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Analysis of Costs for Construction of Milking Parlours of Various Designs

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Abstract

Analysis of construction costs of milking parlours of various capacities and arrangement of animals on milking platforms was done. The studies included also an evaluation of construction parameters of different variants of cow traffic into and from the milking room. The analysis evaluated the costs for concrete and reinforced steel for the different designs. Regression analysis of construction and planning costs was made for the specific models.
The conclusions are focused on minimization of costs for construction of milking parlours with preliminary set of technological parameters.
The parlour capacity influenced proportionally the absolute amounts of reinforced steel and concrete for construction of the technological profile of all studied herringbone milking parlours design variants. The arrangement of cows in the herringbone parlours with identical capacity had an effect on the relative amounts of reinforced steel and concrete.The location of the entry to milking platforms influence the amount of steel and concrete spent for the technological profile of the parlour floor for all observed variants.

Keywords: milking parlours, planning parameters, construction and planning costs, technological conditions

Introduction

One of the primary trends in the development of the modern milking equipment is related to improvement of ergonomic conditions for farmers and the welfare of animals. Installations allowed greater precision of processes were preferred greatly as they resulted in better quality of the produce, higher level of animal welfare and better profitability at the farm. These advantages are offered by milking parlours [1,4].

The design of a milking parlour is dependent on local conditions, milking management practices, herd physiology, the type and size of the milking parlour and the personal preferences of the client [2,11]. The models for traffic of cows [7,9], the size of groups, plans for technology improvement and initial investments were with given priority [2,8,6].

Various types of milking equipment are produced at a global scale, each with their advantages and flaws. The herringbone milking parlours have been proved their efficacy over decades, but continuously undergone development and optimization [4,7]. In the herringbone parlour, cows stand on both sides of the milking duct under an angle of 30º (distance of about 120 cm) or 60º (distance of about 90 cm) [5,6]. The access to the udder is from the side, which is the more natural position of milking and more convenient for the operator. The disadvantages of this milking parlour design consist in delayed traffic of the group by slow cows, inefficient usage of the parlour space etc. [3,10].

Despite the technical and technological variants of the equipment, including the optional equipment, there are no unanimous methodological criteria for optimisation or minimisation of costs for concrete and reinforced steel needed for the construction of a specific milking parlour design.

The purpose of the present study was to perform a comparative analysis of main construction

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costs (concrete and reinforced steel) of different variants of the herringbone milking parlour with previously set technological parameters.

2. Material and Methods

The study investigated several variants of the herringbone milking parlour of different capacity and different design and construction configurations (table 1).

The variants were evaluated on the basis of the following technical and technological parameters:

- Variants with capacities from 2x5 to 2x10 cows with fixed and rapid exits were analysed.

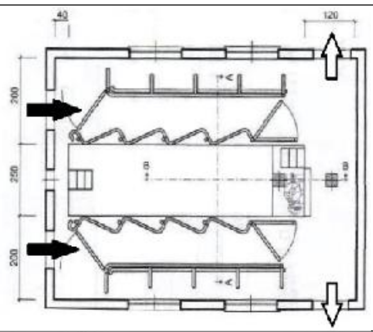
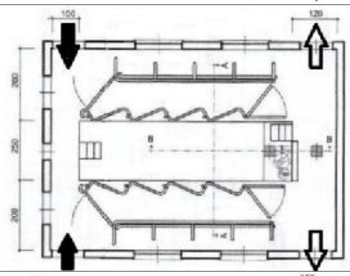
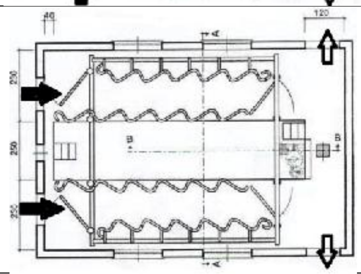
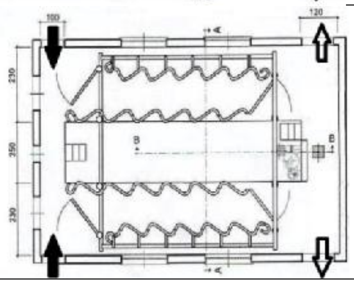
- The pit depth was set to 90 cm, the width - 250 cm, and the depth depends on the capacity.

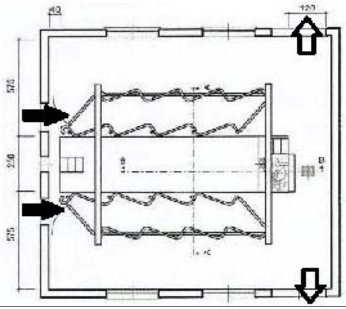
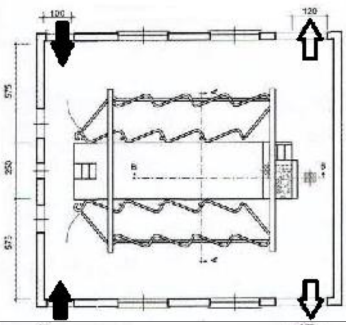
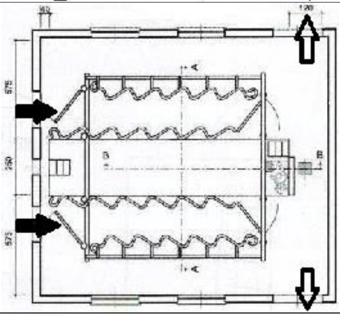
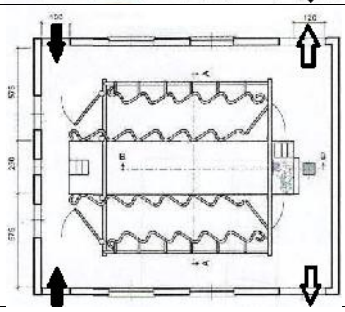
- The thickness of the bottom and walls of the pits, and those of milking platforms was 25 cm (as set by the manufacturers of the technological profile of the floor).

- The light height of milking parlours was h=300 cm

- The milking platform width for herringbone 30° parlours was 200 cm, for herringbone 60° parlours: 230 cm, and for „rapid exit” variants: 575 cm for both 30° and 60° parlours.

Table 1. Variants for the entry/exit traffic of cows in different arrangements of herringbone milking parlours

Variant *	Entry**	Scheme
„A”	„1”	
„A”	„2”	
„B”	„1”	
„B”	„2”	

„C”	„1”	
„C”	„2”	
„D”	„1”	
„D”	„2”	

***** *According to the location of cows vs the long pit axis:*

- Variants „A”: the cows are under an angle of 30° vs the long pit axis;
- Variants „B”: the cows are under an angle of 60° vs the long pit axis
- Variants „C”: the cows are under an angle of 30° vs the long pit axis and with “rapid exit”
- Variants „D”: the cows are under an angle of 60° vs the long pit axis and with “rapid exit”

*** According to the site of entry of cows in the parlour:*

- Variant „1”: with front entry;
- Variant „2”: with side entry

The study was conducted to evaluate the variants according to the following parameters: relative amount of materials (concrete, reinforced steel) spent for construction of the technological profile of the floor. The effect of the number of cow places on the quantity of materials for the different variants was also determined. The results from the comparative analysis and their interpretation are presented in tables and on graphs. The investigation utilised the comparative analytical approach.

The quantity of reinforcing steel spent for construction of the technological profile of parlour floor was determined by the formula:

$$Qst = 2\left[\left(\frac{L}{t}+1\right).B + \left(\frac{B}{t}+1\right).L + 2\left(\frac{h}{t}\right).\left(B_k+L_k\right)\right].m_1 + 2\left[2\left(\frac{B_k+L_k}{t}\right)\right].m_2 \quad ,(kg) \quad [1]$$

The quantity of concrete spent for construction of the technological profile of parlour floor was determined by the formula:

$$Qb = \left[B.L + 2\left(B_k + L_k\right).h \right].d \quad ,\left(m^3\right) \qquad [2]$$

where:

h – Pit depth, m (h is set to 0.90 m);

d – Thickness of reinforced concrete pavement and pit walls, m;

B – Milking parlour width, m;

L – Milking parlour length, m;

B_k – Milkers pit width, m;

L_k – Milkers pit length, m;

m_1 – weight of reinforced steel bar with diameter Φ=8 mm per 1 linear meter, kg/m;

m_2 - weight of reinforced steel bar with diameter Φ=10 mm per 1 linear meter, kg/m;

Q_b – total quantity of concrete for a given variant, m^3;

Q_{st} – total quantity of reinforced steel for a given variant, kg.

The analysis of data from the equations [1] and [2] is being done with respect to the undefined functions:

- Q_b; $Q_{st} = f(C)$
- Q_b; $Q_{st} = f(V)$

Where:

C – Milking parlour capacity;

V – The specific variant for cows positioning angle and entry/exit of cows to and from the parlour.

3. Results and Discussion

In calculations, the quantity of reinforced steel type B 500 with diameter Φ=8 mm was estimated. The calculation should be employed in the construction of floors in all technological areas of the milking centre.

Reinforced steel two-row grill with distance between bars of 15 cm is set in the assignment. The vertical spaces between the grills are fixed by “chairs” from the same steel.

In the assignment, the reinforcement of pit walls was planned to be done with steel bars B 500 with diameter Φ=10 mm. The construction should be done as described above.

Data from table 2, column marked with “1” represent the absolute weight of reinforced steel needed for herringbone milking parlour with front entry of cows. The values indicated that the increasing of parlour capacity was associated with higher amount of reinforced steel. The average rate of increase of all 2x8 variants was 116.1 kg. The relationship between the material spent and the number of cow places was strictly linear. The argument in support of this statement is that the difference in weight utilized was the same between each two increments and equal to the mean arithmetic values – i.e. 116.1 kg.

Data from column “2” depict the relative weight of reinforced steel per cow place from the same construction design (30°, front entry).

Unlike the trend of absolute weights, the relative weights exhibited a reciprocal trend. The analysis of values demonstrated that the increased capacity of the milking parlour was associated with lower relative weight of reinforced steel (from 97.0 to 77.5 kg per cow place).

Table 2. Quantity of reinforced steel for construction of the floor of herringbone milking parlours with different design

Milking parlour capacity	Configuration															
	A1		**A2**		**B1**		**B2**		**C1**		**C2**		**D1**		**D2**	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
	Absolute weight, kg	Relative weight kg/cow place	Absolute weight, kg	Relative weight, kg/cow place	Absolute weight, kg	Relative weight, kg/cow place	Absolute weight, kg	Relative weight, kg/cow place	Absolute weight , kg	Relative weight, kg/cow place	Absolute weight, kg	Relative weight, kg/cow place	Absolute weight, kg	Relative weight, kg/cow place	Absolute weight, kg	Relative weight, kg/cow place
2x5	970	97.0	1012	101.2	833	88.3	878	87.7	1700	170.0	1807	180.7	1375	137.5	1468	146.8
2x6	1086	90.5	1128	94.0	912	76.0	956	79.7	1910	159.2	2017	168.1	1498	124.8	1598	133.2
2x7	1202	85.5	1244	88.9	991	70.8	1034	73.9	2120	151.4	2227	159.1	1621	115.8	1728	123.4
2x8	1318	82.5	1360	85.0	1069	66.8	1112	69.5	2330	145.6	2437	152.3	1744	109.0	1858	116.1
2x9	1434	79.7	1476	82.0	1147	63.7	1190	66.1	2540	141.1	2647	147.1	1867	103.7	1988	110.4
2x10	1550	77.5	1592	79.6	1225	61.3	1268	63.4	2750	137.5	2854	142.7	1990	99.5	2118	105.9

The average difference of the relative weight within the studied interval was 3.9 kg/cow place. Dissimilar to the absolute amount tendency, the dynamics of the relative weight was non-linear. The tendencies described so far are presented on figure1.

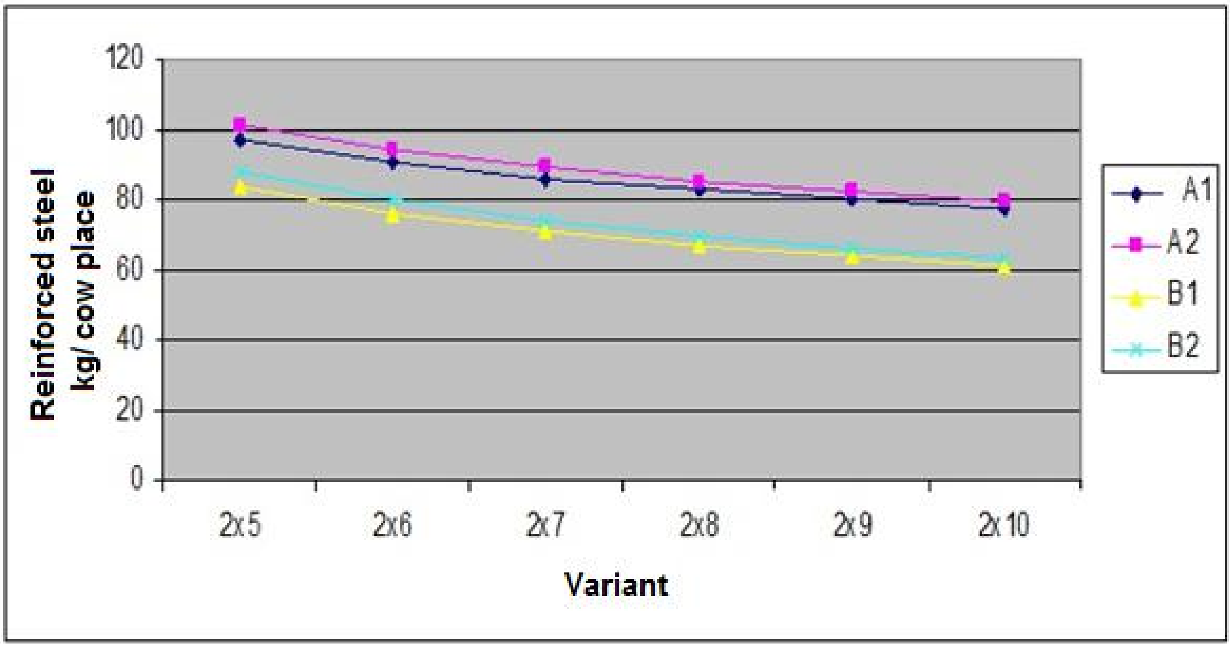


Figure 1. Effect of milking parlour capacity on the relative weight of reinforced steel per cow place in a conventional exit variant

The graph showed that observed relationships were absolutely identical for all discussed variants. The vertical disposition of graph patterns of “rapid exit” variants emphasized the higher absolute and relative weight spent.

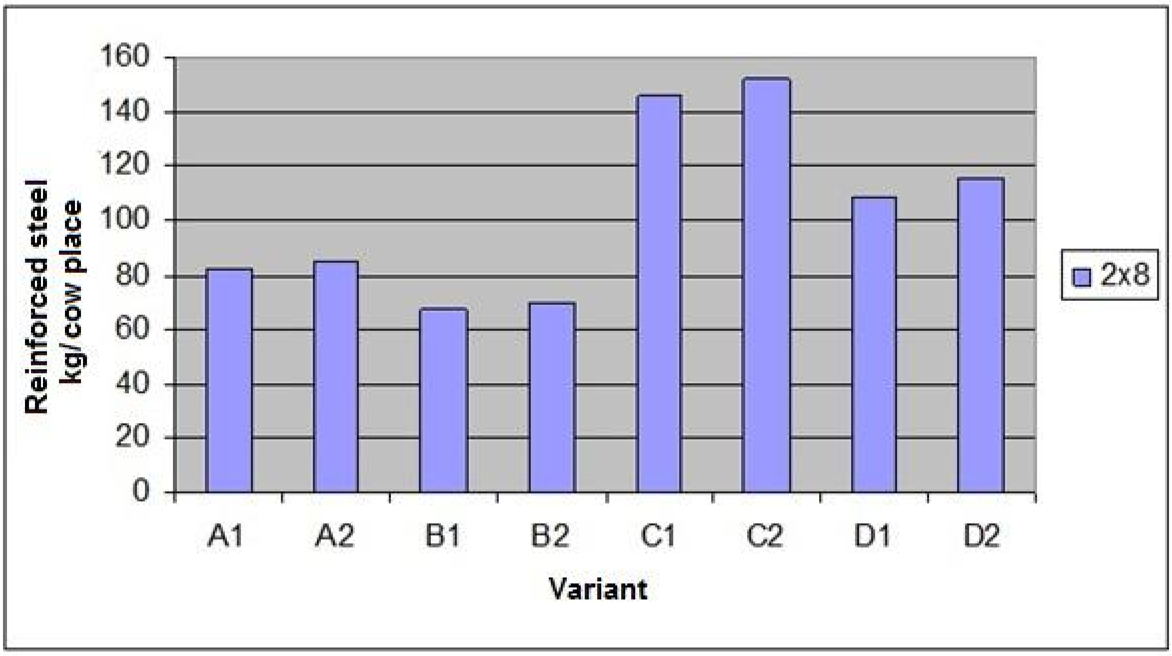


Figure 2. Comparative analysis of the relative weight of reinforced steel for herringbone parlours with different positioning angle and different entry/exit combination

Figure 2 illustrates the relative weights of reinforced steel needed for construction of different herringbone milking parlour variants.

The analysis was made on the 2x8 variant, as it is most commonly used in Bulgaria. The lowest weight of reinforced steel was needed for 60^{o} variants with front entry and conventional exit. The relative weight was 66.8 kg/cow place.

In front entry parlours where cows were positioned at an angle of 30°, the relative weight spent was 82.5kg/cow/place. The comparison showed that when entry/exit parameters were identical, the positioning of cows at 30° was related to higher weight of reinforced steel – by 15.7 kg/cow place or 23.5%.

For variants with identical positioning angle (A1 and A2), the difference of reinforced steel weight per cow place was 2.5 kg in favor of the front entry (relative difference 3%).

A similar tendency was observed with respect to the effect of entry position vs the milking platforms in 60° herringbone parlours. In variants with front entry, the weight of needed reinforced steel was 66.8 kg/cow/place, whereas for the side entry – 69.5 kg/cow place. The absolute difference was 2.7 kg/cow place, i.e. the respective relative difference was 4%.

The comparison of relative weights allowed concluding that the position of the entry door to milking platforms had a more significant effect on the studied parameters when cows were standing at 60° vs the variants at 30°.

The comparison of data in columns C1, A1; C2, A2; D1, B1 and D2, B2 shows the differences in the relative weight of reinforced steel in the respective variants with conventional and "rapid exit". For example, the relative weight of steel for 30° parlour with front entry and conventional exit was 82.5 kg/cow place. On the basis of the same construction parameters and "rapid exit", the value was 145.6 kg/cow place, therefore the construction of a "rapid exit" parlour was related to increased relative weight of reinforced steel by 76.4 %.

Table 3, column 1 presents the amount of concrete for construction of herringbone milking parlors with front entry for cows. Data indicated that parallel to the capacity of the parlour, the amount of concrete increased by 2.8 m^3 on the average. The relationship between the material spent and the number of cow places is absolutely linear (figure 3). Data from table 3, columns "2" represent the relative amount of concrete per cow place using the same construction design. Here, the reduction of the relative amount of concrete (from 1.88 to 1.52 m^3/cow place) along with increase in cow place number could be followed out.

Table 3. Quantity of concrete for construction of the floor of herringbone milking parlours with different design

Milking parlour capacity	Configuration															
	A1		**A2**		**B1**		**B2**		**C1**		**C2**		**D1**		**D2**	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
	Absolute amount, m^3	Relative amount, m^3/ cow place	Absolute amount, m^3	Relative amount, m^3/ cow place	Absolute amount, m^3	Relative amount, m^3/ cow place	Absolute amount, m^3	Relative amount m^3/ cow place	Absolute amount, m^3	Relative amount, m^3/ cow place	Absolute amount, m^3	Relative amount, m^3/ cow place	Absolute amount, m^3	Relative amount, m^3/ cow place	Absolute amount, m^3	Relative amount, m^3/ cow place
2x5	18.8	1.88	19.5	1.95	15.8	1.58	16.8	1.68	35.6	3.56	37.7	3.77	27.7	2.77	29.7	2.97
2x6	21.6	1.80	21.8	1.82	17.6	1.47	18.6	1.55	39.9	3.33	42.1	3.51	30.8	2.51	32.9	2.74
2x7	23.4	1.67	24.1	1.72	19.4	1.39	20.4	1.46	44.2	3.16	46.5	3.32	33.9	2.42	36.1	2.58
2x8	25.7	1.61	26.4	1.65	21.2	1.33	22.2	1.39	48.5	3.03	50.9	3.18	37.0	2.31	39.2	2.45
2x9	28.0	1.56	28.7	1.59	23.0	1.28	24.0	1.33	52.8	2.93	55.3	3.07	40.1	2.23	42.4	2.36
2x10	30.3	1.52	31.0	1.55	24.8	1.24	25.8	1.29	57.1	2.86	59.7	2.99	43.2	2.16	45.6	2.28

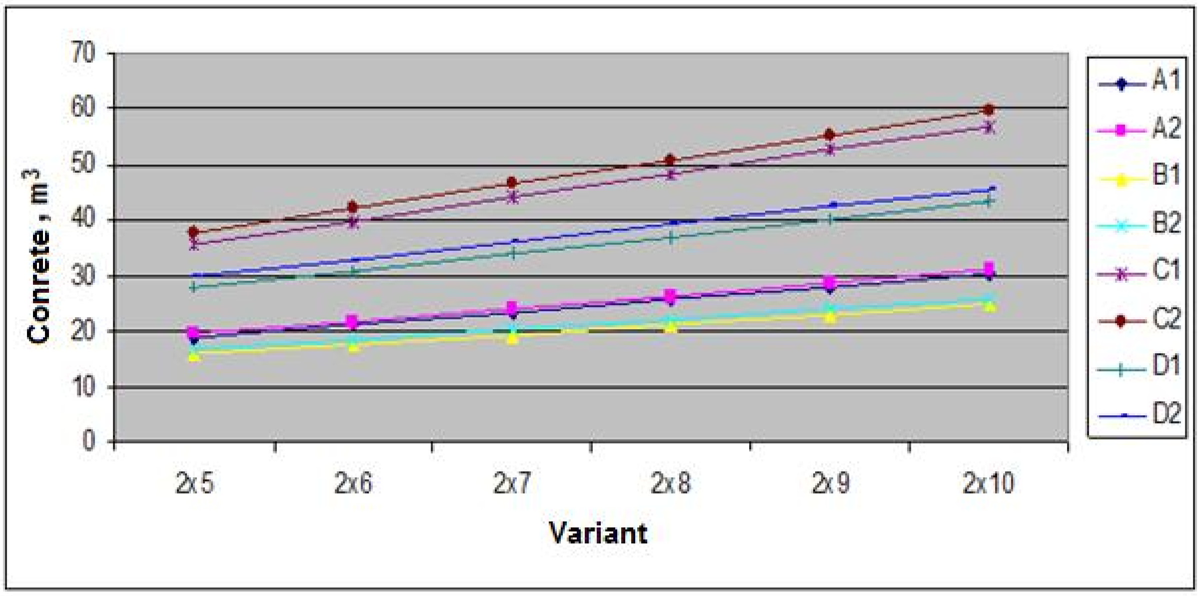


Figure 3. Absolute amount of concrete spent for herringbone parlours with different positioning angle and different entry/exit variant

The average difference between relative amounts of concrete within the studied interval was 0.06 m³/cow place. Unlike trends exhibited by the absolute amount, the dynamics of relative ones was non-linear. The tendencies are shown on figure 4. The relationships were observed for all variants. Herringbone parlours with "rapid exit" underlined the substantially higher amount of concrete that should be spent, both absolute and relative.

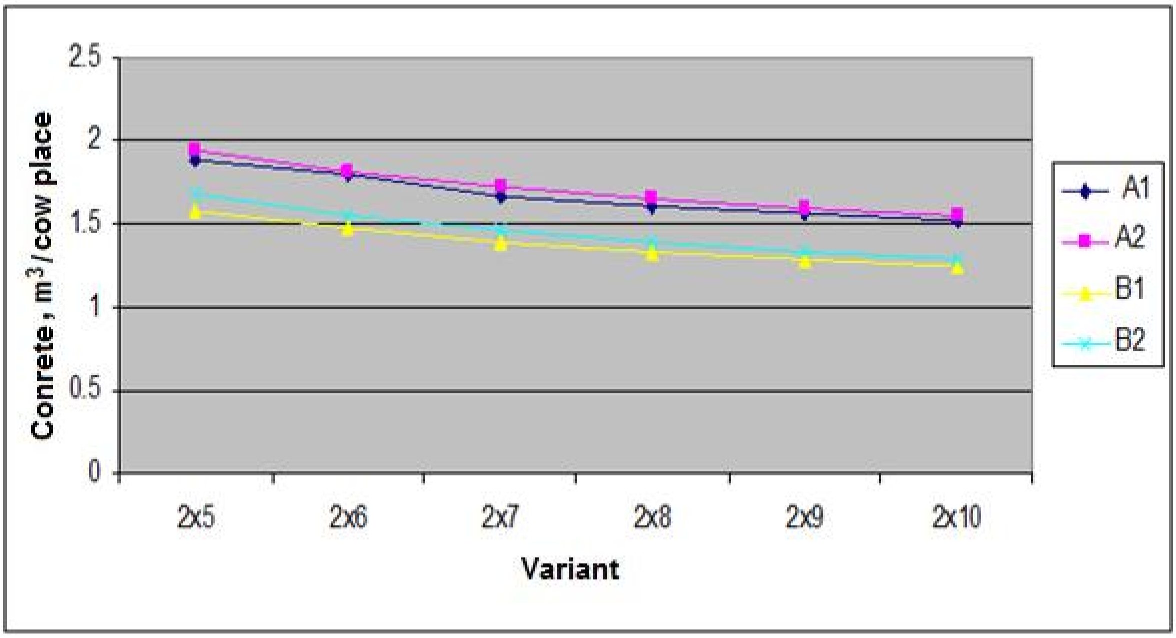


Figure 4. Effect of milking parlour capacity on the relative amount of concrete per cow place in a conventional exit variant

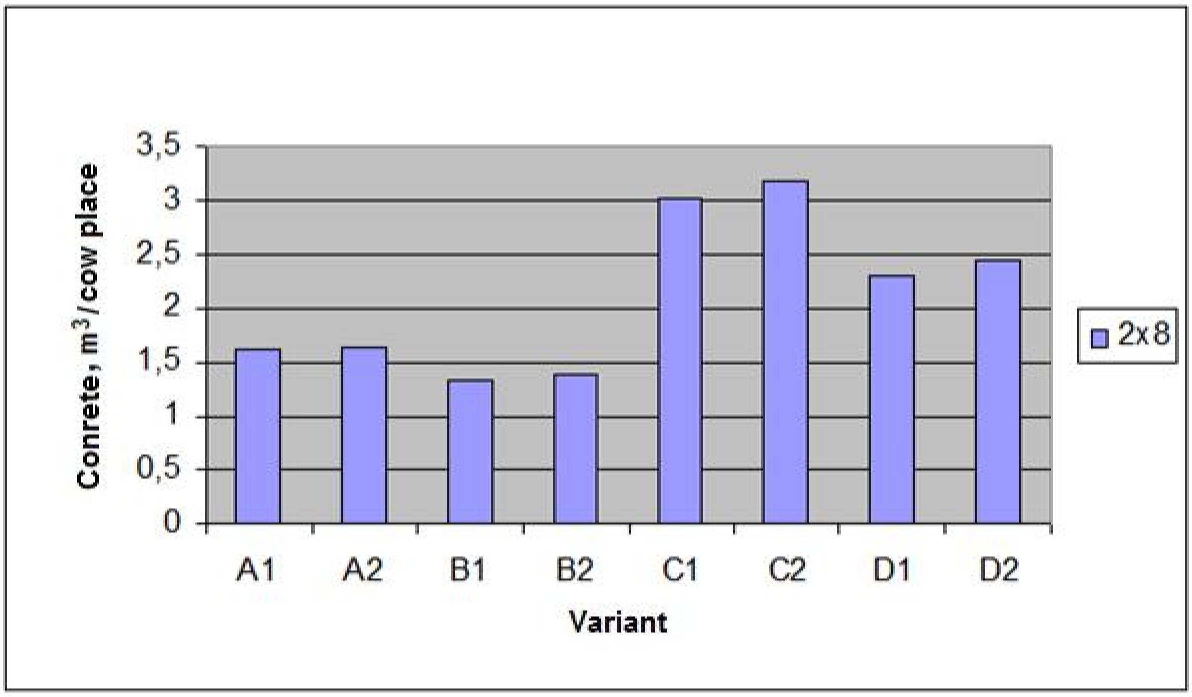


Figure 5. Comparative analysis of the relative amount of concrete for herringbone parlours with different positioning angle and different entry/exit variant

Figure 5 illustrates the relative amounts of concrete for the different herringbone milking parlour variants. The lowest amount of concrete was needed for parlours where cows were positioned at 60° vs the long pit axis, with front entry to milking platforms: 1.33 m³/cow places for the 2x8 variant. The same variant with positioning angle of 30° for a 2x8 parlour already resulted in higher amount of concrete (1.61 m³/cow place). Therefore, when the cow traffic pattern was the same, the positioning of cows at an angle of 30° resulted in higher costs for concrete by 21%. Table 3 shows that for the same angle (variants A1 and A2); the relative difference in the amount of concrete was 0.07 m³ in favour of the front entry i.e. 3.7%. The comparison of variants C1, A1; C2, A2; D1, B1; D2, B2 outlined the differences in the relative amounts of concrete between parlours with conventional and "rapid" exit. For positioning at 60° with front entry and conventional exit, the relative amount of concrete was 1.65 m³/cow places. The same construction parameters with „rapid exit" increased the amount to 3.18 m³/cow place. The relative amount of necessary concrete was considerably increased by 92.7%.

4. Conclusions

The parlour capacity influenced proportionally the absolute amounts of reinforced steel and concrete for construction of the technological profile of all studied herringbone milking parlours design variants. This parameter influenced reciprocally the relative amounts of material per cow place and the average quantitative effect was estimated as -10% per cow place. The arrangement of cows in the herringbone parlours with identical capacity had an effect on the relative amounts of reinforced steel and concrete. The arrangement of cows at 60° vs the pit axis reduced the relative amounts of reinforced steel by 23% and of concrete by 21% compared to 30°variants. The location of the entry to milking platforms influence the amount of steel and concrete spent for the technological profile of the parlour floor for all observed variants. The traffic through the side entry required by 3-4% more steel and by 2.5% more concrete. The exit type influenced strongly the amounts of studied construction materials. In the "rapid exit" variant, the relative amount of reinforced steel per cow place was by 76.4% higher vs the conventional exit and the relative amount of concrete were by 88% higher. The least material-intensive variant with respect to the amounts of reinforced steel and concrete was the 60° herringbone parlour with front entry to milking platforms and conventional exit. The most expensive variant with respect to needed amount of steel and concrete was the 60° “rapid exit” herringbone parlour with side entry

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