Eco-Friendly Building Materials

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Abstract. In recent years, the construction industry has developed an ecological direction, which aims to use natural materials. These materials can be both vegetable and animal origin. Building structures made of such semi-finised products are usualy light, non-destructive for environment, and in many cases made of recycled materials. Such an eco-building model often does not require energy inputs for production. It contributes to the development of energy-saving investments which meet the current technical requirements. These materials can perform an insolating function, like sheep's wool or cellulose, as well as construction or finishing function made of products like plywood, fibrous materials with an external gypsum or wooden panel or clay plaster with straw. Such products are perceived as healthy and cheap, and in many cases available locally. These solutions can have a significant impact in modern construction due to the increase in the prices of traditional construction products and energy savings during construction and investment use. The article aims to provide basic information about selected materials of natural origin and compare them in terms of hygrothermal research.

1. Introduction

Building materials of natural origin, both vegetable and animal origin, may be used as materials for thermal insulation, e.g. straw, sheep wool or cellulose, and find use as a construction materials, for example AleppoPine wood, cork and their composites, cotton stalk fibers, wood-based products, palm wood, wood-based products, textile waste, cotton waste, fly ash and barite, natural fibres [1–7]. The article aims to present basic information about selected materials of natural origin with the presentation of their essential characteristics, relevant to their use in construction. In the construction sector, particularly housing, in recent years more and more apparent trend of "eco-friendly", where the use of the building materials of natural origin are vegetable and animal origin. These types are seen as a cost-effective, energy efficient and healthy. This type of construction requires less energy for production compared to traditional. The advantage of the above solutions is the use, if possible, of materials available locally. Great attention is paid to the fact that these materials do not contain toxic substances harmful to humans. What's more, they can be recycled. This is related to the low energy needed to use to the process. They are also subject to faster and natural biodegradation [8–10]. Examples of natural materials are dried and packed earth, wood, plywood, insulation boards of wood fibers or hemp straw, sheep wool, cellulose materials, chipboard with the outer gypsum board or wood, etc. One of the most popular natural materials is wood. It is used to build houses made of logs and skeletal houses, making roof structures, window and door frames, etc. It is easily available on the market and 100% renewable. Characteristics of the wood are its high strength, flexibility, lightness and rigidity [11 16]. The impregnated wood with special chemical agents is stable, ageing processes are slow, and is resistant to moisture. One of the oldest building materials is earth/ground. In the history of each region and each country, we can encounter both monumental buildings as well as rural buildings made of earth in admixture with other natural materials. Buildings from the ground, are perceived as healthy, friendly to man and the environment [17–21]. The rooms create comfortable thermal and humidity conditions for users. Common products from the earth are green, dried bricks and blocks or walls from slabs in formwork. Another group of materials are natural products, such as sheep's wool, insulating boards from wood fibers or hemp, cellulose, straw, which were used as thermal insulation products. They arouse great interest especially because of their property of absorbing / releasing humidity, which may assist in adjusting the level of humidity in the room. Sheep wool insulation has good thermal and acoustic insulation, however, is not resistant to long-lasting moisture. In contrast, cellulose, obtained by processing waste paper is vapour permeable material which has good thermal and acoustic insulation. In loose form, it can be used to isolate e.g. inaccessible spacea as lofts as well as fillers in skeletal walls. Straw is another material that has been used for a long time and is still used in construction. It is regarded as a natural waste agricultural production, while cheap and easily accessible. Relatively good thermal insulation of straw causes that the partitions do not require additional insulation [11–21]. Houses currently designed in this technology can obtain parameters, e.g. in the field of heat transfer coefficient of septum, similar to passive houses [10–18, 22]. The next group of products are building materials such as natural fibers like flax, hemp and wood. Such products are characterized by good thermal and acoustic insulation. Their disadvantage is flammability, so they must be protected by fireproof impregnates. They are also not resistant to rodents and show poor resistance to moisture. They are used so often for the "housing", i.e. earthen plaster, earth plaster with straw, earth plaster with cellulose, plywood, calcium silicate board, wood fibre insulation board, hemp insulation board, sheep’s wool and straw.

2. Experimental part

The experimental programme consisted of determination of the sorption isotherm, thermal conductivity and vapour permeability tests.

2.1. Determination of the sorption isotherm

Tests were carried out in accordance with EN ISO 12571 [23]. Samples before drying were dried to a constant mass. The samples were then placed under constant temperature conditions of 23 °C and relative air humidity of 0 %, 20 %, 50 %, 65 % and 90 %, respectively until their mass stabilized. Measurements of mass change were made every 24 hours.

2.2. Thermal conductivity λ

Test was performed in accordance with EN 12667 [24]. Samples before the test were dried to a constant weight. Then the samples were conditioned prior to testing under constant temperature (23 ± 2) °C and relative humidity (50 ± 5) %, until a constant weight. Measurements of thermal conductivity λ were carried out in the steady state by the hot plate method, with a FOX 314 apparatus. The measurements were made at the average sample temperature of 10 °C, the difference in temperature at the sample thickness of 20 K and heat movement from bottom to top, on samples with dimensions (300 x 300 x 50–100) mm.

2.3. Water vapour permeability

Determining the coefficient of water vapour diffusion resistance, μ, of samples at steady-state was performed in accordance with EN 12086 [25]. Prior to the tests, the samples were conditioned at a temperature of (23 ± 5) °C and relative humidity (50 ± 5) % until the mass stabilized in three consecutive weighing (change in mass within ± 5 %). The samples were then placed in metal dishes on the bottom of which a drying agent ($CaCl_2$) was placed. Measurements of the change in weight were recorded at an interval of 24 hours. The study was terminated when five consecutive changes in the mass per unit time are constant and housed within a tolerance of ± 5% of the average for each sample tested.

2.4. Density measurement of samples
The density of the samples was determined according to EN 1602 [26]. Before the test, the samples were conditioned at constant temperature conditions (23 ± 2) °C and relative humidity (50 ± 5) % until a constant mass of the sample was obtained (Figure 1).

3. Results and discussion
Samples of natural building materials were tested in the scope of determining their thermal and moisture properties. The materials tested were intended for use as thermal insulation of partitions, structural elements or as finishing materials. Figure 1 shows samples with a twenty-fold magnification, which have been tested.

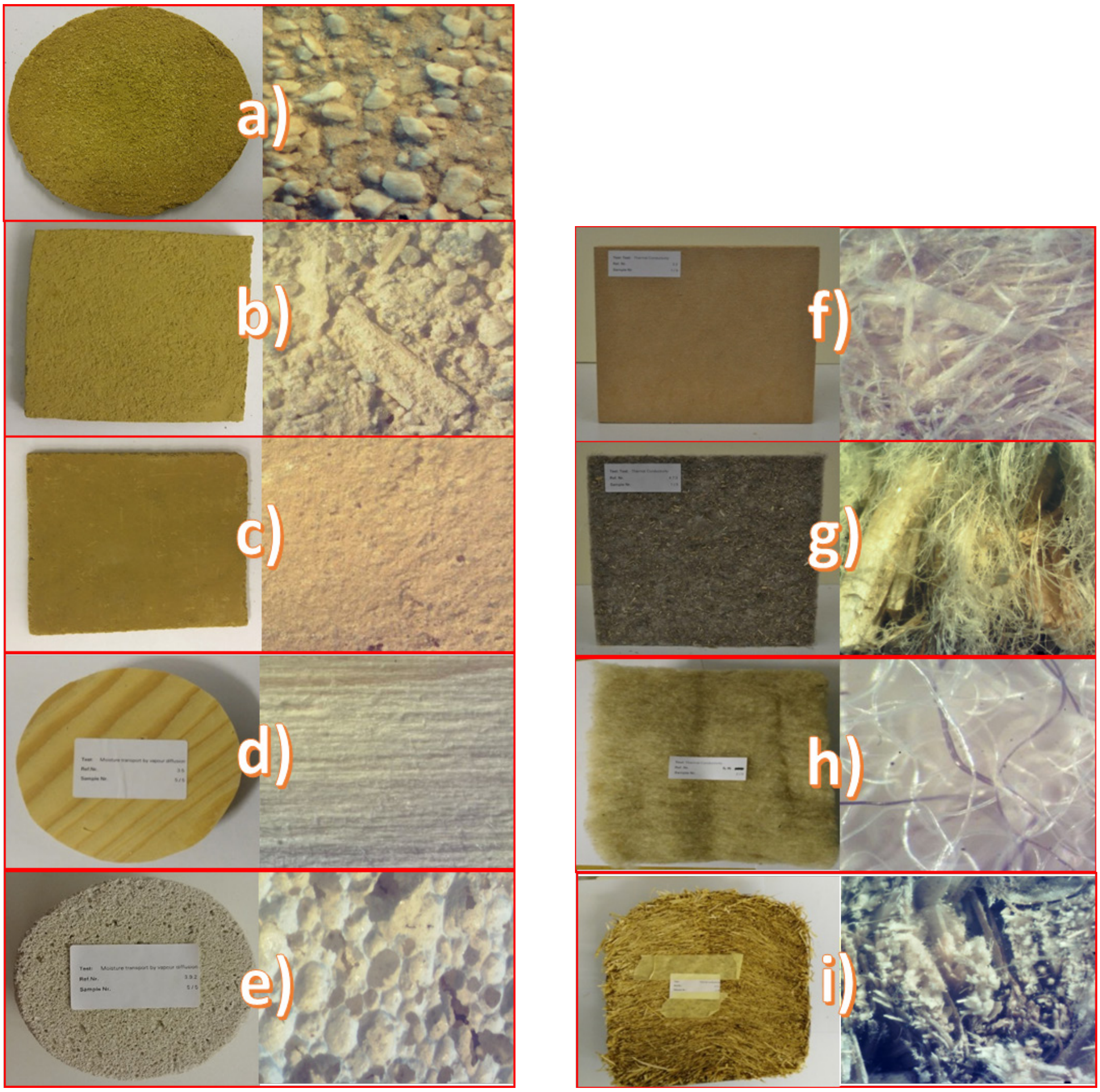

Figure 1. Sample images: a) earthen plaster b) earth plaster with straw c) earth plaster with cellulose d) plywood e) calcium silicate board f) wood fibre insulation board g) hemp insulation board (rigid) h) sheep's wool i) straw

As can be seen from the data in Table 1, samples have different density. Samples with a density of up to 100 kg m^{-3} are insulating products, while a material with a higher density is a construction material for partitions. The value of thermal conductivity is dependent on the kind and the structure of wood: density and water content. By comparing the density with the heat conduction coefficient, it can be stated that these results are similar to traditional construction products. Tested samples have a low diffusion resistance value, which is characteristic for vapour-permeable materials such as mineral wool. This means that water vapour can flow freely through the internal structure of such material. Earthen samples have a diffusion resistance value of about 15. This is a value close to the value of silicates. However, the wooden sample has achieved the highest value of diffusion resistance.

Table 1. Characteristics of samples prepared for tests

Sample	Density kg m^{-3}	Thermal conductivity W m^{-1}K^{-1}	Water vapour permeability
Earthen plaster	2150	0,58	19
Earth plaster with straw	1870	0,79	15
Earth plaster with cellulose	2060	0,69	14
Plywood	500	0,096	103
Calcium silicate board	104	0,041	3
Wood fibre insulation board	61	0,041	3
Hemp insulation board (rigid)	91	0,049	2
Sheep's wool	15	0,044	3
Straw	220	0,11	3

Figures 2–10 present the results of the moisture content in the samples depending on the relative humidity. From the results, it can be seen that the above materials of natural origin like earther plasters, wood fibre board and sheep's wool rather poorly absorb moisture from the air. For the calcium and hemp boards the water content was about 15 kg m^{-3} was obtained while the only material showing the higest moisture content was plywood (Figure 5).

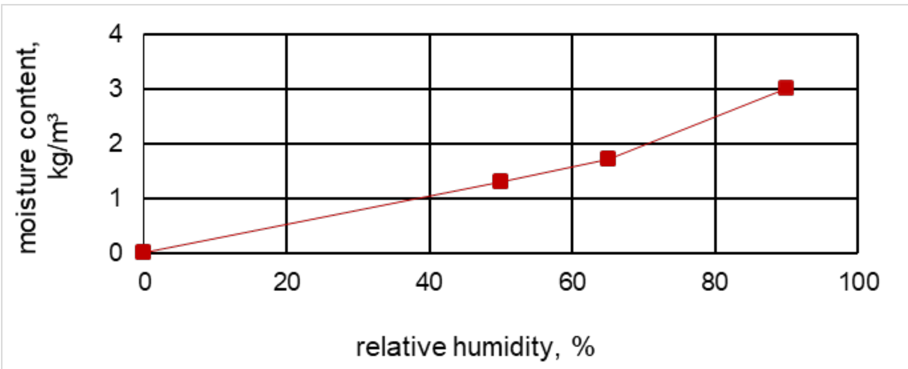

Figure 2. Earthen plaster

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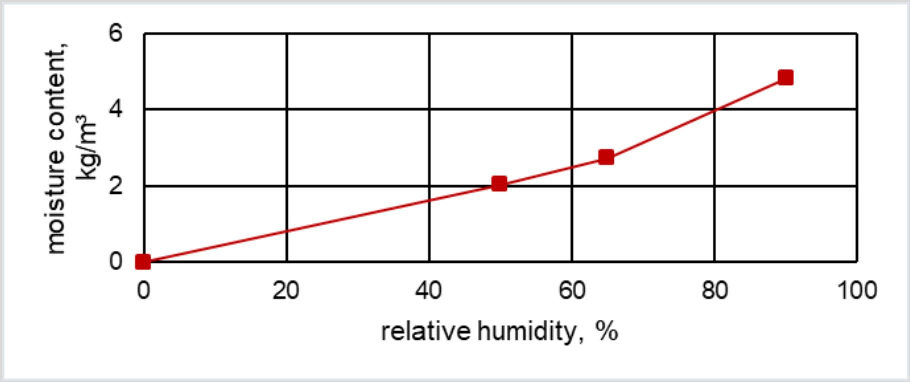

Figure 3. Earth plaster with straw

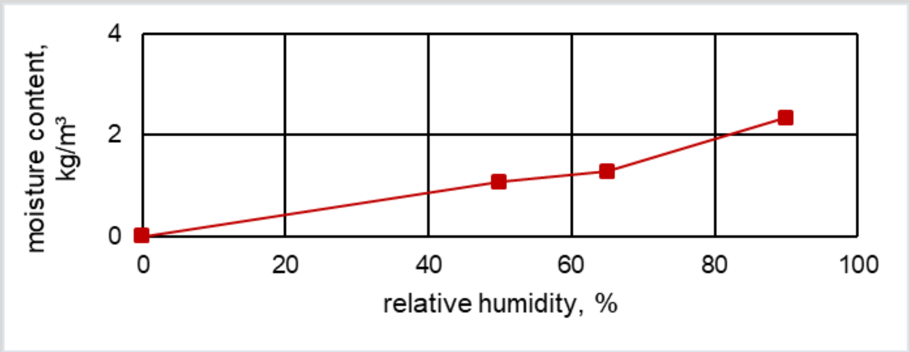

Figure 4. Earth plaster with cellulose

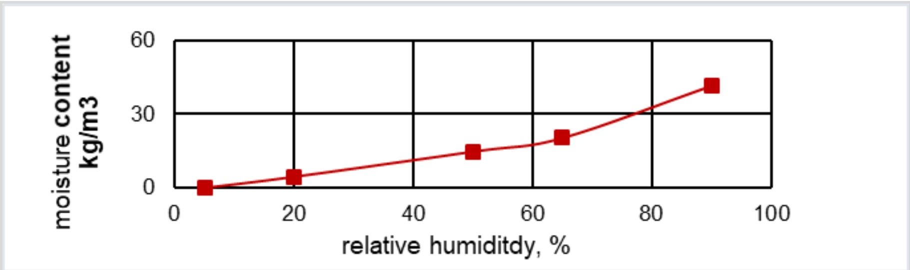

Figure 5. Plywood

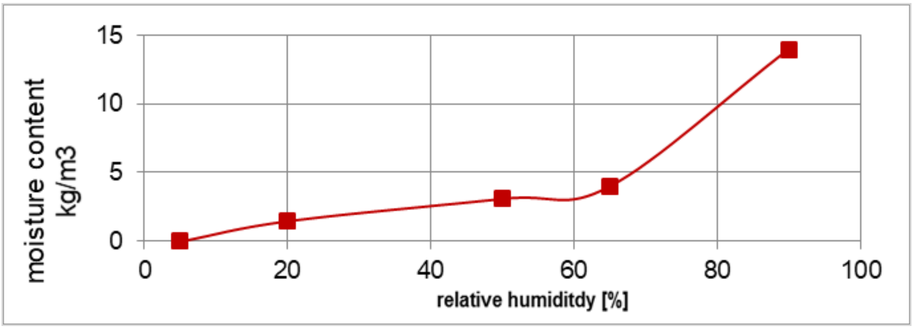

Figure 6. Calcium silicate board

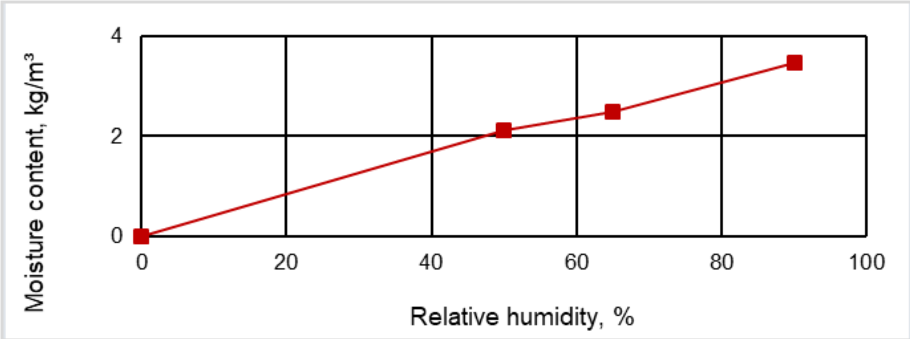

Figure 7. Wood fibre insulation board

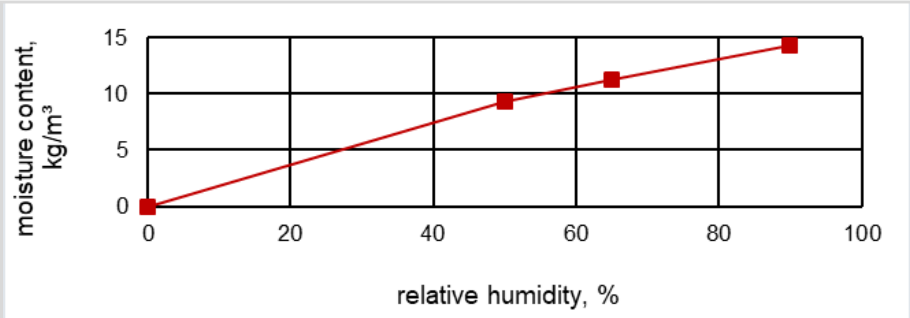

Figure 8. Hemp insulation board (rigid)

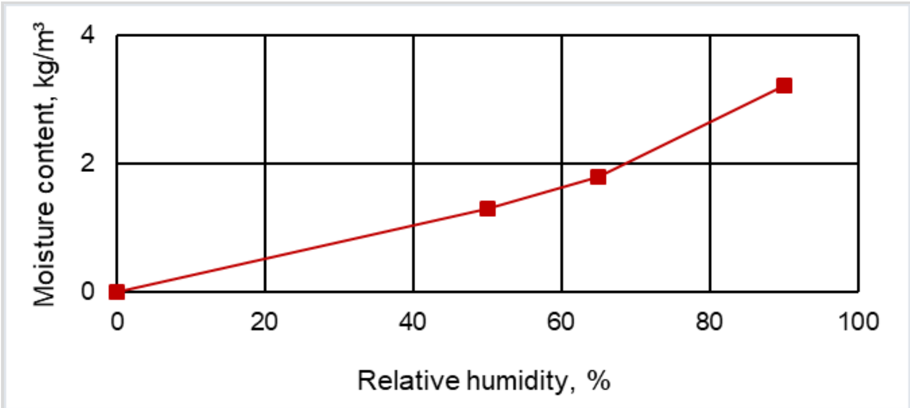

Figure 9. Sheep's wool

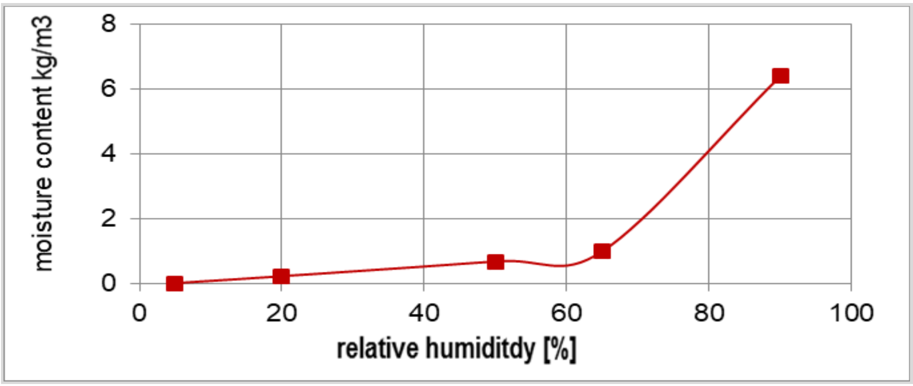

Figure 10. Straw

4. Conclusion

This paper focused on the thermal and mass transfer properties (thermal conductivity, diffusion of water vapour sorption isotherm) of some eco-friendly building materials and the influence of relative humidity of the atmosphere on the inestigated parameters.

Due to the local availability of selected materials, prior to construction, it is necessary to carry out tests to check the quality and suitability of the raw materials used. The use of local and renewable raw materials in the production of building materials fits well into the sustainable development policy. The use of natural materials allows for the construction of both ecological and aesthetic buildings as well as energy-efficient buildings. During the construction itself, we should also take into account the fact that when building naturally, it is necessary to reduce the amount of waste. Hence the growing popularity of prefabricated, biodegradable materials for producing elements, which use a small amount of energy and semi-finished products, is observed.

One can expect more and more interest in this subject and the introduction of specifications for natural building materials. In conclusion, there is a growing interest in "ecological trend" in the construction industry, which suggests that more and more such "natural objects" we will see in housing.

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