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CALCULATION REGARDING THERMAL TRANSFER THROUGH CLOSING ELEMENTS FOR A CATTLE SHELTER KEPT IN LOOSE HOUSING

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Abstract.

This paper presents the calculation regarding thermal transmission due to closing elements for cattle shelter kept loose housing. The shelter is compound from 2 compartments, splitted in the middle by a cross alley. The compartments are divided in feeding area and resting area. The shelter has the opening of 16.35 m, total hall lenght is 40.95 m, with surface about 669.53 sqm and the maximum hight about 6.40 m. After analyzing the calculation of heat transfer through closing elements for a cattle shelter kept in loose housing show that the amount of heat lost through external walls with heterogeneous structure is minimal compared to the classical exterior wall with homogeneous structure.

Key words: *constructive system, shelter, thermal balance, thermal transmission*

INTRODUCTION

Shelters designed for breeding and exploiting animals are designed in such a way as to respond to specific technological requirements imposed by species considering: capacity, biological value, purpose, endowments, all leading to various constructive solutions, that respond to the functional interdependence factors. Conception, projection and execution of these constructions must be done in such ways to match the advanced technologies of exploitation and to offer large possibilities of typing and industrialization. Choosing the constructive system of buildings must be done also through economical efficiency determination, in order to adopt the most beneficial constructive solutions that to base on advanced methods and procedures of execution and to lead to minimizing consumption of scarce materials and high consumer materials of embodied energy by using local materials and high evaluation of industrial waste [5].

MATERIALS AND METHODS

This paper presents the calculation regarding thermal transmission due to closing elements for cattle shelter kept loose housing. The characteristic elements regarding the building location are:

- third climate area related to Romanian climate zoning map, T_e= -18ºC;
- orientation to the cardinal points: EV longitudinal direction, with the main facade to the west;
- the forth aeolian area related to settlements framing map in windy areas;
- seismic zone related to P100-2006:F, ag=0.08;
- corner period related to P100-2006: TC=0.7 sec.

The shelter has the opening of 16.35 m, total hall lenght is 40.95 m. The built surface of the hall is 669.53 sqm. The maximum hight is 6.40 m. The shelter is compound from 2 compartments, splitted in the middle by a cross alley. The compartments are divided in feeding area and resting area. The bearing structure is made from independent frames with 3 openings of 5.70 m, 4.50 m and 5.70 m and spans of 4.50m. The frames pillars are prefabricated and embedded in isolated foundations of glass type, that rests on concrete blocks C8/10. Exterior walls with heterogeneous structure have the following characteristics:

-interior plaster mortar-cement with density $\rho = 1700$ kg/m^3, thickness d = 0.015 m and thermal conductivity $\lambda = 0.87$ W / mK;

- full-brickwork with density $\rho = 1800$ kg/m^3, thickness d = 0.24 m and thermal conductivity $\lambda = 0.80$ W/mK;

-rigid insulation boards of mineral wool with density $\rho = 100$ kg/m^3, thickness d = 0.10 m and thermal conductivity $\lambda = 0.048$W/mK;

-ventilated air layer;

- full-brickwork sitting on the edge with density $\rho = 1800$kg/m^3, thickness d = 0.063 m and thermal conductivity $\lambda = 0.80$W/mK;

-external plaster with mortar-cement with density $\rho = 1800$ kg/m^3, thickness d = 0.02 m and thermal conductivity $\lambda = 0.93$ W/mK.

The roof is made of precast prestressed concrete purlins that support a layered structure consisting of: wood substrates insulation, vapor barrier of polyethylene, 10 cm thick mineral wool (density $\rho = 100$ kg/m^3, thickness d = 0.10 m and thermal conductivity $\lambda = 0.048$ W/mK, according to C107/3-2005) and covering of corrugated iron with $\rho = 7200$kg/m^3 density, thickness d = 0.0035 m and thermal conductivity $\lambda = 50$ W/mK according to C107/3-2005.

RESULTS AND DISCUSSIONS

Geometrical and thermotechnical characteristics of building envelope elements

Calculation of shelter's windows

- State lighting: i = 1/20 for
 i = Sf/Sp;
Sfnec=Sp/20;
$S_p=A_{util}=627.12$ m^2; Sfnec=31.356 m^2;
Sf = 31.356 / 36 = 0.871 m^2 window;
Choose Sf = 1.80 x 0.90=1.62 m^2 window, where h = 90 cm, l = 180 cm and $h_{parapet}$=1.50m.

Number of windows considered for housing of cattle is 36

Establishing geometrical characteristics

-Were calculated related to building's plan and are summarized presented below:

Establishing geometrical characteristics

Levels number: NrNiv=1 ground;

Useful high volume of shelter is V_{util}=1755.936m^3;

Useful area of shelter is: A_{utila}=627.12m^2;

Useful height of shelter is: $h_{utilmediu}$=2.80m;

The surfaces of envelop elements for bulls shelter are showed in table 1, the exterior walls and glazed areas are showed on cardinal orientations.

Table 1. The surfaces of envelop elements for cattle shelter

Nr. crt.	Element of envelope	Element area in m^2 cardinal orientation			
		Facade E	Facade V	Facade N	Facade S
1	Exterior walls (glazed areas)	55.65	55.65	110.565	110.565
2	Exterior walls (opaque zones)	49.40	49.40	80.865	80.865
3	Glazed areas	6.25	6.25	29.70	29.70
4	Ground plate	627.12			
6	Total area envelope stable	1563.66			

- Ground plate area: $A_{ground\ plate}$=627.12m^2;
- Roof area: A_{roof} =706.797m^2;
- Envelope area: $A_{env}=A_{PE}+A_{ground\ plate}+A_{roof}$ =332.43+627.12+706.797=1666.347m^2;

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In figure 1 is presented a building for a simple cattle shelter kept in loose housing.

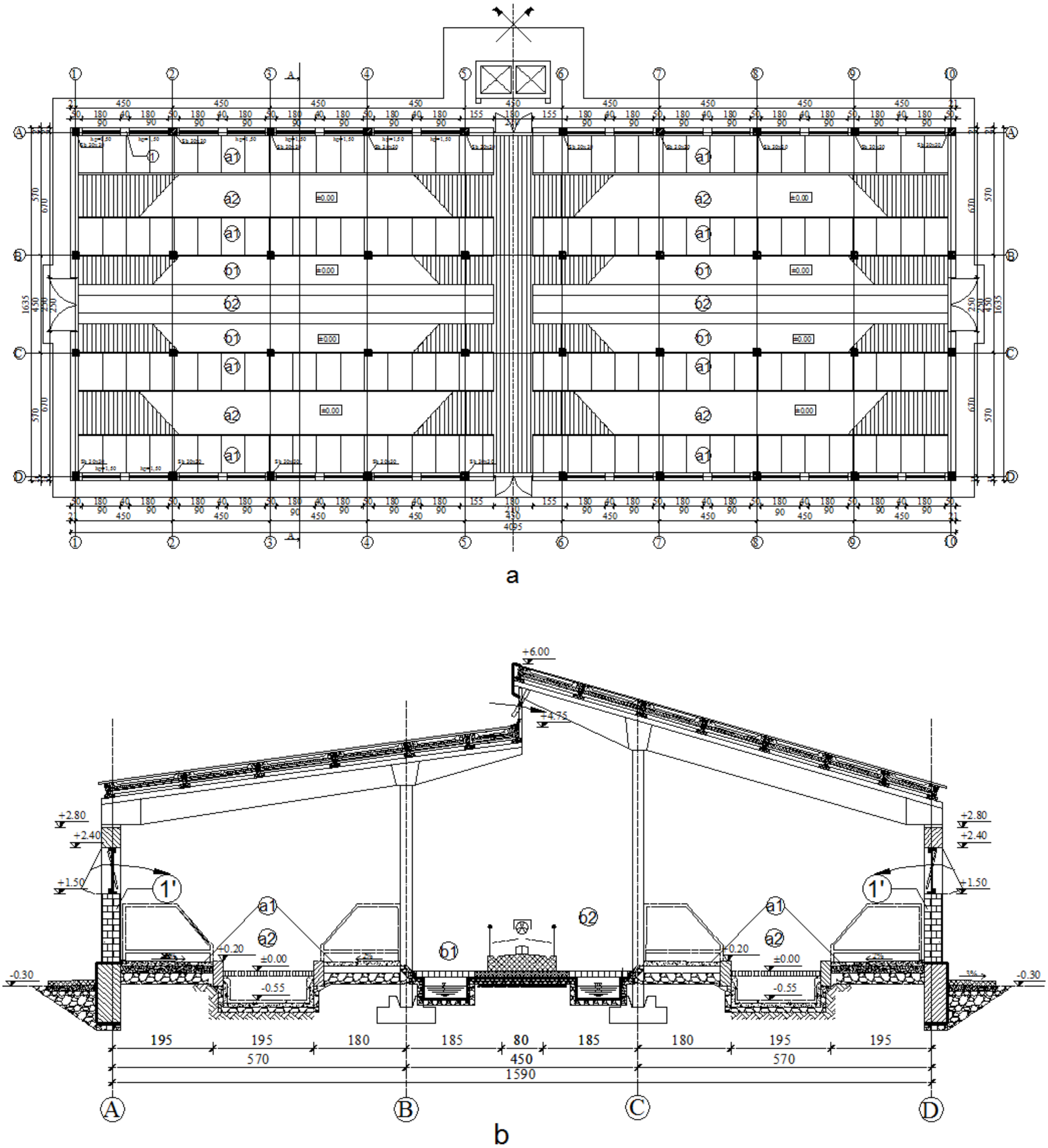

Fig. 1 Shelter for cattle kept in loose housing
a-ground plan, shelter for cattle kept in loose housing; a1-resting area with individual bunks; a2-circulation alley with discontinuous floor across manure drain channels; a3-circulation alley with feeding grills; a4-feeding alley; b-cross section; 1, 1'-exterior wall.

The volume of air required

If it is considered necessary air volume per cow = 25 m^3, total volume of air required is equal to 136 x 25 = 3400 m^3. If the useful area of the stable is 627.12 m^2 and usable height is 2.80 m then the volume useful height is equal to 1755.936 m^3, and the roof volume = 515.97 m^3. Therefore resulting total effective air volume = 2271.906 m^3 and air volume per cow actually = 16.70 m^3.

-Report:

$$\frac{A_{env}}{V}=\frac{1666.347}{2271.906}=0.733\frac{m^2}{m^3}.$$

Calculation of thermal transfer Unidirectional thermal resistances of envelope elements Unidirectional thermal resistances of envelope elements for cattle shelter are calculated with the relation:

$$R = R_{si} + \sum R_{sj} + R_{se}(m^2K/W)$$

where:

$$R_{si}=\frac{1}{\alpha_i};\ R_{se}=\frac{1}{\alpha_e};\ R_{sj}=\frac{d_j}{\lambda_j};$$

d_j-layer thickness;
λ_j- thermal conductivity of calculation;
$R_{si} = 1/\alpha_i = 1/8 = 0.125$ [m^2K/W];
$R_{se} = 1/\alpha_e = 1/24 = 0.042$ [m^2K/W];
On the ground plate R_{si}=0.167[m^2K/W];
Thermal inertia index for exterior wall:

$$D_j=\frac{\sum A_j\times D_j}{\sum A_j}=\frac{55.864}{9.19}=6.078$$

A_j - areas of distinct zones on the surface of building elements [m^2];

D_j -thermal of inertia indices corresponding zones with A_j areas.

Specific thermal resistance unidirectional of the roof :

$R_{oef} = R_{si} + \sum R_{sj} + R_{se}$=2.467($m^2K/W$).

Corrected thermal resistance for characteristic areas of envelope components

$$R' = r\times R[m^2K/W]$$

The roof's window zone
ψ=0.25;

$$r=\frac{1}{1+\frac{R_{roof}\times\sum l_i\times\psi_i}{A}}=\frac{1}{1+\frac{2.469\times 40.95\times 0.25}{706.797}}=0.965$$

$R'_{window\ roof}$ =2.469x0.965=2.382m^2K/W.

$$R'_{groundplat}=\frac{A}{L_s}=\frac{669.532}{278.525}=2.404m^2K/W;$$

Thermal coupling coefficient:
L_s=AxU=669.532x0.416=278.525W/K.

Plate area on the ground
A=40.95x16.35=669.532m^2

<u>Glazed areas</u>
$R'_v=R_v$
R'_f=0.351m^2K/W; A_{FE}=58.32m^2;
R'_{ue}=0.32m^2K/W; A_{uE}=13.58m^2;

Thermal balance

The thermal balance for cattle shelter depends on the following formula:

$$Q_A = Q_C + Q_V\ [W],\ \text{where:}$$

Q_A – Average total quantity released by animals;
Q_C – Heat loss through exterior building elements;
Q_V - Ventilation heat loss;
Q_A = n xq;
n =136 dairy cows;
q=733W (according to Tab. 3.1. - "Agricultural Buildings"-Dumitru Marusciac);
Q_A = 136x733 = 99688W;
$Q_c = Q_1 + Q_2 + Q_3$ [W]

$$Q_1=\sum m_i\times K_{0i}\times S_i\times(T_i-T_e);$$

in wich: Q_1=lost heat quantity through walls and roof, in W; m_i=coefficient of thermal massiviness calculated for each considered construction elements; K_{0i}=total coefficient of thermal transfer through construction element, in W/m^2K; Si=construction element surface, m^2; T_i=lower temperature of calc, T_e=exterior temperature of calc;

For the walls D_j=6.078 (with medium thermal inertia); m_{walls}=1.225-0.05xD = 1.00;
For the roof D_j=2.0675; m_{roof}=1.225-0.05xD=1.121>1;
$M_{windows}$=1.225>1; m_{doors}=1.225>1;

$$Q_1=1.00\times\frac{1}{1.729}\times 260.53\times(12-3.094)+1.121\times\frac{1}{2.469}\times 706.797\times(12-3.094)+$$
$$+1.225\times\frac{1}{0.35}\times 58.32\times(12-3.094)+1.225\times\frac{1}{0.32}\times 13.58\times(12-3.094)=6481W$$

Q_2 = loses through floor;

$$Q_2=\sum S_p\times K_p\times S_i\times(T_i-T_e);$$

$$Q_2=\frac{1}{R'_{groundplat}}\times(S_{warmsurfae}+S_{circsurfae})\times(T_i-T_e);$$

$$Q_2=\frac{1}{2.404}\times(261.76+276.27)\times(12-3.094)=1993W;$$

Q_3 = loses through outline band;

$$Q_3=S_b\times K_b\times(T_i-T_e);$$

$$S_b=1m\times P=1\times 114.6m=114.60m^2;$$

K_b=1.37;

$Q_3 = 114.60 \times 1.37 \times (12 - 3.094) = 1398.26W$;

$Q_c = Q_1 + Q_2 + Q_3 = 6481 + 1993 + 1398.26 = 9872.26W$

$Q_V = V_{max} \times (i_i - i_e)$;

Q_V= heat consumption resulted due to ventilation through allowable flow method;

V_{max} ==> din
- $V_{CO2} = C / (C_i - C_e)$ [m^3/h]
- $V_u = X_A / (X_i - X_e)$ [m^3/h]
- $V_Q = (Q_A - Q_C)/(i_i - i_e)$ [m^3/h]

$V_{CO2} = C / (C_i - C_e)$

C – CO_2 quantity removed by animals

C = 136x320 = 43520[g/h];

C_i – maximum allowed quantity of CO_2 in animals shelter;

C_i = 3 [l/m^3]=0.3%;

C_e – CO_2 quantity in outdoor air;

C_e = 0.3 [l/m^3] ;

$V_{CO2} = C/(C_i - C_e) =$ 43.52/(3-0.3)=16.118 [l/h] =>

V_{CO2} = 0.016118 [m^3/h]

Water vapors:

$V_u = X_A / (X_i - X_e)$

X_A =136x400+10%x136x400=59840 [g/h]

X_i=7.54g/cm^3 for the indoor humidity φ_i=80%

X_e =0.85g/cm^3;

V_u=59840/(7.54-0.85)=8944.69[cm^3/h]= = 0.008944[m^3/h];

Excess heat:

$V_Q = (Q_A - Q_C) / (i_i - i_e)$

i_i = 8.68 [kcal/m^3]

i_e = -5.47 [kcal/m^3]

1 kcal = 4186 J=4186Wxs;

$V_Q = (Q_A - Q_C)/(i_i - i_e)$=(99688-987226)/(8.68+5.47) = 6347W X m^3/kcal;

$Q_V = 6347 \times (8.68 + 5.47) = 89810W$;

CONCLUSIONS

Thermal balance for cattle shelter depends on the one hand of the heat loss through exterior building elements and on the other hand of the heat loss through ventilation. After analyzing the calculation of heat transfer through closing elements for a cattle shelter kept in loose housing show that the amount of heat lost through external walls with heterogeneous structure (interior plaster, brickwork filled with 24 cm thick, rigid mineral wool insulation boards of , ventilated air layer, full-brickwork sitting on the edge and external plaster) is minimal compared to the classical exterior wall with homogeneous structure. An efficient livestock construction has to ensure simultaneously with optimum conditions from inside microclimate (needed to maximize the productive potential) and high economic efficiency investments. In this sense, recently began to show increasingly the tendency in finding some efficient constructive solutions, that satisfy a high range of technological requirements and with high possibilities of industrialization of execution, based on prefabricated elements, standardized of large series.

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