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THE GEOTHERMAL VENTILATION OF PASSIVE HOUSE

Reduction of dependence on expensive imported energy resources causes the need to use energy-saving technologies at construction of the new and renovation of existing buildings. Thermal insulation of facades and the use of sealed windows are widely used to reduce the load on the heating system now. However, the lack of supply of fresh air through leaks in the outer fence negatively affects the hygiene indicators of indoor air. Design of supply-exhaust ventilation is a must for maintaining regulatory of air quantity and improving air quality in rooms of passive houses. Reduce of the load of the ventilation system allows the use of thermo ground-air heat exchangers. This article describes the possibility of using geothermal ventilation in the passive house by the ground-air heat exchangers.

Keywords: geothermal ventilation, ground-air heat exchanger, passive house, coefficient of thermal conductivity, soil temperature

INTRODUCTION

The constant rise in energy sources leads to the need to get rid of dependence on traditional fuels. The passive buildings are one of the promising directions of energy saving. It is characterized by low consumption of energy resources. Life support systems of passive houses draw their energy mostly from non-traditional sources of energy and waste energy. One of the energy-efficient solutions is to use low-grade heat the soil to heat incoming air for the ventilation system. Designing of equipment such a ventilation system of requires an examination of the conditions of its operation in Ukraine.

1. PURPOSE OF WORK

The determination of the technical conditions for the use of ground-air heat exchanger of the geothermal ventilation system in Ukraine.

2. ANALYSIS OF EXISTING STUDIES

One of the main requirements in the passive construction is the lack of inflow of outside air through leaks in the outer enclosures of building. However, the lack

of inflow of fresh air into the room impairs hygiene microclimate parameters, in particular quantity of CO_2, the presence of excess heat, excess moisture, and more. Normative air exchange in a passive house provides compulsory adjustable ventilation system. Typically, air exchange is provided by the supply and exhaust ventilation units. However, such equipment leads to increased heat loss in the passive house because heat exhaust air is not used. Therefore, the use of recuperators of heat is a must in the design of passive houses. In a recuperator heat transfer is carried out between the supply air and exhaust air from the room. The efficiency factor of modern recuperators is 75÷95%. This is achieved by counter flow heat exchangers and special efficient fans.

Ground-air heat exchanger allows to increase the energy efficiency of ventilation systems too. The external air is heated or cooled additionally in soil before recuperator heat. The process of heat transfer takes place through the walls of the ground-air heat exchanger. Since the ventilation system takes heat from the ground, it is called geothermal.

The schematic diagram of the geothermal ventilation is shown in Figure 1. The system works as follows. The first heating of the outside air occurs in the ground-air heat exchanger. Then, in the recuperator, the exhaust air gives its heat to pre-heated air. The warm air enters the room after the heat recuperator. If necessary, the air after the recuperator can be heated to a temperature 20÷30°C using heat pump, gas heater or electric heater.

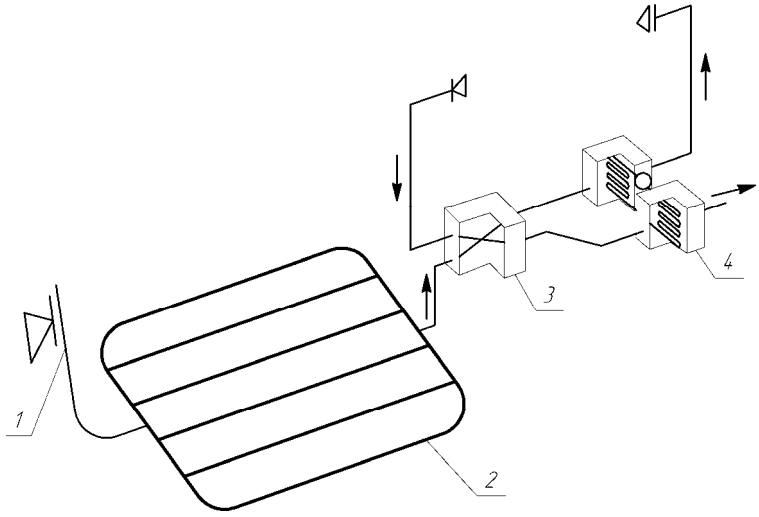

Fig. 1. Schematic diagram of the geothermal ventilation [1]: 1 - air intake unit, 2 - horizontal ground-air heat exchangers, 3 - recuperator (heat pump), 4 - air intake unit

The projecting and sale of equipment for geothermal ventilation is carried out by Rehau in Ukraine. Their AWADUKT Thermo pipe work was specifically designed application with its integrated antimicrobial silver layer. AWADUKT Thermo allows to organize air supply and save energy at the same time.

Depending on the required quantity of supply and temperature of inflow air horizontal ground-air heat exchangers can be arranged in two ways: Domestic loop layout or Tichelmann pipe layout (Fig. 2).

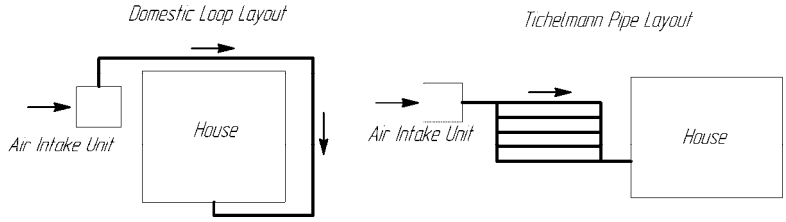

Fig. 2. Options for placement of horizontal ground-air heat exchangers of geothermal ventilation [2]

Domestic loop layout of horizontal heat exchangers is used in the project of geothermal ventilation cottages. Tichelmann pipe layout is used for big public, administrative and industrial buildings.

Calculation of the length of the ground-air heat exchanger is carried out by means of a computer program. Initial data for calculation are: the required amount of air, the depth of laying pipelines, soil characteristics, climatological data of the locality and material pipelines. For example, the schemes of the system of ventilation in winter and summer are given in the Figure 3.

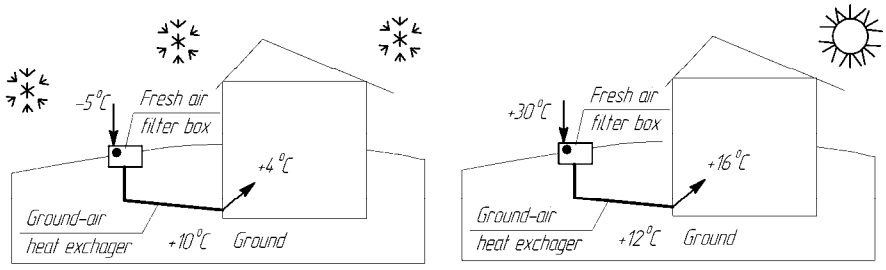

Fig. 3. Scheme of geothermal ventilation [2]

The work of system takes place at ambient air temperature respectively –5, +30°C and soil temperature respectively +10 and +12°C. The depth of laying ground-air heat exchanger is recommended 1.5÷2.5 m [2].

When using geothermal ventilation with the ground-air heat exchanger under these conditions are similar to the companies promised to increase the thermal efficiency of supply and exhaust ventilation in 1.5.

Average soil temperature at different depths, the depth of groundwater, the thermal conductivity of the soil and the amount of solar radiation are the main data necessary for the design of geothermal ventilation systems. A detailed assessment of the calculated climatological parameters are shown the regulations showed the insufficiency or absence of the indicated values.

Soil temperature at different depths is a defining value. Its value affects the amount of heat that will transfer ground to the air in the heat exchanger. Currently there aren't systematic dates about changes of soil temperature from depth. Available only data for some cities in Ukraine (Tab. 1, 2).

Table 1. **The average soil temperature for some of cities in Ukraine [3]**

City	winter		summer		annual	
	Soil depth [m]					
	0.8	1.6	0.8	1.6	0.8	1.6
Kyiv	1.0	2.7	17.3	15.1	8.5	8.5
Odessa	3.2	5.5	23.0	19.6	12.7	12.5
Kharkiv	1.5	2.7	17.1	15.7	8.8	8.9

Table 2. **Temperature dependence from soil depth and city building [4]**

City	Soil depth [m]					
	0.4		0.8		1.6	
	summer	winter	summer	winter	summer	winter
Dnipropetrovsk	23.3	–3.0	21.6	–1.1	18.8	2.0
Kyiv	18.6	0.1	17.6	1.1	16.0	2.5
Lugansk	22.3	–2.0	20.3	0.2	16.7	3.8

For other cities in Ukraine the soil temperature for a specified day and the soil depth can be determined by relationship [5]:

$$T_s(x,t) = \overline{T_s} + A \cdot e^{-x\sqrt{\frac{\pi}{365a}}} \cdot \sin\left(\frac{2\pi(t-t_o)}{365} - x\sqrt{\frac{\pi}{365a}} - \frac{\pi}{2}\right) \quad (1)$$

where:

x - depth of soil [m],

t - day of the year,

$\overline{T_s}$ - the annual average surface temperature of the soil taken equal an annual average outdoor air temperature for the selected region [°C],

A - annual amplitude fluctuation of the surface temperature of the soil [°C],

a - thermal diffusivity of the soil [m^2/s],

t_o - time lag (in days) from a random initial date of the emergence of the minimum temperature in year.

Thermal diffusivity of soil characterizes the rate of change of temperature due to absorption or return of heat. It depends on ratio solid, liquid and gaseous

components, textural and structural characteristics of soil and its moisture. Thermal diffusivity [m^2/s] is determined by the formula:

$$a = \frac{\lambda}{\rho C} \tag{2}$$

where:
λ - coefficient thermal conductivity of the soil [W/(m·K)],
ρ - density of soil [kg/m^3],
C - specific heat of the soil [kJ/(kg·K)].

Temperature field of soil for the selected region possible to simulate in the NeoHeatingPro system on the basis of (1), taking into account the actual soil properties (coefficient thermal conductivity, density, specific heat). The result of the simulation is a graph of the dependence of temperature of the soil depth. Thus, for Kyiv it presents the dependence of the depth of soil temperature for each month of the year (Fig. 4) [6].

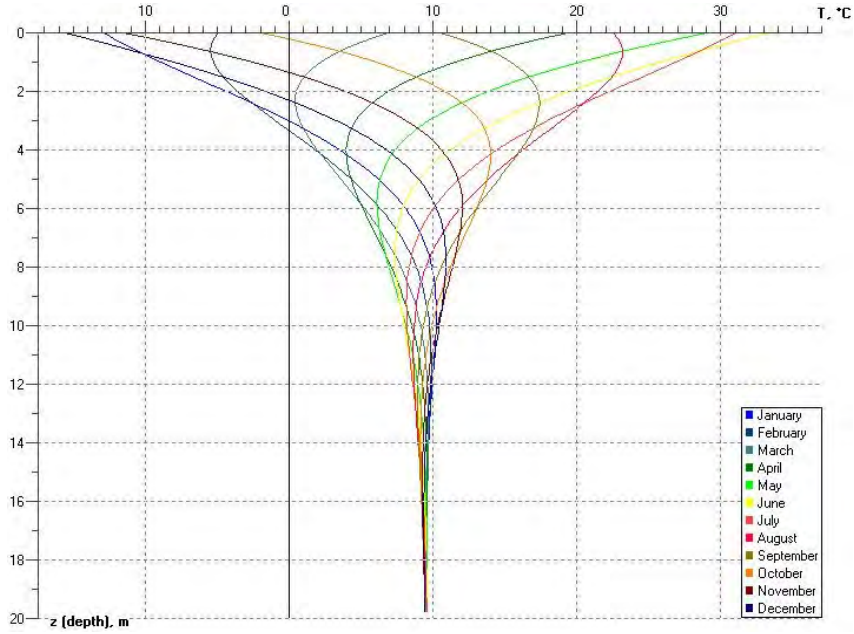

Fig. 4. The dependence of soil temperature from depth in Kyiv [6]

As shown in Figure 4, the values of soil temperature at a depth 1.5÷2.5 m for Kyiv during winter months are negative, or are equal to +2÷+3°C. This temperature is not sufficient for the effective operation of geothermal ventilation. For Ukraine the depth of laying the ground-air heat exchanger is necessary to increase.

CONCLUSION

The analysis shows that it is necessary to conduct deeper research to develop recommendations possibility of installing such systems in regions with temperate climates, particularly in Ukraine.

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GEOTERMALNA WENTYLACJA DOMU PASYWNEGO

W celu zmniejszenia kosztów za import energii zaleca się stosowanie energo-oszczędnych technologii w nowo powstałych, a także istniejących modernizowanych budynkach. Dobra izolacja cieplna elewacji i szczelne okna przyczynią się do zmniej-szenia zużycia ciepła w użytkowanym obiekcie. Jednak brak świeżego powietrza ma ujemny wpływ na jakość powietrza w pomieszczeniach. Stąd też zastosowanie wentylacji nawiewno-wyciągowej jest gwarancją poprawy jakości powietrza w budynkach pasywnych. W artykule opisano możliwość zastosowania wentylacji geotermalnej z wykorzystaniem gruntowych wymienników ciepła w budownictwie pasywnym.

Słowa kluczowe: wentylacja geotermalna, wymiennik ciepła ziemia-powietrze, dom pasywny, współczynnik przewodności cieplnej, temperatura gruntu