EXPERIMENTAL INVESTIGATION OF ROCKWOOL INSULATION HYGROTHERMAL PROPERTIES RELATED TO MATERIAL STRUCTURE

by

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The hygrothermal properties related to rockwool insulation material structure with different additives are presented using rockwool insulation products obtained from row material of southern Serbia (Vranje region) in the wide range of reference temperatures (10 °C to 70 °C). The hygrothermal properties of basic sample (without additives) are compared to two samples with different additives for two sets of rockwool insulation samples namely: light-soft-panels with density of 50 kg/m^3*, and middle-weight-panels with density of 80 kg/m*^{3}*. It is shown that there is significant (approximately 10%) improvement of thermal conductivity for additives based on zeolite. Also, correlation of thermal conductivity and sorption properties of selected samples are presented.*

Key words: *rockwool, insulation, sorption, thermal conductivity, zeolite*

Introduction

The thermal conductivity as well as the moisture content is key thermal transport properties of building materials. The role of insulating materials in the building energy and moisture balance is more significant when compared with the other materials of the building structures. The laboratory measurements of these values of the insulating materials are very important either for the manufacturers or the contractors. The available bibliographic data for these materials are strongly incomplete and somewhere out of date.

Rockwool has long been among the most popular growing medium on earth. Originally used as insulation it was called "Mineral Insulation". It is used primarily for drip hydroponic systems. Rockwool is made by melting a combination of rock and sand and then spinning the mixture to make fibres which are formed into different shapes and sizes. The process is very similar to making cotton candy. While versatility and ease have contributed to its popularity, there are several advantages and disadvantages to this type of growing medium which should be considered along with the pros before deciding on whether or not to be used.

Advantages of rockwool:

– rockwool holds an incredible amount of water which gives you a buffer against power outages and pump or timer failure,

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– rockwool holds at least 18% air at all times (unless it is sitting directly in water). This supplies the root zone with plenty of oxygen, making overwatering less likely.
– rockwool holds together very well so it can not spill. It also comes wrapped in plastic, making it easy to handle and keeping evaporation to a minimum.

Disadvantages of rockwool:

– rockwool is hard to dispose of. If it is buried, it will last indefinitely.
– the fibres and dust from the rockwool are bad for lungs. It is strongly advised that we wear a dust mask when handling it to prevent problems.
– rockwool has a high pH which means we have to adjust our nutrient solution low so that the root zone is neutral. Rockwool is also susceptible to pH shifts meaning more routine maintenance to keep the pH levels correct.

However, it is common practice to use rockwool products as green building insulation in order to increase building durability, reduce demand for row materials, conserve energy, and enhance indoor environmental quality. Rockwool insulation products are capable of maintaining their initial physical characteristics throughout the life of the buildings in which they are used. Also, rockwool insulation is non-combustible and water-repellent and allows for reduced probability that deterioration may occur if moisture is controlled to building's envelope. Commonly, it contains an average of 7-8% post-industrial recycled content.

Furthermore, rockwool insulation provides excellent thermal resistance and can play a significant role in reducing energy used in heating and cooling residential and commercial buildings. Rockwool fibres and particles are amorphous (non-crystalline). The majority of airborne fibre levels in buildings containing one or more rock and/or slag wool products are very low, generally less than 0.001 fibres per cubic centimetre. Abovementioned general properties of rockwool insulation are strictly related to its material structure, such as porosity, chemical compounds contents of basic stone, as well as added additives.

Also, it is well known fact that hygrothermal properties of rockwool are strictly depended of material structure, primarily of additive contains [1]. A study of hygrothermal properties related to rockwool insulation material structure with different additives has been performed using rockwool insulation products obtained from row material of southern Serbia (Vranje region) in the wide range of reference temperatures (10 to 70 °C) [2].

In the current literature was taken on the fibrous insulation material basis, based on the model of the thermal characteristics of conductivity of the wet fibrous material [3], the characteristics of the structure of solids materials [4], the equivalent conductivity of the air in the pores under the influence of vapor diffusion [1].

What is the detailed analysis of these works imposes itself is the issue more modern approach to the problem of lowering the partial pressure of water vapor within the air layer , or in the interstices of the skeleton of such a porous system, which was the basic idea in this paper.

In fact, for quite wet porous fibrous materials, in which all the pores filled with water, we calculate the thermal conductivity by the thermal conductivity of air in the pores replaces the thermal conductivity of liquids. The influence of the structure of a solid (the association between individual particles of solid material) must be expressed by the same analogy, in the same manner as in the dry matter.

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Experimental methodology

Material studied

Two sets of rockwool insulation samples have been investigated, namely: light-soft-panels (LSP) with density of 50 kg/m^3 and middle-weight-panels (MWP) with density of 80 kg/m^3. Rockwool is on basalt base (70%) and dolomite (30%) as a smelter. Contain of constituent mass fraction of basic samples (BS) without additives is specified in tab. 1, referred to dry material [2].

Additionally, for each set LSP and MWP, two combinations of additives (denoted as I and II), differing by contains of zeolite, bentonite, P_2O_5, Al_2O_3, TiO_2, and Na_2HCO_3, have been investigated [2]. Contain of constituents mass fraction of additives is presented in tab. 2. Prevailing additives are zeolite (90%) or bentonite (20%), while the rest of additives are added in order to increase adsorption performances at the low relative humidity (5-30%).

Share of constituents' mass fraction of bentonite and zeolite are given in tabs. 3 and 4 [2].

Table 1. Constituent mass fraction of basic samples

Constituent	Mass fraction [%]
H_2O	0.18
SiO_2	43.20
Al_2O_3	15.69
Fe_2O_3	5.24
CaO	26.40
MgO	6.86
SO_3	–
S	0.00
Na_2O	1.79
K_2O	0.54
CO_2	0.12

Table 2. Constituent mass fraction of additives

Constituent	Mass fraction of additive samples [%]	
	I	II
Zeolite	40	90
Bentonite	20	8
P_2O_5	–	–
Al_2O_3	20	2
TiO_2	20	–
Na_2HCO_3	–	–

Table 3. Constituent mass fraction of bentonite

Constituent	Mass fraction [%]
SiO_2	51.82
TiO_2	0.34
Al_2O_3	26.86
Fe_2O_3	2.30
MnO	0.10
MgO	1.27
CaO	1.44
Na_2O	0.75
K_2O	2.07
SO_3	–
H_2O-110 °C	5.56
H_2O-1100 °C	7.20

Experiments

Thermal conductivity

The measurement of thermal conductivity was performed by the steady-state method of hot plate. The sample is separated from heat and sinks sources with a thin layer of rubber. Surface temperatures of the sample at three points have been performed on both sides of the sample. Device for testing was in accordance with the Serbian national standard SRPS A2.020./83. The samples have been prepared by draying at 105 °C and cooling at desired temperature into the hermetic chamber [2].

Table 4. Constituent mass fraction of zeolite

Constituent	Mass fraction [%]
SiO_2	64.88
Al_2O_3	12.99
Fe_2O_3	2.00
TiO_2	0.37
CaO	3.26
MgO	1.07
Na_2O	0.95
K_2O	0.89
H_2O	13.30
Cu	0.093
Mn	0.104
Zn	0.093

Desorption isotherms

For the experimental determination of desorption isotherms, a static method has been used. The method is based on monitoring the weight of the sample in the calm atmosphere of sealed thermal stability court over saline solution that provides the desired relative humidity. Measurements were carried out so as for each isotherm (0 °C, 20 °C, and 50 °C) of samples were prepared from five different moisture contents. The moisture content of the material was determined by the standard gravimetric method of drying at 105 °C.

Experimental results

Experimental thermal conductivity

Experimental results of thermal conductivity of LSP and MWT are summarised on figs. 1 and 2, respectively, for both basic sample of rockwool without additives (BS) and samples of rockwool with additives given in tab. 2 (I and II). Also, there is a bar of ±10% referred to basic samples. It is clearly evident that both rockwool samples with additives have lower thermal conductivity than basic sample in the range of –10%.

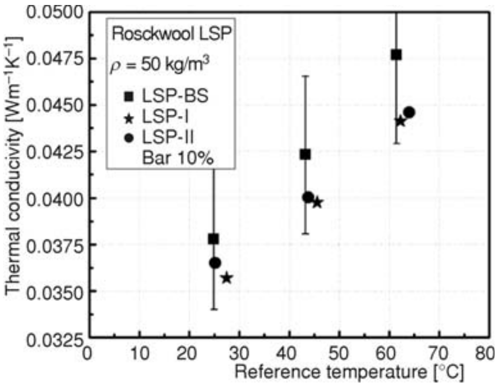

Figure 1. Thermal conductivity *vs.* reference temperature for LSP rockwool samples

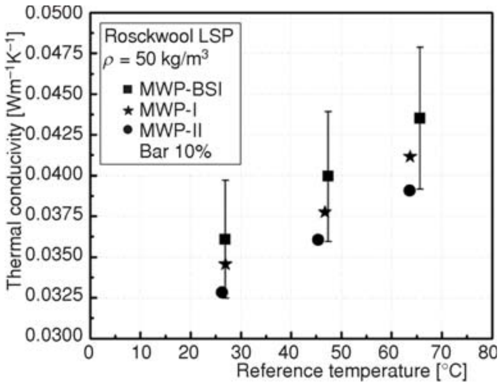

Figure 2. Thermal conductivity *vs.* reference temperature for MWP rockwool samples

Normatively, by ISO 10456:2007 3rd ed. [5], declared thermal values should be given under one of the sets of conditions: 10 °C or 23 °C. The reference values of thermal conductivity are summarized in tabs. 5 and 6. Beside this, obtained thermal conductivity gradients in the range of reference temperature (outdoor temperature) are very useful in calculation of dynamic thermal performances of buildings.

Based on obtained experimental results, it can be concluded that:

– thermal conductivity is increasing with increasing temperature,

Table 5. Summarized thermal conductivity

Sample	Reference temperature	
	10 °C	23 °C
MWP-BS	0.0328	0.0353
MWP-I	0.0314	0.0338
MWP-II	0.0301	0.0323
LMP-BS	0.0336	0.0371
LMP-I	0.0314	0.0345
LMP-II	0.0332	0.0359

Table 6. Improvement of rockwool thermal conductivity

Sample	Thermal conductivity difference			
	10 °C		23 °C	
	[Wm^{-1}K^{-1}]	[%]	[Wm^{-1}K^{-1}]	[%]
MWP-BS	0.0000	0.00	0.0000	0.00
MWP-I	0.0014	3.91	0.0015	4.35
MWP-II	0.0027	7.67	0.0030	8.49
LSP-BS	0.0000	0.00	0.0000	0.00
LSP-I	0.0022	6.56	0.0026	6.90
LSP-II	0.0004	1.12	0.0012	3.14

– MWP samples have lower thermal conductivity in the whole temperature interval,
– sample II MWP containing 90% zeolite has the lower thermal conductivity, and
– however, in the case of LSP samples, the lover reduction of thermal conductivity has been obtained for additive of combination bentonite and zeolite (sample I), compared to MWP samples.

Experimental desorption isotherms

Fitted experimental desorption isotherms for zeolite as the most effective additive and samples of rockwool LSP and MWP are presented on figs. 3, 4, and 5, respectively.

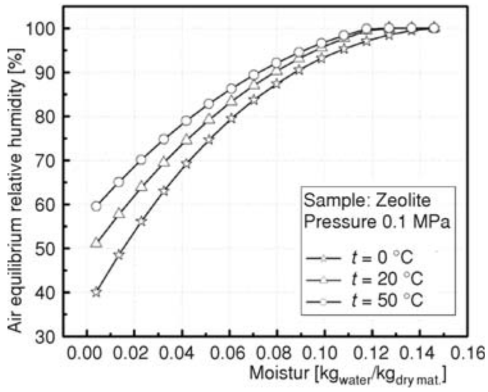

Figure 3. Desorption isotherms for zeolite

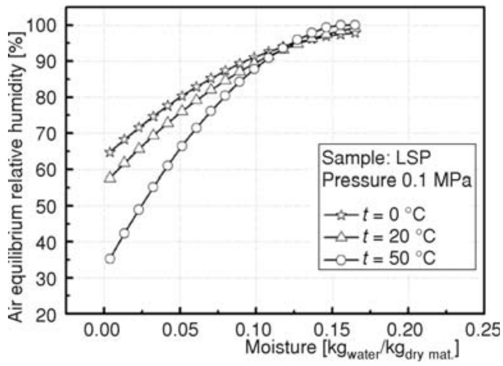

Figure 4. Desorption isotherms for LSP rockwool

Based on obtained experimental desorption isotherms for zeolite, LSP, and WMP samples it can be concluded that air equilibrium relative humidity reached maximum at the approximately the same contains of moisture (0.14-0.15 $kg_{water}/kg_{dry\ mat.}$) of zeolite and LSP, whereas in the case of WMP, it is approximately 0.4 $kg_{water}/kg_{dry\ mat.}$.

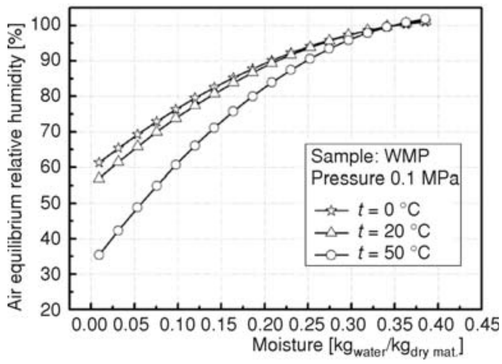

Figure 5. Desorption isotherms for WMP rockwool

Conclusions

The study's summary states: "Insulation materials are exposed to environmental influences (*i. e.* humidity). Due to diffusion processes as a consequence of gradients of the temperature or the humidity, the moisture content of the insulation can increase. High temperatures at high moisture contents lead to a strong increase of the effective thermal conductivity because of pore diffusion." In other words, conventional insulation materials conduct more heat when wet.

- If insulation materials are applied for operating temperatures considerably above ambient temperature, the dimensioning of the insulation thickness should not be performed with the thermal conductivity according to the values given in standard literature.

- Furthermore the values indicated in standard literature are not sufficient for applications with higher operating temperatures.
- Insulation materials are not always completely dry after delivery (depending on the kind of insulation)
- Insulation materials exposed to environmental influences show increased moisture contents.
- The dimensioning of the insulation of components of heating systems with a linear relation between the thermal conductivity and the temperature and moisture content is more accurate, than with the data given in standard literature.
- In the range of higher temperatures (>50 °C) as well as for detailed calculations and simulations the effective thermal conductivity should be considered [6].

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