THERMO PHYSICAL PROPERTIES OF SAMPLES MADE OF UNBURNT CLAYEY SOIL AND SAPROPEL MIXTURE

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Abstract. The dependencies of heat conductivity of samples made of sapropel and clay on the amount of sapropel and absolute humidity have been investigated. Sapropel in unburnt clay samples from 1 % to 2 % of dry mass reduces the heat conductivity of the samples from 18 % to 30 % subject to absolute humidity. The heat conductivity of dried unburnt clay samples with 2 % to 4 % sapropel additives does not change. When absolute humidity of samples increases during the measurements of heat conductivity, it becomes obviously dependable on the amount of sapropel. The amount of sapropel is more significant to heat conductivity (Beta = -0.723) than absolute humidity (Beta = 0.672). The heat conductivity of the samples formed at $16 \div 35$ MPa pressure increases enhancing formation pressure. The heat conductivity of the samples formed at pressure over 35 MPa reduces enhancing formation pressure. When absolute humidity of a sample increases, heat conductivity also increases and increases the most to the samples formed at 35 MPa pressure. Absolute humidity of the samples (Beta = 0.766) is more significant for the prognosis of heat conductivity than formation pressure (Beta = 0.326) of the samples.

Keywords: heat conductivity, sapropel, formation pressure.

Introduction

In Lithuania the investigations of sapropel usage in manufacturing of building materials started only in 1992. The suitability of sapropel in making heat isolating materials and ceramic articles was investigated then.

As far back as 1950s in Latvia, Belarus and Germany investigations were carried out on the purpose to use sapropel in the industry of building articles. There were interests in the sticking properties of sapropel [1]. Organic sapropel with the amount of nitrogen 5-7 % has enough sticking properties. Nitrogen and free amino acids have the largest contribution to such properties.

Heat insulation panels from sapropel, boon and sawdust were produced in Belarus. In Lithuania in 1992 the investigation of heat insulation panels made of waste and organic sapropel was introduced at the Heat Insulation Institute [2]. Grinded boon and sawdust were used as aggregate.

The scientists from Kaunas Technological University tried to use limy and organic sapropel for manufacturing of ceramic articles [3]. Dried and grinded sapropel was mixed into clay. It was established that when sapropel amounts up to 7-10 % the articles are torrefied quicker, they do not deform in the process of burning and their strength and water permeability are almost unchanged. Organic sapropel is applied to manufacture ceramics of porous structure, which fits all the requirements of heat isolating articles.

It was established that sapropel provides unburnt clay samples with more positive properties than other additives. The influence of limy and organic sapropel as an additive on the density, linear shrinkage, bending and compressing strength, and heat conductivity was investigated [4]. It was established that organic sapropel and limy one as an additive function irregularly. The density of unburnt clay samples while drying depends on the sort and amount of the inserted sapropel. Limy sapropel reduces the density of air dried samples and organic sapropel enhances it.

The dependence of heat conductivity of unburnt clay samples on the amount of organic sapropel at different humidity of samples was investigated [5]. After inserting 20 % of organic sapropel, the heat conductivity of unburnt clay samples reduces by 40 %. Such influence of organic sapropel on clay is positive in producing materials for building walls. When humidity of unburnt clay samples increases, the heat conductivity increases, too. When humidity of samples is maximal, heat conductivity is almost significantly less than in analogous samples of pure clay, though maximal humidity of pure clay is almost twice less than in unburnt clay samples with 20 % of organic sapropel as an additive.

The purpose of the work is to investigate the dependence of heat conductivity in unburnt clay samples having 1-4 % of sapropel additives on formation pressure of the samples; and the dependence of heat conductivity of the samples on their absolute humidity during the period of investigation.

Materials and methods

The work deals with the investigation of samples made of sapropel and clay. Samples with 1 %, 2 % and 4 % of sapropel have been used in various variations of investigation. Humidity of forming mass is equal to 7 %. The formed samples were dried at room temperature till constant mass. Then they were kept in a thermostat at temperature of 105 ºC till their mass did not change. The components of forming mass, formed and dried samples were weighed with 0.01 g precision digital balance EK – 610i.

After that the heat conductivity was measured at different absolute humidity. The samples were weighed before and after each measurement.

Heat conductivity was measured using heat conductivity gauge FOX 200 created by LaserComp Company [6; 7].

The dependence λ of the heat conductivity of the samples on different formation pressure in absolute humidity with 2 % additive of sapropel is presented in Fig. 1. According to the results, it can be seen that the heat conductivity of the samples, formed using 16 MPa forming pressure, is the least, and, formed using 35 MPa forming pressure, is the highest. The calculated trend lines show large reliability of the experimental results (coefficient R^2 changes within 0.9844 and 0.9994). According to the results we can see that when formation pressure p_f increases, heat conductivity also increases, and at 35 MPa, when humidity reaches the maximal value and is further enhanced to 40 MPa, lessens. The peak speed of growth is observed at 16-21 and 31-35 MPa. When humidity of the samples increases during measuring, the dependence of heat conductivity on formation pressure p_f also increases.

Samples with 1 %, 2 % and 4 % of sapropel have been used in various variations of investigation. The samples were formed using 21 MPa pressure; humidity of forming mass is equal to 7 %. Dependencies of heat conductivity λ of samples with different amount of sapropel on absolute humidity W are presented in Fig. 2. It can be seen in Fig. 2 that when the additives of sapropel are equal to 1 %, the heat conductivity in a dry sample is 0.32 W·(mK)$^{-1}$.

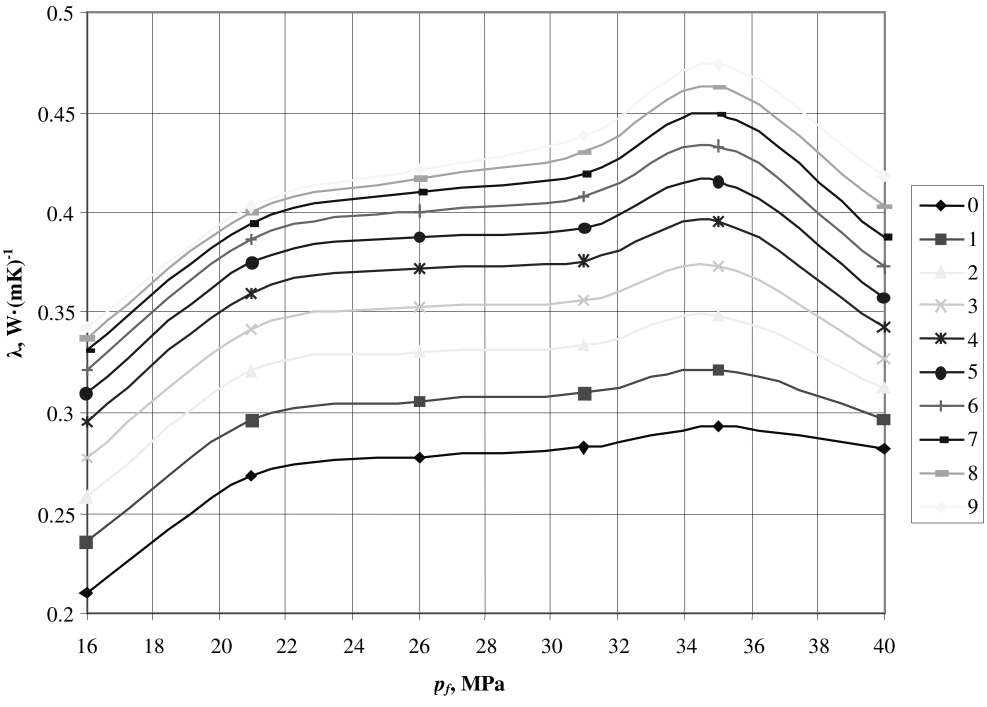

Fig. 1. **Dependence of heat conductivity on formation pressure at different absolute humidity of samples; numbers at symbols mean absolute humidity W_b during the course of measurement**

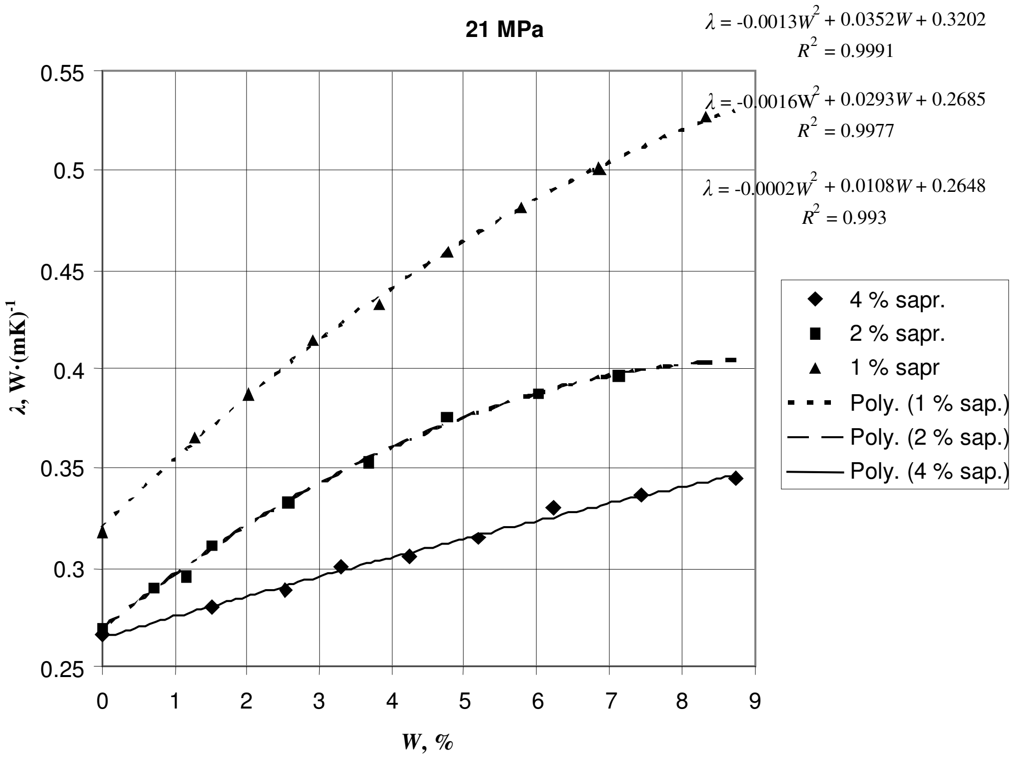

Fig. 2. **Dependencies of heat conductivity λ of samples with different amount of sapropel on absolute humidity *W***

When absolute humidity of a sample is equal to 5 %, the heat conductivity is about 0.47 W·(mK)$^{-1}$, *id est,* grows 47 % in respect of a dry sample. When absolute humidity of a sample is 8 %, the heat conductivity reaches about 0.32 W·(mK)$^{-1}$.

Analysis of experimental results

Heat conductivity in materials is proportional to density. However, radiation, diffusion and condensation process with steam-heat (secret steaming) together with the conduction mechanism are observed in heterogeneous materials. Air and water steam get warm over the lower plate, which temperature is 35 ºC, and gain height owing to diffusion and convection. The upper plate has temperature of 30 ºC. Here a part of water steam (the part which exceeds partial pressure of saturated water steam) condenses and steam-heat (secret steaming) exudes. It can be proved by the increase of the heat conductivity, when absolute humidity of a sample is 0-2 % (Fig. 1). In further enhance of humidity the increase of the heat conductivity lessens.

It proves that when the formation pressure increases, the particles of a sample get closer, the volume of pores lessens and, in turn, heat transfer in capillaries of a sample also lessens owing to diffusion and transfer of secret steam-heat. However, at the same time heat transfer from particle to particle increases too, because the reduced volume of pores enhances the contact surface of touching particles. The fact that at pressure of 35 MPa the maximal of heat conductivity is observed (Fig. 1) does not contradict the dependence of the density on the formation pressure. The particles of a sample are the closest at such pressure. When such pressure is exceeded water with small particles is being withdrawn increasingly.

The received results have been processed applying the programme SPSS – 15. Linear regression has been used for the analysis. The coefficient of determination of a model has been equal to 0.76, and it shows that according to a model of linear regression 76 % of heat conductivity λ dispersion is explained. Formation pressure p_f and absolute humidity of a sample W_b during measuring are statistically significant ($p < 0.001$) [8] for the prognosis of heat conductivity. The results of the model analysis are presented in Table 1.

Table 1

Dependence of heat conductivity of a model on formation pressure p_f and humidity W_b, the results of analysis

Size	Non-standardized coefficient	Standardized coefficient	p
	B	Beta	
Constant	0.218	-	0.000
Formation pressure of samples p_f	0.002	0.326	0.000
Absolute humidity of samples W_b	0.017	0.766	0.000

According to the non-standardized coefficients presented in Table 1 we can write a linear regression equation, which describes the experimental results:

$$\lambda = 0.218 + 0.002 p_f + 0.017 W_b , \tag{1}$$

where p_f – formation pressure of samples, MPa;
W_b – absolute humidity of samples, %.

It can be seen from the values of the non-standardized coefficient B, that when the formation pressure increases 1 MPa, the heat conductivity increases 0.002 $W\cdot(Km)^{-1}$, and when the absolute humidity increases 1 %, the heat conductivity increases 0.017 $W\cdot(Km)^{-1}$. According to the standardized coefficients we can draw the conclusion that in the samples absolute humidity is more important during measurements than formation pressure p_f.

When the amount of sapropel is increased, the heat conductivity in the samples reduces, though, when it is within 2 and 4 %, the heat conductivity of dry samples hardly depends on the concentration of sapropel (Fig. 2). When the absolute humidity of the samples is higher during the measurements the heat conductivity increases significantly.

It can be explained by the fact that when the amount of sapropel is enhanced, small particles of sapropel obstruct capillaries and in such case the diffusion of air and vapour lessens. The graph (Fig. 2) shows that comparing the samples with 2 % and 4 % of sapropel we can notice that the absolute humidity of samples is 5 %, heat conductivity differs 0.06 $W\cdot(Km)^{-1}$, and the difference of heat conductivity of the samples having 1 % and 4 % of sapropel respectively is 0.15 $W\cdot(Km)^{-1}$, when absolute humidity is 5 %. When the absolute humidity of the samples increases, the heat conductivity of sapropel particles increases, too. Heat contact among clay particles becomes better and heat transfer grows more intensively, because air in capillaries has more water vapour. However, when the amount of sapropel in the samples increases, the particles of sapropel obstruct capillaries; consequently, the dependence of heat conductivity on the humidity of a sample becomes more pronounced.

The received results of heat conductivity were processed using SPSS – 15 programme applying linear regression (Table 2).

Table 2

Results of statistic analysis of dependences of heat conductivity

Size	Non-standardized coefficient B	Standardized coefficient Beta	p
Constant	0.384	-	0.000
Amount of sapropel	-0.041	-0.726	0.000
Humidity of a sample	0.018	0.672	0.000

From the results given in Table 2 it can be seen that they are not statistically reliable ($p < 0.001$), though it is enough to p to be less than 0.05 [8]. According to the non-standardized coefficient B heat conductivity λ is expressed by the equation of linear regression:

$$\lambda = 0.384 - 0.041x + 0.018W \, , \tag{2}$$

where λ – heat conductivity W $K^{-1} \cdot m^{-1}$;
x – amount of sapropel in dry mass in %;
W – absolute humidity of a sample %.

According to the standardized coefficient Beta the conclusion that the amount of sapropel is statistically more significant (Beta = -0.723) than the humidity of a sample can be drawn. The coefficient of determination of a received model R^2 = 0.880. It proves that 88 % of heat conductivity λ dispersion can be explained according to a model of linear regression.

Conclusions

1. Sapropel in unburnt clay samples from 1 % to 2 % of dry mass reduces heat conductivity of samples from 18 % to 30 % subject to absolute humidity.
2. Heat conductivity of dried unburnt clay samples with 2 % to 4 % sapropel additives does not change.
3. When absolute humidity of samples increases during the measurements of heat conductivity, it becomes obviously dependable on the amount of sapropel.
4. The amount of sapropel is more significant to heat conductivity (Beta = -0.723) than absolute humidity (Beta = 0.672).
5. When absolute humidity of a sample increases during the measurement, its heat conductivity also increases and becomes booming for samples formed at 35 MPa pressure.
6. Absolute humidity of samples (Beta = 0.766) is more important than formation pressure of samples (Beta = 0.326) for the prognosis of heat conductivity

References

1. Курзо Б.В. Закономерности формирования и проблемы использования сапропеля. Минск, 2005, 224 с. (In Russian)
2. Žvironaitė J. Sapropelio panaudojimo statybinių medžiagų pramonėje galimybės // Tarptautinė konferencija. Vandens telkinių būklė ir gerinimo metodai. LŽŪU, 1997, pp. 112-113. (In Lithuanian)
3. Mandeikytė N. Keramika su sapropelio priedais // Tarptautinė konferencija. Vandens telkinių būklė ir gerinimo metodai. LŽŪU, 1997, pp. 114-117. (In Lithuanian)
4. Gurskis V., Navickas J., Vaišvila A. The influence of aditional elements on the building materials characteristics of unburned clay // Proceedings of international scientific conference hydraulic engineering and land management, Kaunas, 1996, pp. 58-59.
5. Navickas J., Gurskis V. Kalkinio ir organinio sapropelio įtaka nedegto molio bandinių savybėms // Vagos. ISSN 1648-116X. Nr. 67(20), 2005, pp. 95-100. (In Lithuanian)
6. Navickas J. Agrofizika ir agrometeorologija: mokomoji knyga, Akademija, Lietuvos žemės ūkio universitetas, 2008. (In Lithuanian)
7. FOX200 and FOX300 Series Instruments Manual (1999-2005). LaserComp Inc.
8. Čekanavičius V., Murauskas G. Statistika ir jos taikymai, Vilnius, 2000. (In Lithuanian)