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Influence of material solution of cover shells on stable daylight

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Abstract

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The impact of material solution of cover shells on stable daylight. Light is supplied to the stable via a roof skylight, where wired glass is the infill of skylight structure, through open side walls, whereby the influx of light on one side is influenced by the shelter, and through the open gates, which are located in the front walls of the stable were assessed. Measurements of light intensity inside the stable were carried out in two height levels. Simultaneously, measurements were performed outside, on non-shadowed plane. Daylight factor was calculated from the measured values of internal and external comparative illuminance. Resulting values were processed into tables and graphs. The roof skylight has clearly the greatest influence on the lighting of the stable. Its disadvantage is that the stable overheats in these places in summer. Here, it would be appropriate to replace the fill of the skylight with translucent light elements.

Keywords: stable for dairy cows; shelter, skylight; illuminance; daylight factor

The lighting of the stable premises is an important factor in production stalls. Peters (1994), Doležal and Černá (2006), and others present the results of research where dairy cows that move daily in good light conditions during 16–18 h have about a 5–16% higher usefulness. Aharoni et al. (2000) analysed the effects of day length and the daily change of illuminance during the year and heat load prevailing on test days, the influence of illuminance on dairy cows milk yield and composition in hot weather. The four-hour difference between the shortest and the longest day plus the seasonal change in day length presented the increase in milk yield of 1.9 kg of milk/day for a cow calving during the shortest days in comparison with a cow calving during the longest days. However, in summer, under high solar radiation – even though there is no problem with ambient light, the milk yield of cows may be at risk just because of heat stress for cows not provided with a shielded area. A shielding shelter reduces the illuminance, but cools the environment down. Ridge skylights improve the lighting but they are a risk of increased heat load of animals in summer (Lendelová et al. 2012).

The standard STN 36 0088:1993 reported a value of 60 lx for illuminance of a free cubicle housing of dairy cattle and the value of 1.0% for daylight factor. The new standard STN EN 12464-1:2012 specifies the values for illuminance in general for farm animal buildings, this value is 50 lx. A higher value (200 lx) is only in cubicles for sick animals and in stables for newborn animals. For farmers, the recommended illuminance level is at least 200 lx in the living area

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(Doležal, Černá 2006); the required value of daylight factor in the stable premises is from 0.5% to 2% (Chloupek, Suchý 2008). The best solution is to have the desired values of illuminance achieved primarily through daylighting. It is the most natural way for animals and the most effective way for farmers.

Daylight in the stable is affected by the size of roof light elements, the material from which skylights are made, the illumination of side walls, shielding by surrounding buildings as well as the purity of the walls inside the stable.

MATERIAL AND METHODS

Daylight was examined in the stable for dairy cows. The ground plan dimensions of the stable were 66,160 × 28,050 mm. The stable headroom was 2,800 mm at the side walls and 4,700 mm below the roof skylight. The opening size of the roof skylight in the ridge of the roof was 54,000 mm × 2,400 mm. Boards of the skylight were made of transparent wired glass. Animals were placed in two rows of boxes near the side walls of the stable, with a manure passage between them. The feed passage with feed tables was situated below the skylight in the middle of the stable. The side walls of the stable had a parapet at the bottom that reached up to 830 mm above the floor. The sheets for covering the side walls were pulled. There were only grids against flying birds on the open sides of walls. In the front and back part of the stable, there were six gates, from which two gates had dimensions 2,700 × 3,000 mm, and the next two gates had dimensions 3,000 × 3,000 mm. In the middle part, there were two gates with dimensions 2,700 × 2,900 mm. The plaster inside the stable was contaminated by animals, which also had an impact on the illuminance of the stable. The shelter, which was covered with black geotextile in summer to shield 58 lying cubicles placed directly at the peripheral wall of the stall, was built from one side of the stable. The intensity of daylight was measured in the stable in five profiles, i.e. at 0.5 m above the floor, which is the height of measuring the physiological and working lighting for buildings with cattle, and at 0.85 m above the floor, which is the height of measurement in terms of the working environment. In each profile, there were 11 measuring points that represented individual parts of the stable such as measurement under the shelter, in lying cubicles, and manure and feed passages (Fig. 1). The accuracy class of measurement was 3, the num-

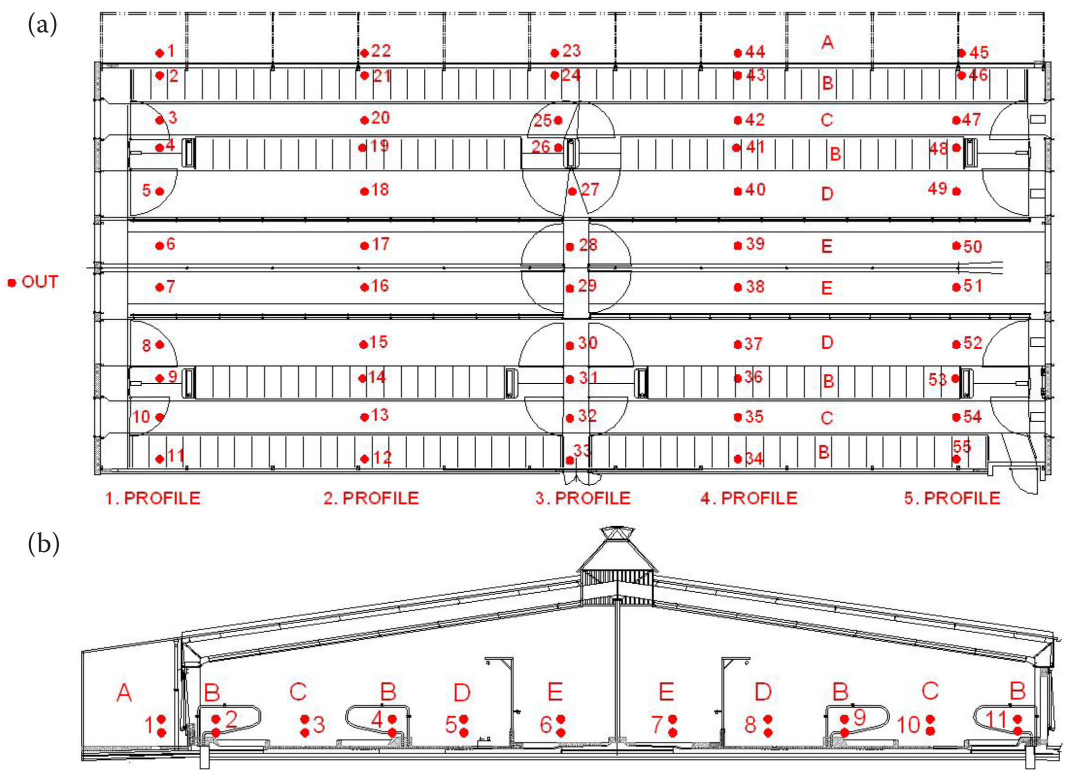

Fig. 1. Plan of the investigated building and measuring points (a) ground plan and (b) a cross-section of building

A – shelter; B – cubicle lying; C – manure passage; D – feeding area; E – feed passage; •1 – measurement points

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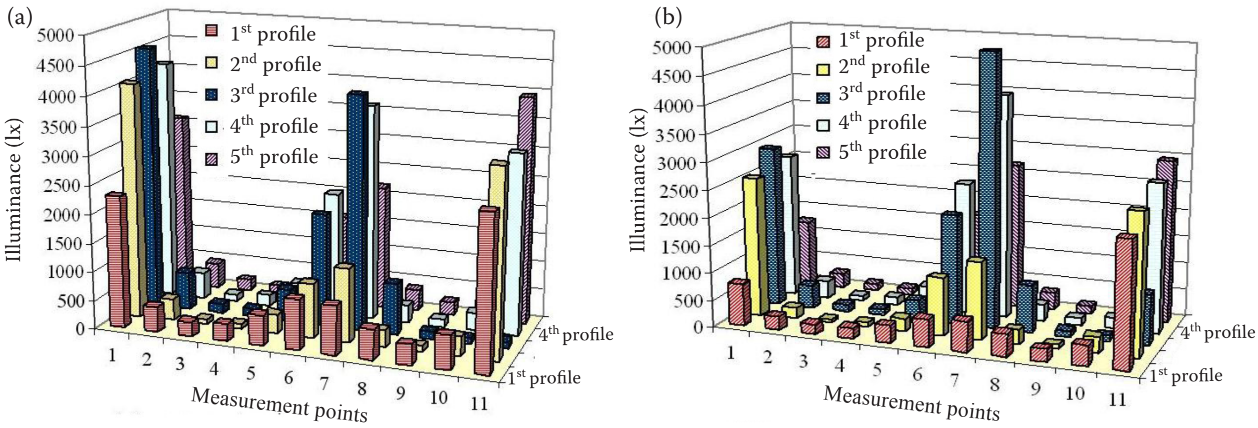

Fig. 2. Illuminance values (a) 0.5 m and (b) 0.85 m above the ground level

ber of repetitions inside was 5, and at the same time the measurement took place continuously also outdoors in the plane that was not overshadowed.

In addition to illuminance values, we assessed daylight factor values (D), which were calculated according to Eq. (1):

$$D = (\bar{E}/\bar{E}_h) \times 100 \quad (\%) \qquad (1)$$

where:

$\bar{E}$ – average illuminance in the point of the given plane of indoor premises (lx)

$\bar{E}_h$ – average value of outside comparative illuminance (lx)

Uniformity of daylight (r) is an important parameter in monitoring the stable building. For indoor premises with upper or combined lighting, the following relationship applies:

$$r = D_{\text{min}}/D_{\text{m}} \qquad (2)$$

where:

D_{min} – lowest value of daylight factor (%)

D_{m} – average value of daylight factor (%)

Desired value in stable premises with upper or combined lighting is $r \geq 0.30$. For humans, the accurate mid-class visual activity value is $r > 0.2$ (Chloupek, Suchý 2008).

RESULTS AND DISCUSSION

The measurement locations are shown in Fig. 1, and the illuminance values in the individual points measured in the heights of 0.5 m and 0.85 m are listed in Table 1 and in Fig 2. The highest illuminance values occurred under the shelter (indicated in Fig. 1 with the letter A) (where these values are affected only by dark geotextile by which the shelter is covered) and under the skylight of the roof in the feeding passage (E). High illuminance values were also in the lying cubicles near the wall where there is no shelter (B, point 11). In this section, light is supplied into the stable through the open side wall. An exception was in case of measuring points in the third profile. In this section, there is a full wall in which closed doors are located. On the opposite side of the stable where there is also an open side wall, the illuminance values in the lying cubicles were several times lower due to shelter structure. Inwards the stable, illuminance values decreased (manure passages – C). These values were lower than the values in lying cubicles near the walls. The shelter effect can still be observed here. The skylight structure had already no effect on stabling in lying cubicles that were not placed near the wall. These values were already coped and they were the lowest in the whole stable. Feed passages (D) were affected by the skylight. These values were rising again.

The results of measured values demonstrate how the cover shell structure influences the natural lighting of the stable. The skylight consisting of transparent glass has clearly the greatest impact. However, its disadvantage is that the stable overheats in summer due to transparent glasses and minimum thermal insulation. This deficiency could be removed by replacing the transparent glass by colourless translucent glass with protective surface modification. Open sidewalls have also a great impact on the lighting of stables. The shelter which is located along one side shadows the stable indeed, but simultaneously it protects the animals from overheating in summer. The geotextile covering the shelter is coiled in winter so it does not affect the supply of light or solar radiation into the stable.

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Table 1. Values of illuminance (*E*) in measurement points 0.5 and 0.85 m above the ground level

No. of measurements	Profile *E* (lx)				
	1st	2nd	3rd	4th	5th
0.5 m above the ground level					
1	2,305	4,088	4,580	4,196	3,098
2	445	375	644	458	445
3	259	92	155	118	205
4	295	82	135	183	155
5	527	338	565	473	287
6	888	931	1,951	2,149	1,562
7	846	1,276	4,051	3,731	2,160
8	527	287	896	311	370
9	351	107	122	130	214
10	589	345	89	302	315
11	2,669	3,237	111	3,141	3,944
0.85 above the ground level					
1	783	2,545	2,945	2,647	1,229
2	242	208	429	322	257
3	182	68	137	99	119
4	199	79	125	135	105
5	321	233	372	413	223
6	520	1,062	2,011	2,420	1,659
7	549	1,418	4,953	4,073	2,670
8	417	262	863	291	323
9	223	80	108	116	152
10	376	300	91	194	173
11	2, 263	2, 557	932	2, 716	2, 968

The width of the stall has also some impact on natural lighting. Even though the stable's side walls and roof skylight are opened, it has an inadequate lighting in some parts, as can be seen on the daylight factor values (Table 2 and Fig 3). In the manure corridors as well as in the lying cubicles not located near the side walls, illuminance values are lower than the recommended values for this type of housing. In such cases, it is advantageous to place the windows in the roof shell. If this is not possible, it would be appropriate to adjust the surface of the ceiling structure to light, at the best white, material.

The influence of the shelter and ceiling structure can also be seen at the levels where we perform the measurements. Higher values of illuminance are reached when measuring at the height of 0.5 m. There is less impact of the shelter and ceiling structure. These values are coped under the skylight.

Values of daylight uniformity for measurements at 0.5 and 0.85 m above the floor are shown in Table 3.

According to general technical requirements for buildings, stables for cattle must be constructed in such a way that they will ensure a healthy indoor environment and will not threaten the housing and animal breeding (Pogran et al. 2011). Therefore, it is necessary to monitor the microclimatic properties of the environment in stalls as well as air containing gases, dust and microorganisms that are by-products of the decomposition of animal excrements, often due to an imperfect metabolism of nutrients (Karandušovská et al. 2012).

According to Dahl and Petitclerc (2003), environmental influences on lactation efficiency are frequently associated with reductions in milk output. Heat stress, for example, leads to depressed feed intake and, subsequently, losses in production. Conversely, cold stress may limit nutrients available for milk synthesis. Fortunately, one environmental factor, photoperiod, can exert a positive effect on dairy performance when managed properly.

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Table 2. Values of daylight factor (D) in measurement points 0.5 and 0.85 m above the ground level

No. of measurements	Profile D (%)				
	1[st]	2[nd]	3[rd]	4[th]	5[th]
0.5 m above the ground level					
1	9.04	15.35	14.89	11.12	8.93
2	1.88	1.52	1.58	1.07	1.32
3	1.06	0.39	0.30	0.26	0.59
4	1.09	0.37	0.26	0.36	0.43
5	1.83	1.60	1.15	1.20	0.77
6	3.41	4.53	4.06	5.55	3.94
7	3.54	6.26	8.45	9.22	5.29
8	2.32	1.43	1.92	0.63	0.89
9	1.59	0.54	0.23	0.22	0.51
10	2.57	1.76	0.18	0.58	0.71
11	11.22	15.16	0.19	6.64	10.04
0.85 m above the ground level					
1	3.22	9.32	9.08	7.24	3.58
2	1.00	0.82	0.97	0.77	0.76
3	0.72	0.28	0.24	0.23	0.34
4	0.68	0.35	0.26	0.28	0.29
5	1.18	1.08	0.73	0.92	0.56
6	2.07	5.15	4.22	6.28	4.13
7	2.38	6.93	10.48	10.30	6.52
8	1.87	1.30	1.86	0.66	0.78
9	1.00	0.39	0.21	0.20	0.36
10	1.61	1.53	0.17	0.34	0.41
11	9.44	12.56	1.59	5.64	8.08

Besides the mentioned parameters, monitoring of lighting conditions is equally important in terms of the internal environment. According to Chastain (1994), proper lighting is an environmental factor that is often overlooked or given little attention during the planning, construction and maintenance of livestock facilities. However, it is just as important to the efficient operation of a livestock operation as ventilation, heating, or cooling.

Photoperiod management has a number of physiological effects on the dairy cow. During lactation, greater duration of exposure to light (i.e. long days) relative to controls results in increases in milk production during lactation (Dahl et al. 2000). Conversely, cows exposed to reduced duration of light during the dry period produced more milk during the subsequent lactation, relative to cows exposed to longer days (Miller et al. 2000).

It is the best for animals as well as for farmers in terms of financial aspect to achieve the maximum distribution of natural light. By open side walls and roof skylight, the supply of light is very good. However, the parts that are away from the skylight as well as from the side walls do not comply with

Table 3. Uniformity of daylight

Measurement in stable	$\bar{E}$ (lx)	$\bar{E}_h$ (lx)	D_{max} (%)	D_{min} (%)	D_m (%)	r (–)
0.5 m above ground level	1,129	35,345	15.35	0.18	3.58	0.05
0.85 m above ground level	930	35,916	12.56	0.17	2.79	0.06

$\bar{E}$ – average illuminance in the point; $\bar{E}$ – average value of outside illuminance; D_{max} – highest value of daylight factor; D_{min} – lowest value of daylight factor; D_m – average value of daylight factor; r – uniformity of daylight

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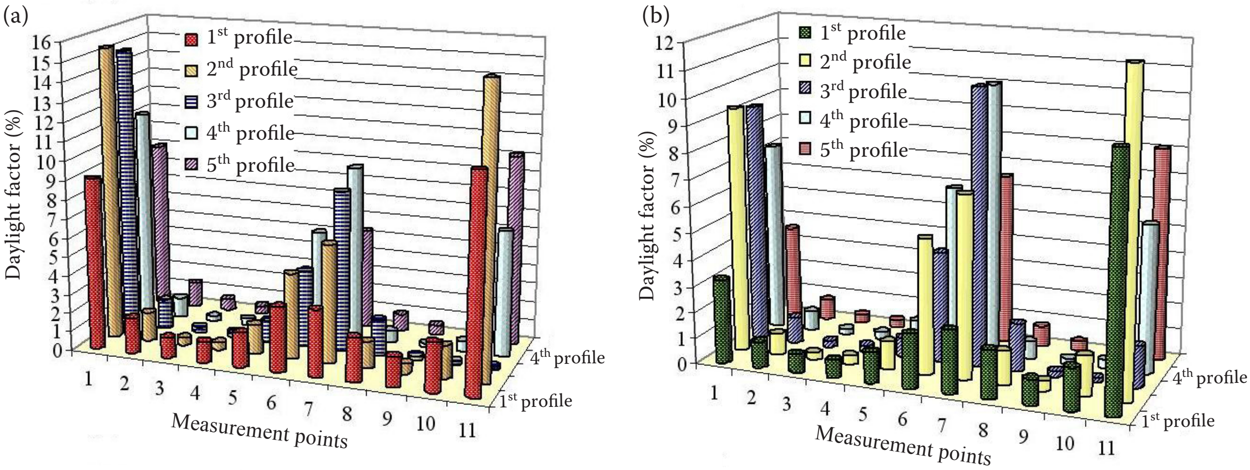

Fig. 2. Values of daylight factor (a) 0.5 m and (b) 0.85 m above the ground level

the recommendations for the breeder (Doležal, Černá 2006). Lighting conditions in some parts of the stable can still get worse in the winter months when sunshine duration is significantly shorter. Fluctuations among the values of illuminance across the stable are considerable. This is also seen on uniformity daylight values (Table 3) that are significantly lower than the required values. This is very unfavourable for animals because excessive fluctuations in light intensity can negatively affect the response of animals, for example by moving to more favourable conditions (Chloupek, Suchý 2008). The non-uniformity of daylight is well seen in Figs 2 and 3. A preferred solution for improving the uniformity of daylight would be if evenly spaced windows from translucent material would be made in the ceiling structure. It is also necessary to complete the surface treatment of lightning panels in terms of their overheating in hot summer. As long as it is not possible, it is proper to adjust the ceiling structure so that it has the lightest colour.

CONCLUSION

The work deals with the influence of cover shell material solution on stable daylight. To assess the lighting in the stable premises, illuminance measurements were performed and daylight factor and uniformity of daylight were calculated. From the given values we can see that high values of illumination are under skylight as well as at the side walls that are open. The disadvantage is that for the given stable width light is not uniformly distributed and illuminance values are insufficient in some parts. Another disadvantage is the overheating of stable under the skylight. To improve the conditions in the stable, it would be appropriate to monitor what would be the impact of changed ceiling of stable on illuminance. In terms of thermal and technological point of view, it must also be assessed which material is the best for using as a filling for the skylight in order to maintain a sufficient supply of light with reducing the overheating of the stable. The best solution in terms of illumination would be the reconstruction of the roof shell, where windows from suitable material would be evenly placed. However, such a solution would be financially more expensive.

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