Thermal Characteristics of the Old Piggery Wall Constructions

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Abstract: *This paper presents study of the thermal characteristics of wall constructions at the older piggery object. The aim of this paper is verifying of the building construction thermal characteristics and existence of the thermal bridges by thermography method and calculation of the heat flux and thermal power in the critical construction details. Unsatisfactory thermal characteristics of the older piggery building construction there are negative because heating of this objects causes wasting of energy. Thermal bridges induce intensive heat flux and decrease surface temperature of the construction which causes devaporation with intensive growing of mildews. Moisture of the building materials causes faster degradation of the construction. Piggery environment contaminated by spores of mildews is negative for hygienic conditions of the animals and workers. The results of the paper indicate that the thermal characteristics of building construction influencing energy losses and hygiene of indoor environment in piggery.*

Keywords: *piggery, construction, heat flux, thermal bridges, energy consumption.*

INTRODUCTION

For pigs a critical parameter is room temperature, which must be maintained around 26 °C [1].

The vital and productive processes in pigs require a relatively constant body temperature. Climatic conditions in pig housing, primarily ambient temperature are monitored and automatically adjusted based on a set point temperature. However, the thermal environment is not only determined by dry-bulb temperature, but is also influenced by wet-bulb temperature, radiant temperature and air velocity [2]. If the thermal environment does not satisfy the current thermal needs of the pigs, it can lead to hygiene and welfare problems [3, 4].

Thermal insulation is one of the most effective ways of saving energy used for heating and cooling buildings. In a moderate climate, the fact of heating air inside buildings, especially in winter, but also in transitory periods (autumn and spring) is significant as far as thermal energy demand is concerned. Therefore, determining and selecting the optimum thickness of insulation is the main objective of many research works [5-7]. Building envelope is designed to protect the inner space from harsh outdoor climatic conditions, hot and cold alike, and hence provides necessary thermal comfort to occupants. In addition, building envelope should be designed and built in a way to reduce energy consumption also reduces adverse impact of power plants on the environment. There are many ways followed by building envelope designers to reduce energy consumption. Building material (thermal mass) and insulation play a major role in this endeavor with regard to transmission part of the AC load. Thermal bridges, when present, are enemy number one to almost all measures taken to reduce this load. They drastically act to reduce the building envelope thermal resistance (R-value) and hence increase the transmission loads and accordingly jeopardize the beneficial use of thermal insulation. The R-value is a key parameter use to characterize building envelope effectiveness regarding heat transmission and hence thermal bridging effects [8]. Contemporary national regulations throughout the world specify requirements for the insulation of the various building´s elements, according to specific thermo physical properties and the calculation procedures adopted, based on various standards, varying from simple one-dimensional steady state considerations to more sophisticated two dimensional dynamic ones, which inevitably lead to executing building simulation procedures. Still, the problem of thermal bridges, appearing for example at the junction between two separately insulated elements, or between a vertical and a horizontal element, is not always dealt with properly. This leads to underestimated thermal losses during the design process, the insulation study or the various calculation methods in general, and, consequently, to higher (in comparison to estimates) energy requirements in practice. Moreover, in many countries actual construction practices tend to only partially implement the insulation foreseen by regulations, because of construction difficulties, the conflicting stability issues of the various building elements, the lack of properly trained/qualified personnel and finally, because of minimal or inefficient controls on behalf of the authorities. The aforementioned discrepancy between estimated and actual thermal losses appears despite the fact that both analytical and simulative methods enable the designing engineer to achieve a very good approximation of the thermal losses [9, 10].

The goal of the paper is evaluation of the thermal characteristics of the old piggery construction. Next part of the paper deal with the calculation of the heat flux and heat power.

MATERIALS AND METHODS

The analyzed piggery is located at region Znojmo (south-east part of the Czech Republic). This piggery is part of the livestock production farm. Piggery is forty years old. Main parameters of the ground area of piggery are: width 12m, longitude 85m, construction height 2.55m and rooftop height 10m. This object consists of ground floor for animal production and garret. The piggery is used for fattening of 800 pigs. Housing of farm animals is in groups which are separated by steel barriers. The building is designed from massive materials. The masonry is from traditional ceramic bricks with internal and external lime-cement plaster having a thickness of 15mm (total thickness 450 mm; α_k=2.00 W·m^{-2}·K^{-1}). Masonry is from low-tech material and has low thermal insulation ability. In the walls there are old windows (steel frame, protecting net and jalousie for regulation of ventilation; width 0,9m, height 1,35m), modern windows (three-sectional PVC frame with double thermal glazing α_k=2.00 W·m^{-2}·K^{-1}). There are also old wooden doors (α_k=4.00 W·m^{-2}·K^{-1}) and modern doors (three-sectional PVC frame with thermal double glazing α_k=2.10 W·m^{-2}·K^{-1}). Ventilation has only simple regulation (without electronic regulation system and technical equipment for heat recovery). The ceilings are from steel girder, ceramic boards and concrete without thermal insulation. Roof structure consists of wooden rafters and asbestos cement roofing. The flooring is from concrete board and grates with deep sewers. Flooring has not any thermal insulation. There is warm - water floor heating system in the object.

Conditions of thermal imaging measurement: atmospheric temperature -7 and -8 °C, relative humidity 83 %, cloudy.

Thermal analyses were executed by FLIR E320 thermal camera. For thermal imaging measurement purposes was measured the air temperature, air humidity, distance from the monitored object and material emissivity. Determination of material emissivity was executed by creation of measuring points on the materials, where was executed thermal analyses. On these points was measured temperature with using OMEGA HH11 contact thermometer (accuracy of temperature measurement: ± 0.1°C). The most significant prerequisite was to prevent fluctuation of temperature in the course of time. The aforementioned point was also monitored using FLIR E320 thermal camera. In case that the temperature values proved to differ, the temperature in the thermal camera was calibrated by the means of setting up the emissivity value in the user interface of this device. The final emissivity value was determined at the time when the temperature values on both the devices were balanced.

The air temperature and humidity were measured using OMEGA RH81 thermo-hygrometre featuring the temperature measurement accuracy of ±1°C and humidity measurement accuracy of ±4% (at the temperature of 25°C and relative humidity within the range of 10–90%). The temperature and humidity were measured in the close vicinity of the thermal camera and measured equipments, and the arithmetic mean was subsequently calculated on the basis of these values. The reflected temperature was not measured because any heat sources were not in surroundings, which could influence the measurement. The measurement was realized in cloudy conditions. During temperature measuring of the storage tank there has temporarily changed conditions in somewhat cloudy. There could be a little deviations of measurement in consequence of solar radiation. The solar radiation there was only for a short time and could not expressively affected measurement. This is the reason why we uncared this fact in calculation.

The thermal screening measurement was conducted at a constant distance from measured equipments. Three thermograms were created in the course of one hour. The distance of the camera from measured equipments was determined using Leica DISTO^{tm} A5 laser EDM device (measurement accuracy: ± 1.5 mm at a distance between 0.2 and 200 m). The thermal imaging measurement as such was conducted using FLIR ThermaCAM E320 thermal camera (FOV: 25°). The average temperature of the surface was calculated using ThermaCAM QuickReport software in which each pixel of the video recording was allocated to one temperature value. An arithmetic mean was subsequently created on the basis of all values.

Coefficient of free convection along vertical walling for calculation of total heat losses by convection was calculated according to Mc Adams, C. King and F. Michijev [11]. Results of calculation in accordance with different authors were compared.

Coefficient of free convection along vertical walling was calculated according to equation:

Mc Adams [11]

$$\alpha_k = 1{,}78 \cdot \Delta t^{0{,}12} \quad [\mathrm{W \cdot m^{-2} \cdot K^{-1}}] \tag{1}$$

C. King [11]

$$\alpha_k = 1{,}51 \cdot \Delta t^{0{,}33} \quad [\mathrm{W \cdot m^{-2} \cdot K^{-1}}] \tag{2}$$

F. Michejev [11]

$$\alpha_k = 1{,}55 \cdot \Delta t^{0{,}33} \quad [\mathrm{W \cdot m^{-2} \cdot K^{-1}}] \tag{3}$$

Total heat loses of object were calculated according to equation:

$$q_t = \alpha_k (t_1 - t_2) \quad [\mathrm{W \cdot m^{-2}}] \tag{4}$$

Where is:

α_k – coefficient of free convection along vertical walling [W·m^{-2}·K^{-1}]
t_1 – air temperature [°C, K]
t_2 – surface temperature of walling [°C, K]

RESULTS AND DISCUSSION

First object for thermo vision analysis of piggery there is north-east façade. Because this façade is very long, there are three thermograms. Thermograms are presented at the Fig. 1, 2, 3 and 4. This construction consists of traditional ceramic bricks masonry (thickness 450 mm) with low thermal insulation. There are only simple old, steel windows for ventilation. Thermograms presented that there are evident increased heat flow in some parts of the construction. The reason of existing thermal bridges there is low thermal insulation of masonry. Similar problems with old construction and importance of intensive thermal insulation are presented in [5, 12]. Problems with The high energy losses are caused by ventilation, because there is not technical equipment for heat recuperation. Warm water floor heating system without thermal insulation causes intensive heat flow at lower parts of the wall. Next thermal bridges there are in the contact of the wall and ceiling. Ceiling construction has not intensive thermal insulation. Similar situation with thermal bridges and their influence to energy performance of building is presented in [8-10]. There is not heated attic and that is evident from thermograms. Temperature range of the masonry surface is from -5,7 °C to 2.2 °C. Average surface temperatures are presented in the Table 1. Similar situation there is at the south-west long façade of the piggery. We could not make a closely measurement of this façade (because there was rugged terrain). General thermogram of this façade is presented at the Fig. 6. Calculation of heat fluxes and heat power of measured constructions are presented in the Table 1.

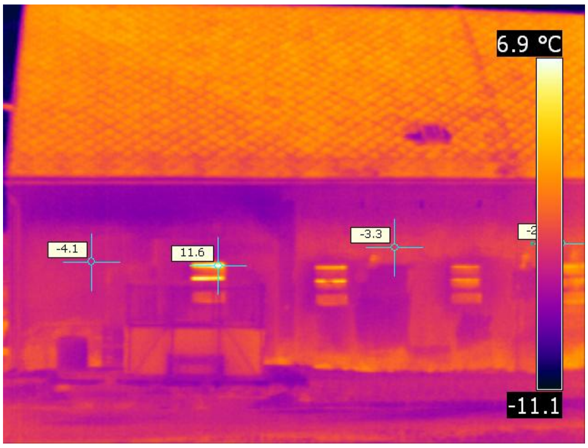

Fig. 1. North-east façade of piggery (part 1)

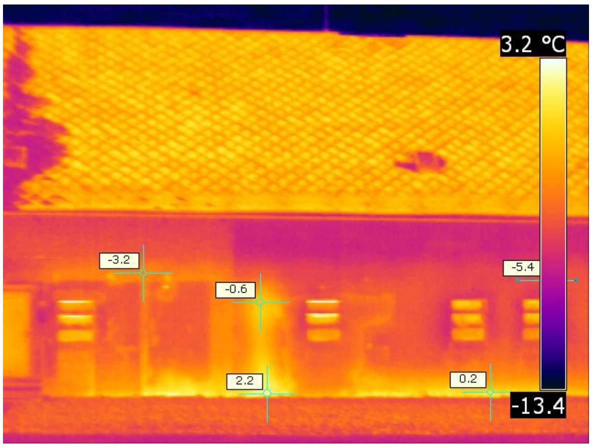

Fig. 2. North-east façade of piggery (part 2)

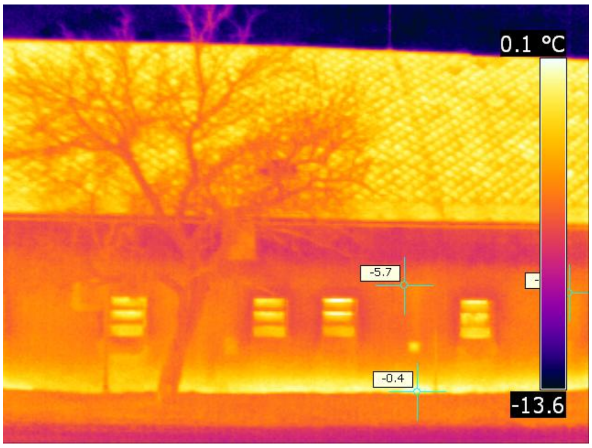

Fig. 3. North-east façade of piggery (part 3)

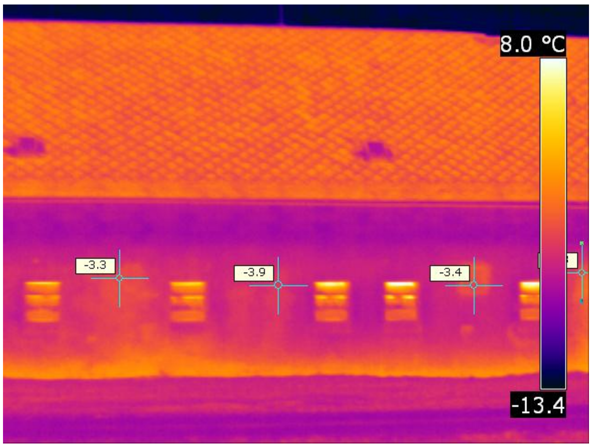

Fig. 4 North-east façade of piggery (part 4)

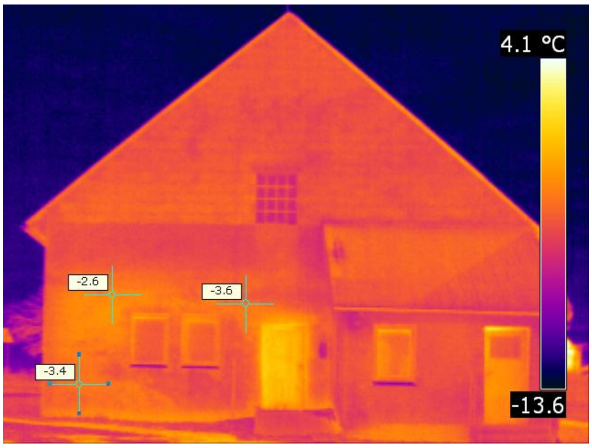

Fig. 5 North-west façade of piggery

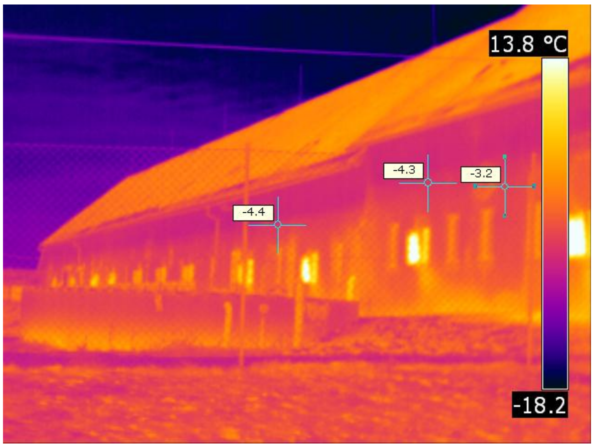

Fig. 6 South-west façade of piggery

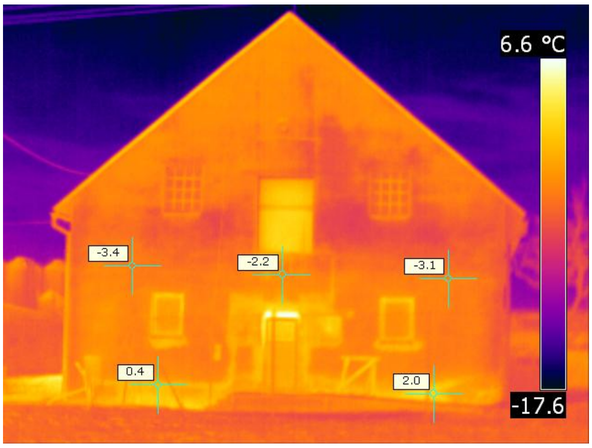

Fig. 7 South-east façade of piggery

The thermogram of north-west façade is at the Fig. 5. and south-east façade is at Fig. 7. These facades are side face wall and back wall of piggery. The constructions of masonry are mainly from bricks but only small surfaces are from concrete. Concrete has lower thermal insulation that is evident at thermograms. There are modernized windows and doors from three-sectional PVC frames with thermal double glazing. These windows are not for ventilation of stable, because in this part of the piggery there are feed processing rooms. The situation of more intense heat flux at the lower part of the wall it is similar to other façades. Apparently higher temperature of the door surface is caused by different emissivity. Temperature of the surface was (from -3,6 °C to 0.4 °C). Calculation of heat fluxes and heat power of measured constructions of piggery are presented in the Table 1.

Table 1: Heat fluxes and other physical values

No. Object	Description of the measured object				McAdams		King		Michejev	
		t_a	t_s	Area of the surface	Heat Flux	Heat Power	Heat Flux	Heat Power	Heat Flux	Heat Power
		[°C]	[°C]	[m²]	[W·m⁻²]	[W]	[W·m⁻²]	[W]	[W·m⁻²]	[W]
1	North-east facade of piggery (part 1)	-8	-3.5	32	20.59	659.00	27.65	884.7	28.38	908.18
2	North-east facade of piggery (part 2)	-8	1.1	48	20.85	1001	28.06	1347	28.81	1382.7
3	North-east facade of piggery (part 3)	-8	0.8	50	23.99	1199.6	33.14	1657.2	34.02	1701.1
4	North-east facade of piggery (part 4)	-8	-3.2	56	23.73	1328.8	32.71	1832	33.58	1880.5
5	North-west facade of piggery	-7	-3.1	32	31.48	1007.4	45.76	1464.5	46.98	1503.2
6	South-east facade of piggery	-7	-3.1	32	20.85	667.30	28.06	897.99	28.81	921.77
	Total heat power of the measured constructions					5863		8083.3		8297.5

Where is:

t_a - air temperature

t_s - average temperature of the surface

CONCLUSION

The energy efficiency of buildings is significantly affected by building construction properties. The Piggery is heated farm building with high energy performance. Old constructions have low thermal insulation and that caused high heat losses. Next problem there is absence of heat recuperation for energy savings. These facts are evident at our experimental piggery. Thermograms of piggery proved thermal characteristics of construction and critical details where high heat fluxes are. Calculation of heat power presented higher energy performance of this old construction. New buildings of piggery have to stricter technical limits of energy performance. Old buildings of piggery should be modernized for energy savings.

ACKNOWLEDGEMENT

This paper was supported by project CZ.1.02/5.1.00/10.06433 Acquisition of instrumentation for BAT centre at Mendel University in Brno for categories of food processing activities and categories of facilities for disposal or destruction of animal carcasses and animal waste.

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