Drainage Capacity of Concrete Slatted Floors for Dairy Cattle

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ABSTRACT

The design of concrete slatted floors in animal houses is a compromise between having good drainage capacity and good support for the feet of the animal. Clean and dry alleys in cubicle housing for dairy cows are of great importance for the cleanliness and welfare of the cows and also the milk quality. The drainage capacities of concrete slatted floors were tested in a laboratory arrangement using two different consistencies of manure obtained from either high-yielding dairy cows or from dry cows. Twenty-two floor arrangements with different combinations of single slats ranging from 50 to 150 mm, together with slot widths ranging from 20 to 50 mm, and with a void ratio (the ratio between the slot area and the total floor area) between 16.7 and 33.3 % were tested. The results were analysed by multiple regression. When manure from high-yielding cows was used, the drainage capacity was dependent on the void ratio, with the greater void ratio the better the drainage capacity was obtained. When using manure from dry cows, the drainage capacity was dependent on both the void ratio and the slot width, shifting to narrower slots required an increase in the void ratio to maintain good drainage capacity.

Keywords: Drainage, slatted floor, dairy cattle, cleanliness, Sweden

1. INTRODUCTION

In animal houses, draining floors are usually used to reduce the labour demand related to manure handling. Concrete slatted floors are commonly used in Sweden as well as in many other countries as the flooring in cow walking areas. Using slatted flooring means that the floor will be cleansed by self-cleaning and by the feet of the cows trampling down the manure, if no scraper is used. The floor design will thus be a compromise between good drainage capacity and good support for the feet. Most frequently used in Swedish dairy cattle housing are slatted floors with single slats of 125 mm width and slots of 35 mm. The advantage of single slats is the relative low weight which enables the farmers to put them into place by hand. More common in many European countries are constructions of slatted floor elements which allow narrower slats and reduce floor unevenness. According to Swedish regulations, the void ratio (the ratio between the slot area and the total floor area) of the floor may be at most 28 % and the slot width at most 35 mm (Swedish Animal Welfare Agency, 2004). The CIGR (1994) guidelines state 90-160 mm slats together with 30-35 mm slots as suitable flooring for cattle of 200-825 kg weight.

Investigations have shown that cows do not avoid the slots when walking on the slatted floors (Kirchner and Boxberger, 1987), but floor design may influence the walking behaviour of the animals (Telezhenko and Bergsten, 2005). The pressure distribution of the foot–floor contact area will vary with the floor design (Nilsson *et al*., 2006). Many claw diseases are caused by an extreme local overload (Distl and Mair, 1993). The wider the slats and the more narrow the slots that are used the less pressure that will occur (Kirchner and Boxberger, 1987; Nilsson *et al*., 2006), but at the same time, the draining capacity of the floor will decrease (Boxberger and Pfadler, 1980; Svennerstedt, 1999).

Clean and dry flooring in the walking areas for dairy cows is of great importance for the cows' welfare. Floors covered with slurry increase the risk of the animals slipping and falling (Albutt *et al*., 1990), and also change their walking behaviour (Phillips and Morris, 2000). Wet and dirty floor surfaces increase the incidence of hygiene related claw diseases (Bergsten and Pettersson, 1992), and affect the hardness of the claws (Borderas *et al*., 2004). Great amounts of manure on the alley in cubicle housing may also affect the cleanliness of the cubicles and cows, and subsequently the milk quality and the risk of mastitis (Galton *et al*., 1982; Barkema *et al*., 1998; Shreiner and Ruegg, 2003). Besides the width of the slats and the size of the slots, the cleanliness of slatted floors is dependent on the manure consistency, and the number of steps taken by the cows on the slatted floor (Boxberger and Pfadler, 1980; Boxberger and Pfadler, 1982).

The object of this study was to investigate how different widths of slats and slots affect the drainage capacity of concrete slatted floors for dairy cattle.

2. MATERIALS AND METHODS

2.1 Testing Equipment

The drainage capacity of the floors was tested in a laboratory arrangement, previously applied by Svennerstedt (1999). The testing equipment was constructed of steel with an upper and lower level. On the upper level, the slatted floor to be tested could be laid on an area of 1200 × 1200 mm. Above the upper level there was a frame with a bucket from which the manure sample to be tested was dropped, and from the same frame water was sprinkled over the manure through a bucket with holes. At the lower level, the manure and water passing the slatted floor could be collected for weighing.

2.2 Testing Performance

The tests were performed with a standard procedure, with 4 replicates on each tested floor setup and manure consistency. Two manure consistencies, one from high-yielding dairy cows and one from dry cows, were used. A method described by Svennerstedt (1999) was applied where a real situation for cows was simulated; 5 kg manure was dropped from a height of 1200 mm followed by 3 kg sprinkled water, simulating urine. The floor was trampled by hand in a fixed pattern with a dummy made of wood with 4 claws (Figure 1). In total, the dummy hit the floor area 21 times, equal to 58.3 steps/m^2. After the simulated trampling, the manure and water were left on the slatted floor to drain off for 10 min. The manure and water from the bottom level were then collected and weighed. The drainage capacity was calculated as the ratio between the collected amount of manure and water on the bottom level, and the total amount of manure and water dropped on the floor. The testing equipment was cleaned with water before each test.

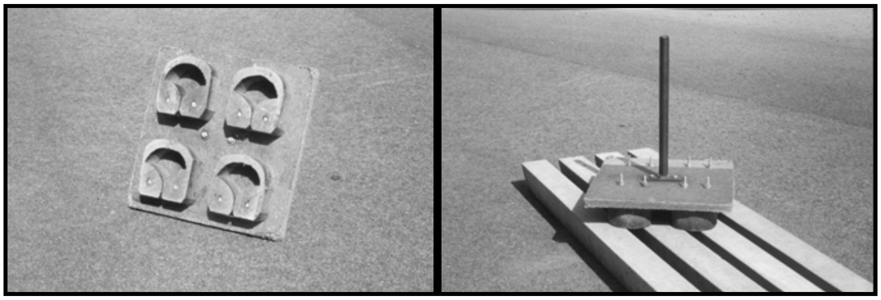

Figure1. Dummy made of wood with 4 claws. The floor was trampled by hand with the dummy in a fixed pattern.

2.3 Slatted Floors

Slats of 5 different widths were used; 50, 75, 100, 125 and 150 mm, respectively. The slats were constructed as 1200 mm long single slats of concrete with a V profile and the sides inclined 1:5 (Figure 2), except for the 50-mm slats where the load-bearing steel consisted of a U-steel. The height of the slats varied between 50 and 150 mm depending on slat width. After 2 weeks of hardening, a surface finish was made by grinding the upper surface of the slats with a carborundum block in order to obtain a standardized surface, corresponding to a few years use in practice. The sides and bottom of the slats had got a smoothed surface from the plywood formwork. The slats were placed and fixed on the upper level of the testing arrangement with a specified slot width in between. Seven different slot widths were used; 20, 25, 30, 35, 40, 45 and 50 mm, respectively. In total, the drainage capacity of 22 different combinations of slats and slots with a void ratio between 16.7 and 33.3 % were tested (Table 1).

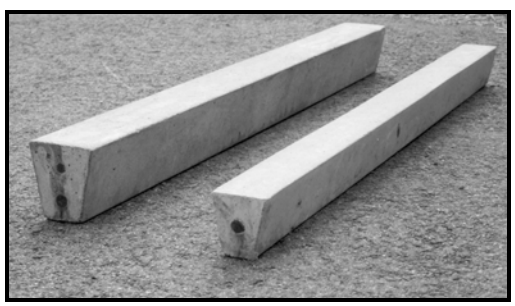

Figure 2. Design of tested concrete slats.

Table 1. Void ratio (%) of tested floors with different combinations of slats and slots

Slot width (mm)	Slat width (mm)				
	50	75	100	125	150
20	28.6	21.0	16.7		
25	33.3	25.0	20.0		
30		28.6	23.0	19.4	
35		31.8	25.9	21.9	18.9
40			28.6	24.2	21.1
45			31.0	26.5	23.1
50			33.3	28.6	25.0

2.4 Manure

Fresh manure was collected from the alleys in a cubicle system for dairy cows, and water was used to simulate urine. Manure enough for 4 replications was collected from high-yielding dairy cows and from dry cows, respectively, before each floor arrangement. The consistency of the manure for each floor arrangement was measured before use in the experiment by determination of the dry matter content and the slump. A slump cone with a height of 300 mm, a bottom diameter of 200 mm and a top diameter of 100 mm was used. The cone was filled with manure and after the removal of the cone the height of the sunken manure pile was measured (after 30 s). The difference between the full cone height and the measured manure pile height was calculated as the slump.

2.5 Statistical Analyses

Statistical calculations were performed using the MINITAB version 14 for Windows (Minitab, 2003). The mean value of the drainage capacity for each tested floor arrangement and manure type was calculated from 4 measurements, and used as the observation unit. For each type of manure, the relationships between the measured drainage capacity and the void ratio, slat width, slot width, slump and dry matter content, respectively, were analysed by a multiple regression procedure. The predicted models were selected using stepwise regression analyses (Alpha to enter/remove = 0.05).

3. RESULTS

3.1 Manure Consistency

The manure from the high-yielding dairy cows used in the experiment was estimated as being loose and had a mean and standard deviation of dry matter content of 13.6 ± 0.53% and a slump of 181 ± 12 mm, respectively. Manure from the dry cows was estimated as being more firm and had a dry matter content of 14.2 ± 0.35% and a slump of 28 ± 17 mm, respectively. Within each tested type of manure, the slump and dry matter content of manure did not significantly affect the drainage capacity and were not included in the predicted statistical models.

3.2 Drainage Capacity

The drainage capacity of the floors differed between the loose manure from the high yielding dairy cows and the firmer manure from the dry cows. When the manure from the high-yielding dairy cows and water was used, the drainage capacity for the different floor types varied between 53.5 and 78.4%. Lesser drainage capacity, between 41.3 and 75.5%, was measured when the manure from the dry cows together with water was used.

Analyses using stepwise regression showed that the parameters influencing the drainage capacity were the void ratio for loose manure, and the void ratio and width of the slots for the firmer manure. Results from the multiple linear regression analyses of the effect of the void ratio on the drainage capacity of loose manure and slot width and void ratio on the drainage capacity of the more firm manure are presented in Tables 2 and 3, respectively. Adding the parameter slot width to the model for loose manure only increased the R^2-value from 85.9 to 86.9%

Table 2. Results of linear regression analysis of the influences of the void ratio on the drainage capacity of loose manure from high yielding dairy cows and water on concrete slatted floors (n=22)

	Coefficient	Standard error	t-value	P-value
Constant	40.555	2.784	14.57	<0.001
Void ratio (%)	1.195	0.108	11.02	<0.001
Root-MSE(SD)	R-Square	Adj. R-Square		
2.391	85.9%	85.2%		

Table 3. Results of multiple linear regression analysis of the influences of the slot width and void ratio on the drainage capacity of firmer manure from dry cows and water on concrete slatted floors (n=22)

	Coefficient	Standard error	t-value	P-value
Constant	17.527	3.262	5.37	<0.001
Void ratio (%)	0.884	0.128	6.91	<0.001
Slot width (mm)	0.609	0.062	9.88	<0.001
Root-MSE(SD)	R-Square	Adj. R-Square		
2.653	92.0%	91.1%		

The greater void ratio, the better drainage capacity of the slatted floor was obtained when loose manure from the high yielding dairy animals was used. The calculated drainage capacity at different void ratios according to the regression analysis in Table 2 is presented in Figure 3. When firmer manure from dry cows was used, the drainage capacity was dependent on both the slot width and the void ratio. When a narrower slot width was used, a larger void ratio was required to obtain good drainage capacity. The calculated drainage capacity, at different void ratios, according to the regression analysis in Table 3, is presented as a function of slot widths in Figure 4.

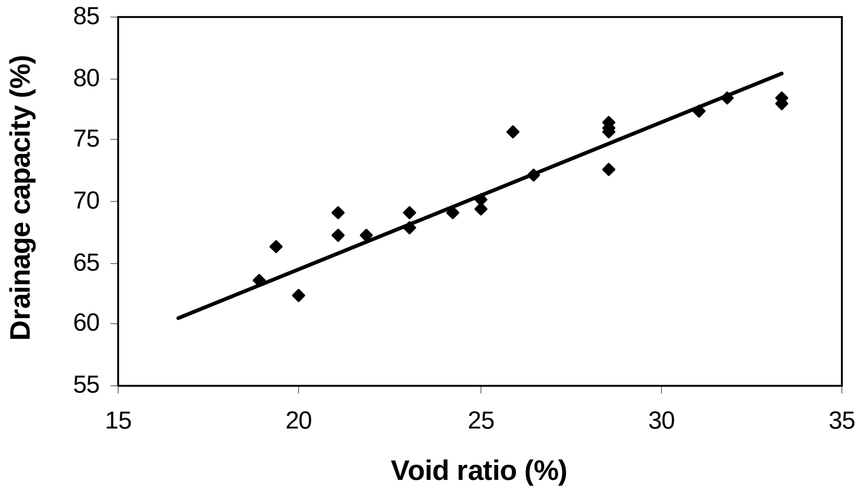

Figure 3. Average measured drainage capacity (dots) for different floor arrangement and calculated drainage capacity (line) of loose manure from high yielding dairy cows and water as a function of the void ratio according to the regression analysis in Table 2.

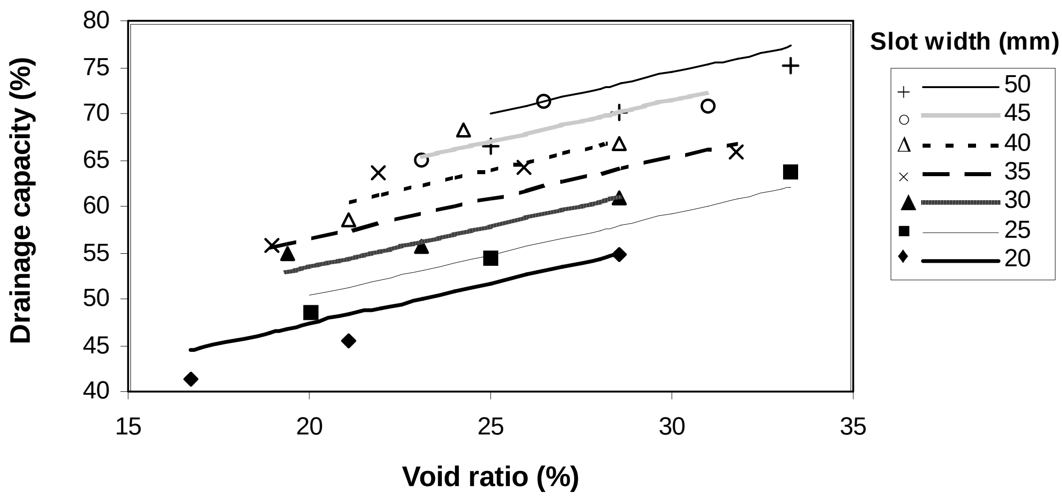

Figure 4. Average measured drainage capacity (dots) for different floor arrangement and calculated drainage capacity (lines) of firm manure from dry cows and water as a function of the void ratio at different slot widths according to the regression analysis in Table 3.

According to the results of the regression analyses presented in Table 2 and 3; Figure 5 and 6 show the expected drainage capacity of slatted floors with different widths of slats and slots when manure from high yielding dairy cows and dry cows are used, respectively.

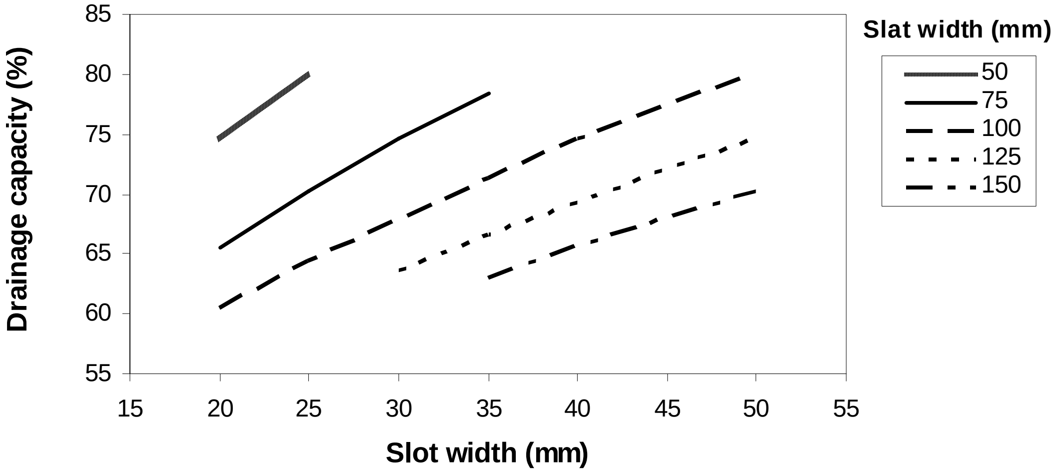

Figure 5. Expected drainage capacity of slatted floors with different widths of slats and slots, with manure and urine from high-yielding dairy cows, based on the results of the regression analysis in Table 2.

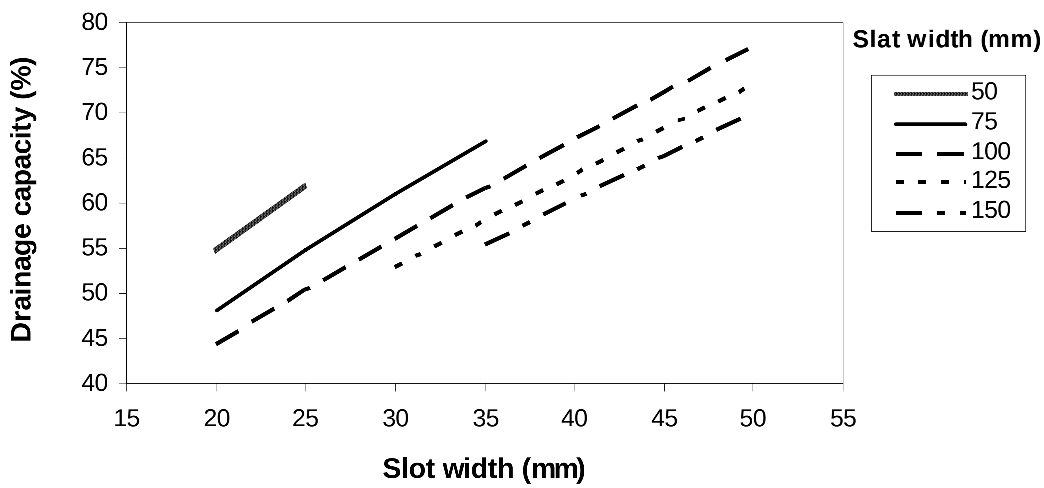

Figure 6. Expected drainage capacity of slatted floors with different widths of slats and slots, with manure and urine from dry cows, based on the results of the regression analysis in Table 3.

4. DISCUSSION

The results presented here agreed with those of previous studies by Boxberger and Pfadler (1980; 1982). They found that the self-cleaning of the floor was dependent on the void ratio and the consistency of the manure, and that the number of steps taken on the manure covered slatted floor affected the floor cleanliness.

The differences in manure consistence in manure from high-yielding cows and dry cows affected the drained capacity. There was only 0.8% difference ($P<0.001$) in dry matter content between loose manure from high-yielding dairy cows and the more firm manure from dry cows. Larger difference was found between the different slumps. The slump seems to be a better parameter than the dry matter content to describe the manure consistency.

The frequency of the steps taken by the cows on the slatted floor is of importance for the floor cleanliness (Kirchner and Boxberger, 1987). The use of slatted floors means that the floor cleaning to a great extent is handed over to the cows. On the other hand, it is necessary that the claws should be clean and dry. The use of slatted flooring also limits the size of the walking areas; too large areas tend to be manure contaminated because too few steps are taken by the cows on a specific area. Scrapers used frequently on slatted floors improve significantly the cleanliness (Magnusson *et al*, unpublished data), but this could be considered as an unnecessary or a too expensive use of two systems with the same purpose.

The cleanliness of floors in housing systems for dairy cattle is of great importance for animal welfare and for milk quality. However, the floor design of the slatted floor has to consider both cleanliness, and good support for the claw and the pressure distribution between claw and slatted floor. When consideration was taken to both the requirements for cleanliness and the support of the claws, the recommendations for the design of slatted floors for dairy cows were to use a slat width of 80 mm and a slot width of 25 – 30 mm (Kirchner and Boxberger, 1987). To construct slats of 80 mm width using traditional concrete and reinforcement would only be possible using slatted floor elements. This would also be an advantage with respect to maintaining the evenness of the floor. However, in Sweden these recommendations have rarely been applied.

Nilssons *et al*. (2006) showed that the contact pressure between the claw and floor changes with the slat and slot widths. The present results indicated that smaller slats and slots narrower than 125 and 40 mm, respectively, are favourable to use. More research is needed to fully understand how the different slat and slot widths affect the claws. Attention should be paid to the pressure distribution under the claw and a discussion of the possibilities of changing the dimension of the presently used concrete slatted floors has begun. In such a discussion it is of great importance not to forget the drainage capacity and the cleanliness of the floor. In Sweden, the regulations concerning slatted floors for adult dairy cows were changed in 2004. Today the maximum permissible slot width is 35 mm. Before 2004 it was 40 mm (Swedish Animal Welfare Agency, 2004). However the old slats of 125 mm are still the most used, which means that the void ratio has decreased from 24 to 22%. Although it is only a small decrease it is still unfavourable for maintaining cleanliness. The void ratio is allowed to be at the most 28%; consequently there is some opportunity for different floor designs. The design of the slatted floor may then be modified to fulfil the optimal claw pressure distribution of foot-floor interface. The results of this study show for dairy cows with loose manure that as long as the void ratio is constant, the drainage capacity will not be affected. For dry cows and heifers with firmer manure, changing the floor to narrower slots should be combined with a greater void ratio to be able to keep the cleanliness level of the floor.

The present study was carried out in a laboratory arrangement using standardized methods in order to reduce the variation of the different parameters. In practice, the floor is not cleaned during the housing season and the manure can adhere between the slats. However, in practice a slot width as small as 25 mm works (Boxberger & Pfadler, 1980). In Sweden single slats are used by tradition in the walking alleys for dairy cows and this is the only alternative the domestic industry offers to the farmers. Using slatted floor elements, or with new materials and techniques, it should be possible to construct floors with smaller slat widths.

5. CONCLUSIONS

The design of slatted floors with use of 50 to 150 mm slats and 20 to 50 mm slot widths within the range of the void ratio from 16.7 to 33.3% affect the drainage capacity of the floors. For high-yielding dairy cows with loose manure, the greater the void ratio of the slatted floor, the better the drainage capacity and cleaner floor irrespective of the slat and slot widths. For dry cows and heifers, with firmer manure, the drainage capacity of the floor is dependent on both the void ratio and the slot width; floors with narrower slots need greater void ratios to maintain good cleanliness.

6. ACKNOWLEDGEMENTS

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