FROM CONCEPTUAL IDEA TO CONSTRUCTION OF NEW FREE STALL FOR DAIRY COWS USING AUTODESK AUTOCAD PROGRAM

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Abstract: Buildings and equipment on a dairy farm facilitate the job of caring for the animals. When dairy facilities are considered to be built or renovated certain technological normative and recommendations must be taken into account. We design new conceptual design for free stall and created blueprint. The speciality of this model represents a stable manufacturing and technical facilities. The production part of the stables included lying cubicles for 148 cows, nursery, pens for sick animals, pens for calves and breeding heifers, and pens for cow in the end of the lactation - together approx. 200 livestock units. For new blueprint and a conceptual design of new stall we use Autodesk AutoCAD 2015 software. The program has proven effective and easily understandable. With it, we can quickly and efficiently draw and performed our ideas.

Key words: AutoCAD, conceptual design, free stall, equipment

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1. Introduction

Dairy facilities can have a dramatic impact on milk production and cow health. All components of the dairy must be sized correctly to create an environment that is ideal for the dairy cow and the employees who will operate the facility (Wierenga & Hopster, 1990; Smith and al., 2002). Buildings and equipment on a dairy farm facilitate the job of caring for the animals. When dairy facilities are considered to be built or renovated certain technological normative and recommendations must be taken into account (Bicker at al., 2000; Næss & Bøe, 2010).

According to Bickert at al. (2000) a sound management plan is the basis for planning new construction or remodelling of dairy facilities. In accordance with the changing technology of farming and size of the animals they are also changing norms. Well designed and properly managed animal housing provides the ability to adopt the best management practices currently recommended. Plan space, equipment, environment, food rations, and care to meet the needs of each group. Manage replacements in groups according to their specific requirements. Facility design should allow for easy implementation of the management plan for each group.

Among the goals of the management program are these (Tucker, 2009):

- Increase milk production per cow.
- Increase milk quality (i.e. reduced somatic cell count, reduced plate count, increased protein, etc.).
- Lower calf mortality.
- Improve the genetic quality of the animals.
- Provide quality water and feeds.
- Raise healthy replacement animals.
- Improve overall herd health.
- Increase labor efficiency.
- Maximize operator safety.
- Improve environmental protection.
- Increase profitability.
- Improve animal welfare.
- Provide plenty of fresh air.
- Maintain good neighbor relations.

According management program by design of animal housing, we need to provide (Bayne, 1996):

- Adequate resting and exercise space.
- Covered, dry resting areas.
- Absence of excessive drafts.
- Good quality fresh air.
- Adequate space to access feed and water.
- Space to group animals by size or age.
- Clean lots to maintain sanitary conditions.
- An isolation area for sick animals.
- An area from which to observe the animals.
- Treatment breeding facilities.
- Space for handling, restraining and observe animals.

In Slovenia is the problem that there are many farms, which are managed by the outdated and undersized stables. This mean poor working conditions for workers and bad living conditions for the animals. New development needs introduced in rural demands from farmer to implement new or different ideas and new or different technology that is adapted to the new urban and economic standards.

For many years, the layout of facilities has been studied efficiently, since there are many factors that need to be in mind when distributing spaces to implement an industrial process. For the the presentation of conceptual design there are many drawing programs that allows to write sketch and make male idea to praxis.

The main objective of this study is to test the program Autodesk AutoCAD 2015 software for design of new blueprint and a new conceptual design of stable. Menu Bar from this program is presented in Figure 1.

Fig. 1. AutoCAD® Menu Bar

2. Methodology

Examined a model showing the free stall for dairy cows, with all the accompanying storage and other facilities.

The entire model is composed of:

- Free stall,
- Storage facilities for solid manure and slurry,
- Storage facilities for bedding - straw,
- Storage areas for hay,
- Silos for dry concentrate,
- Silos as a storage area for silage and
- Accommodation facilities for the workforce.

Speciality of this presented model is free stall with production and technical places.

2.1 Calculated storage facilities

We try to presented stall model for dairy cows, with all the accompanying storage and other facilities. We calculated needed capacity based on the given normatives and recommendations.

As the basic data for further calculation of storage capacity is necessary to first prepare balanced feed ratio for each category of cattle. An example of such a calculation is given in the following table 1.

Category of animals	Grass silage (kg)	Corn silage (kg)	Hay (kg)	Concentrate (kg)
Cows	16	20	3	4,6
Young cattle	7	15	2	1,2

Tab. 1. Daily feed ration for animals.

2.1.1 Storage area for hay

Type of feed	Volumetric weight (kg/m ³)
Long hay	70-120
Cut hay, (5 cm)	90-120
Baled hay cubicle	130-170
Round baled hay	70-110
Rerated hay	120-170
Hay tower	150-180
Straw	80-100

Tab. 2. Volumetric weight of stored hay.

We calculated storage area for hay as show by Eq. (1):

$$\frac{\text{number of animals} \times \text{hay intake / animal per day} \times \text{storage days}}{\text{volumetric weight of hay}} \quad (1)$$

Storage area for hay is 1800 m³ with additional space for manipulation.

2.1.2 Storage area for grass - maize silage

Type of feed	Volumetric weight (kg/m ³)
Grass and corn silage	
35 % DM	550
30 % DM	625
25 % DM	710
Feeds grainy	750
Groats	600
Flour	500
Fodder beet	660

Tab. 3. Volumetric weight of silage with different dry matter (DM) and other feed.

Storage area for grass and maize silage is computed as:

$$\frac{\text{number of animals} \times \text{consume feed / animal per day} \times \text{storage days}}{\text{volumetric weight of feed}} \quad (2)$$

Storage area for grass and maize silage is 3650 m³ with additional space for manipulation.

2.1.3 Storage area for compound concentrate

Since the feed rations include also a concentrate there is required to have a space for temporary storage. Usually the storage of concentrate is located near the entrance of the stall as also in our case. Since this concentrate is bought in bulk form several times a year, there is no need to provide storage capacity for whole year. For calculation for storage capacity of concentrate, we take the volume of the silos container which is 100 m³.

2.1.4 Storage area for straw

Farming method	Consumption of straw	
	long straw	catted straw
	(kg/animal)	
Free stall		
with liquid manure		0,0-0,5
with solid manure	1,0-2,0	0,8-2,0

Tab. 4. The daily need for straw.

For calculation of storage area for straw we used next equation:

$$\frac{\text{number of animals} \times \text{straw use/ animal per day} \times \text{storage days}}{\text{bulk density of straw}} \quad (3)$$

Storage area for straw is 1095m³ with additional space for manipulation.

2.1.5 Manure storage area

Adequate storage capacity is needed for convenience, maintaining maximum fertility, and preventing water pollution. Storage capacity depends on number and body weight of animals, type and amount of bedding, and desired storage period. The required area for solid manure in the loading height of 2 m.

Solid manure (slurry separated)	Required surface (m ²)
Average amount of bedding straw	3,5
Many amount of bedding straw	4,0

Tab. 1. Required area for solid manure.

Solid storage manure we calculated as follows:

$$\text{The number of LSU* X required are} \quad (4)$$

*Livestock units – reference units

Storage area for solid manure is 700m².

Storage space for slurry (urine from cattle) from stall and from storage area for solid manure is 650 m³.

2.2 *Recommended norms for internal layout of stall*

By designing of the capacity for free stall we use also normatives given by Expert Group - CAFS (2013):

2.2.1 *Stall Base and Bedding:*

- Feeding desk
 - width 500 cm, the feeding desk by the wall - 400 cm,
 - height of the feeding place above the feeding corridor 20-25 cm,
 - free height above the feeding desk 350-400 cm,
 - width of the feeding space - at least 70 cm,
 - percentage of cows which can at the same time which may at the same time feeding at feeding table - at least 80% using the total mixed ratio.

2.2.2 *Corridors – width:*

- by the feeding desk
 - three or four-line stall 400-450 cm
 - double-row stall 320-400 cm
- between the lines of cubicles 250 to 300 cm
- transitions between corridors
 - without feeder troughs 240-300 cm
- waiting place before the milking parlour - at least 1.5 m² / cow.

2.2.3 *Lying cubicle:*

- length
 - by the wall 260-280 cm
 - opposite the wall 230-250 cm
- width of 120-125 cm
- lying cubicle with straw bedding
 - 5 to 10 cm above the level of the raised corridor
 - 12 to 20 cm high rail at the entrance of the cubicle.

2.2.4 *Light:*

- at least 10% of the light surface in relation to the floor area of stall.

2.2.5 *Water:*

- 6 cm per cow water troughs.

2.3 *AutoCAD Maps*

Today, the majority of the Mechanical CAD systems are capable of creating three-dimensional solid models. Nonetheless, all CAD systems create designs using basic geometric entities and many of the constructions used in technical designs are based upon two-dimensional planar geometry. The method and number of operations that are required to accomplish the basic planar constructions are different from one system to another (Shih, 2015).

3. Results and discussion

We design new conceptual design for free stall and created blueprint (Fig. 2; Fig. 3). The speciality of this model represents a stable manufacturing and technical facilities. The production part of the stables included lying cubicles for 148 cows, nursery, pens for sick animals, pens for calves and breeding heifers, and pens for cow in the end of the lactation - together approx. 200 livestock units (LSU).

Before the last conceptual design was implemented we prepare different version of different free stalls. Taking into account the above needs and realistic implementation possibilities, we opted for the following solution. The breeding of dairy cows is performed in free stall system, meaning that the cows are free to move around the stables, with free access to milking units, feeding tables and racks, and free moving back into lying cubicles.

Next to the lying cubicles which are in three rows, there are also three muddy corridors, feeding corridor, feeding alley, separation box, different pens and milking parlor.

Fig. 2. Free stall – full design

In stables lying cubicles straw is used for bedding. Muddy corridors are planned to be fully reinforced concrete floor, cleaned using cable-drawn scraper blade.

The size of corridors and lying cubicles is designed accounting the size and body mass of different group of animals.

Feeding animals with voluminous part of the meal is carried out on feeding table through the automatic steering trailer two times daily with a complete feed ration (TMR). Feeding of concentrate feed is carried out with feeding machine in the milking parlor (robot) or in the barn with four automatic feed stations. Feeding ratio represents according to Brus and al., (2015) over 40 % of total costs in cattle breeding and can thus decisively affect the economic feasibility of the operation.

The technical part of stables representing milk room, office for veterinarian and workers, space for the engine room and locker room. The estimated model is also necessary to provide accommodation facilities for two workers, as presented milking requires a 24-hour readiness in the event of failure.

Specificity of that stable represents the milking parlor, milking process runs fully automated using a milking robot. Due to a large number of dairy cows, two automated milking units are required. For particular milking system, stables must be designed in a way that simulates natural behavior of cows and at the same time attract cows to visit the milking robot often. The intervals between milking must be constant. In addition, cows must have free access to feed. Milking of cows after calving takes place in calving pen using the milking pitcher.

Ventilation of stables is performed naturally. Fresh air comes into the free stall through openings in the walls, which are covered with steel wind nets discharge of hot air is carried out through the ridge openings over the entire roof structure.

All interior accessories such as barrier elements, a feeding barriers, feed dispensers, brushes drinking troughs, must be design in a way following recommendations and normatives.

Fig. 3. Part of free stall – pens for calves, pen for sick animals, calving pens, milk room, engine room and office

Fig. 4. Free stall – milking robot, lying cubicles, feeding alley, feeding corridor

Using the program Autodesk AutoCAD 2015 is suitable for designing of livestock facilities and the necessary parallel storage buildings. Major problems in the design of this program has not been detected, as we have previous knowledge in the field of agriculture engineering and computer science. The program requires adequate powerful computer hardware that enables flawless operation.

Based on the proposed design solution the investor can decide to build and makes the subsequent procedures to obtain a building permit. After completion of the investment before the start of production he must acquire an operation license. An example of the described project in production is shown in Figure 5.

Fig. 5. Milking cows in free stall

4. Conclusion

Free stall is a system that combines several factors: correct installation of equipment (control barrier, boxes for different categories of animals, ventilation system), appropriate sizing (width of different corridors, length of the lying cubicles...), materials (concrete filled insulated flooring, rubber mats ...), management (hygiene, feeding method, stocking density) and animals. The presented model is a conceptual solution stall with production and technical facilities and mechanization.

For implementation of our conceptual idea we use Autodesk AutoCAD. The program has proven effective. The use was effective because we can quickly and efficiently draw and performed. Also we can include accurately all the necessary equipment needed in the free stall. Program did not seem too difficult to use, especially it was easy understandable. We can conclude, that the use of this program for the designing of agricultural buildings is indispensable.

In the future, we want this design approach transferred to the general practice in wider use in the modernization of agricultural facilities. Simultaneously we will study the improvement of animal welfare parameters.

5. References

- Bayne, K. (1996). Revised Guide for the Care and Use of Laboratory Animals available. American Physiological Society. *The Physiologist*, 39(4), 199-208. PMID: 8854724
- Bickert W. B.; Holmes, B.; Janni, K.; Kammel, D.; Stowell, R. & Zulovich, J. (2000). *Dairy cattle—Equipment and supplies—Handbooks, manuals, etc.* I. Iowa State University, Bickert, W.G. II. Midwest Plan Service. Dairy Handbook Revision Committee. ISBN 0-89373-095-5
- Brus, M.; Pazek. K.; Rozman, C. & Janzekovic, M. (2015). The feeding ration optimization model for Simental bulls. In: DAAAM International scientific book 2015, Katalinic. B., (Ed.). pp. 337-344, Published by DAAAM International scientific book 2015, ISSN 1726-9687, Vienna, Austria
- Danish Agricultural Advisory Center (2012). *Housing Design for Cattle: Danish Recommendations: Interdisciplinary Report*, National Department of Farm Buildings and Machinery, ISBN: 978-87-91566-75-2
- Expert Group for the construction of farm buildings in Chamber of Agriculture and Forestry of Slovenia (CAFS) 2013. Stables for dairy cows - recommended norms, p. 2.
- Fregonesi, J. A.; von Keyserlingk, M.A.G.; Viera, D.M. & Weary, D.M. (2007a). Effects of bedding quality on lying behavior of dairy cows. *Journal of Dairy Science* 90, 5732#5736
- Næss, G. & Bøe, K. E. (2010). *Layouts and space allocation in Norwegian freestall dairy barns*. Transactions of the ASABE, 53(2), 605-611
- Onstott, S. (2014). *AutoCAD 2015 and AutoCAD LT 2015 Essentiall*, Autodesk Official Press. John Wiley & Sons
- Shih, R. H. (2015). AutoCAD 2015 ®2D Fundamentals Tutorial - First Level, SDC PUBLICATIONS. pp 40
- Tucker, C.B.; Weary, M.A.G.; von Keyserlingk, K. & Beauchemin, A. (2009). Cow comfort in tie-stalls: Increased depth of shavings or straw bedding increases lying time. *Journal of Dairy Science*, 92:2684–2690. ISSN : 0022-0302
- Wierenga, H.K. & Hopster H. (1990). The significance of cubicles for the behaviour of dairy cows. *Applicated Animal Behavior Sciences*, 26:309-337