/*Round sand* 1-2.2 mm		
Beton planbefestigt ***Solid concrete***	Gummigranulat/*Rubber granulate*	2 kg/m^2		
	Profiliert/*Profiled*	**Rillen/*Grooves***		
		Breite/*Width*	**Tiefe/*Deep***	**Abstand/*Apart***
		10 mm	2.5 mm	40 mm
Beton perforiert ***Perforated concrete***	Profiliert/*Profiled*	5 mm	1 mm	15 mm
	1	Geglättet/*Smoothed*		
	2	Mit Quarzsand abgestreut *Surface-dressed with silica sand*		
	3			
Gummimatten ***Rubber mats***	1	Vertiefungen schüsselförmig *Dish-shaped hollows*		
	2	**Gripprofile/*Grip profiles*** Rillen zwischen Erhebungsflächen *Grooves between raised areas:* Breite/*Width* 1-3 mm Tiefe/*Deep* 1 mm		
	3			
	4			

Fig. 2



Results of open (V_{op}) and closed (V_{cl}) void volume parameters of different as-new flooring materials

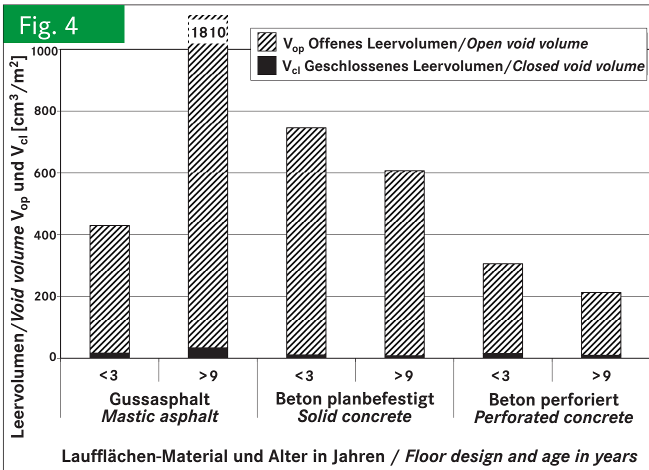
Fig. 3



Gummimatte 1 *Rubber mat 1* Gummimatte 2 *Rubber mat 2*

Close-up photographs of as-new flooring materials

Fig. 4



Results of open (V_{op}) and closed (V_{cl}) void volume parameters of different flooring materials under practical conditions

the drainability of a floor and the more faeces-urine mixture remains permanently in the hollows of the topography even after a dung-removal process (so-called residual soiling), the greater the emission-active volume available. Surfaces with a high proportion of open void volume are advantageous. Texture and slope must be designed so as to produce a drainage effect, however. In the situation without a slope, the sum of open V_{op} and closed V_{cl} void volume is relevant for emissions. Where there is sufficient slope, urine can drain from the open void areas; in this case, only the closed void volume is relevant for emissions. If the results are viewed according to material groups, considerable differences in surface design become apparent within the coatings, the perforated floors and the rubber mats.

Conclusions

In order to meet the different requirements for floor surfaces, it is essential to find a suitable compromise between the minimum required size and grip of the grain structure on the surface (roughness) on the one hand, and as low a residual soiling (emission volume) as possible on the other. Floor surfaces require a displacement space for the faeces-urine mixture. Under practical conditions, it is not possible to adequately clear coarse-textured surfaces with the available dung-removal technique. Fine-textured surfaces such as mortar coatings or concrete with calcifications are for their part unfavourable in terms of traction between claw and floor. According to findings to date, textures with an average grain size, such as sand in the 0.7–1.2 mm range or elastic rubber mats with fine surface textures, also best fulfil requirements vis-à-vis animal welfare [6]. Ageing brings about changes in the surface texture of concrete and mastic asphalt. Whereas roughness decreases in concrete with advancing age, coarser textures in mastic-asphalt surfaces arise with use. These findings illustrate the requirement for suitable formulas and a surface treatment which reduce chemical and mechanical wear in these materials. In the further development of floor surfaces, we must aim for surface textures with low void volumes at the same time as high skid resistance over the entire useful life of said floors.

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Authors

Dipl.-Ing. Beat Steiner elaborates floor materials in stables and manure removal at Forschungsanstalt Agroscope Reckenholz-Tänikon (ART), E-Mail: beat.steiner@art.admin.ch

Dr. Margret Keck is concerned with emission reduction in animal production at ART.

Dr. Michael Kilian used optical parameters for the assessment of floor materials in cattle housing within his degree thesis at Bayerische Landesanstalt für Landwirtschaft, Institut für Landtechnik und Tierhaltung, Freising-Weihenstephan (head **Dr. Bernhard Haidn**).