ROLE OF VERMICULITE IN ENERGY EFFICIENCY RELATED TO CIVIL ENGINEERING

Professional paper

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Abstract

In order to improve communication with the nature and to give contribution in domain of green architecture, vermiculite is recommended. Discovered in the geological environment as a raw material, vermiculite has offered wide range of physical features interesting for civil engineering. The most significant characteristic of the material is thermal insulation, not only at high, but also at low temperatures. In the paper, features of vermiculite, as well as its application, are presented.

Keywords: *vermiculite, temperature, energy efficiency, green architecture.*

Introduction

Vermiculite as mineral - occurence in the nature. Vermiculite (from the Latin word *vermicu-lare* – vermiform), according to the chemical term (Fig. 1), $(Mg-Fe)_3Al(AlSi)_4O_{10}(OH)_2$•4H20, belongs to the group of hydrated minerals.

Although it crystallizes monoclinically, it must be noted that the crystals are very rare way of occurrence of this mineral. Vermiculite occurs in terms of surface weathering of mica (biotite) and transition into chloride.

It may also contain variable amounts of calcium and a small amount of alkali metals. Recently, vermiculites with significant content of sodium, nickel and copper, have been discovered [2].

Figure 1. Vermiculite as mineral.

Color of vermiculite is grim to nankin, rarely darkly green or brown/yellow. It is transparent to translucent mineral, characterized by vitreous luster.

At high temperatures, particularly when heated by flame (approx. 700^{0}C), it expands, significantly increasing its volume.

This procedure is known as exfoliation and it is usually achieved in purpose-designed commercial furnaces. By its physical - chemical characteristics, it is distinctive. Some of the characteristics are presented in the Table 1.

Vermiculites are similar to mica from which they are formed, but both of them are fundamentally different.

Table 1. Characteristics of vermiculite

General data	
Chemical formula	$(Mg_{0,5},Ca_{0,5},Na,K)_{0,7}(Mg,Fe,Al)_3$ $[(OH)_2\|(Al,Si)_2Si_2O_{10}] \cdot 4H_2O$
Molecular weight	504.19 g/mol
Crystal system	Monoclinic
Cleavage	Perfect for {001}
Mineral hardness Mohs scale	1.5 – 2
Sheen	
Scratch colour	Pale yellow
Relative density	2.3 – 2.7 g/cm³

Vermiculite almost does not exist in a pure form in the nature. In an octahedral part of the layer, ions of magnesium and aluminum are stored. This mineral has a high value of cation exchange capacity and expandable crystal lattice.

According to the certain properties, vermiculite is a typical member of the group of smectites, when it occurs in a fine disperse form as a clay mineral. However, it also appears as macroclastically layered silicate. According to MacColme, vermiculite possess the mixed type of layer (2:1:1), which is present in the chlorite, or with additional layers of water molecules (Fig. 2).

It can be formed through sedimentation, too and in that case, it is present in different sedimentary formations, but also clay and soil.

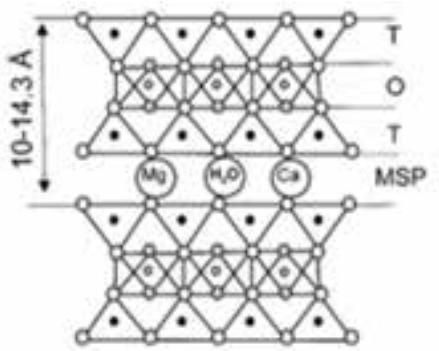

Figure 2. Structure of vermiculite $(MgFeAl)_3(SiAlO_5)_2 \cdot 4H_2O$)

It is existent in the Earth's crust, but in some parts of the land is distinguished more. In Table 2, distribution of vermiculite in various countries is presented.

The mentioned features are reason why vermiculite can be widely used.

Table 1. Vermiculite – production in tonnes per year (POTTER,1995).

	T	%
South Africa	221.748	46.4
USA	171.000	35.8
Russia	40.000	8.4
Japan	15.000	3.1
Brasil	16.000	3.3
Zimbabwe	9.000	1.9
Others	5.252	1.1
Total	478.000	100

Vermiculite has not been explored enough and it is expected to get information related to its characteristics and use in the future.

1. Features of Vermiculite

Physical features. Density of vermiculite is up to 2500 kg/m^3.

Hardness is measured by Mauss scale and it shows that vermiculite is relatively soft mineral (1.5-2). At the temperatures over 700°C, it expands significantly.

Depending on the origin, its volume can be enlarged 30 to 40 times.

Expansion occurs because the amount of the air inside the material increases. In that way, a very low coefficient of thermal conductivity is provided, which classifies it as a very good thermal insulators.

Coefficient of thermal conductivity varies in the range of 0.05-0.2 W/mK, depending on the bulk density achieved by the expansion (Fig. 3).

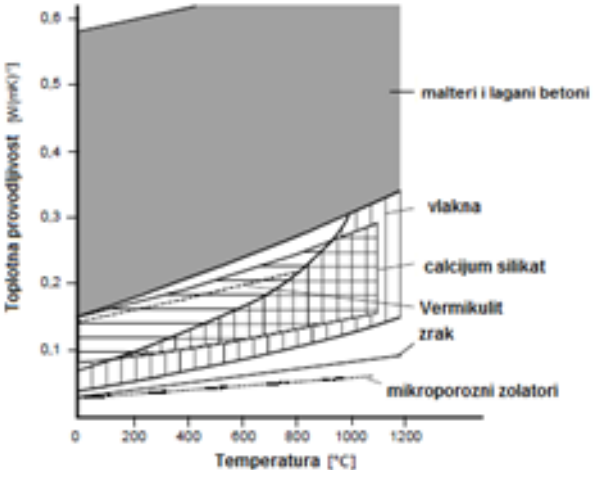

Figure 3. Thermal conductivity of some materials.

Microporosity, which results after expansion of vermiculite, gives the most convenient very small coefficients of thermal conductivity. That is also way of energy management and energy efficiency!

Expanded vermiculite characterized by micropores has very favorable absorption characteristics of sound frequency values.

Under the frequency of 1000Hz, the absorption coefficient is between 0.7 and 0.8, and that is why it can be considered as a very good protection related to the sounds of speaking.

It is not hygroscopic and its thermal resistance to the heat conductivity is stable and very high, not only at low, but also at very high temperatures.

As it is non-flammable, it can be expected only a phase change at very high temperatures (Fig. 4).

Melting point of vermiculite is 1350 ^0C, and the beginning of the sintering starts at 1280 ^0C.

Chemical features. Naturally occurring vermiculite is chemically stable, with pH value as distilled water, that is 7.0 . It shows neutral reaction. Therefore, it can not be classified as a base or as acid. It is inert to organic solvents and insoluble in water. It can not be decomposed, but also it is without smell and irritating properties.

It has good absorption properties in the gas and liquid environments. Absorption is of physical character.

Chemical content is the following:

- SiO_2 38.0-49.0%
- MgO 20.0-23.5%
- Al_2O_3 12.0-16.5%
- Fe_2O_3 5.4-9.3%
- FeO 0-1.2%
- K_2O_5 7,9%
- Na2O 0.8%
- CaO 1.5%
- TiO2 1.5%
- Cr_2O_3 0-0.5
- MnO 0.1-0.3%
- Cl 0-0.5%
- CO_2 0-0.6%
- S 0-0.2%
- H_2O 1.2-1.5%

Figure 4. Example of extremely low heat conductivity.

During heating, there are no dangerous pollutants emitted. Further, vermiculite collects impurities in the gas and liquid substances. Vermiculite is a sterile, non-toxic, durable, resistant to oxidation, does not lead to the formation of fungi and pests.

Thanks to the mentioned characteristics, vermiculite is used for different purposes (Fig. 5).

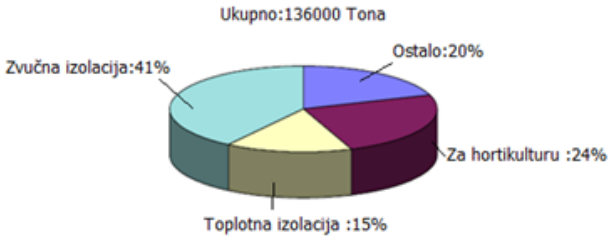

Figure 5. Example of vermiculite use in Western Europe 1999 (Eliot, 2000).

2. Use of Vermiculite.

2. 1. Vermiculite boards for fire protection and thermal insulation:

- Creation of fire and thermal insulation units of industrial zones (vermiculite panels)
- Industrial fire walls (plates) with a very high fire resistance time t = 2.5 h 1300^oC (production of fire doors and partitions)
- Fireproof pastes, coatings of metal structures
- Brake pads filled with vermiculite

- Completing the cast steel molds
- Ceramic vermiculite panel for insulation of profitable parts castings
- In places where it is necessary to withstand 1300 ^{o}C
- Lining of furnaces, doors and other parts of boilers and furnaces.

Vermiculite plates are made from pure vermiculite, and when heated, do not emit harmful and toxic substances.

The plates withstand temperatures of (-260 to 1350) °C, and are very practical for use.

Vermiculite boards have multiple roles:

- fire protection, thermal insulation, sound insulation and as decorative elements, but also
- for stoves and fireplaces (Fig. 6).

Figure 6. Vermiculite as insulation material in stoves and fireplaces.

Thermal insulation of fireplaces, stoves and boilers is the most important step in their safe use. For this purpose, various materials are used, but vermiculite plates are recommended as the most reliable.

Characteristics of such boards are:

- plate density.....650-900 kg/m^3
- maximum resistance to bending.....1.0 mPa
- maximum strength pressure..... 1.2 mPa
- maximum thermal conductivity .....0.18 w/mK
- sound conductivity coefficient.....0.45 (f=500gC)
- **Better combustion.** Vermiculite plates are characterized by significantly lower heat capacity of fireclay. The heat remains in the combustion chamber and does not withdraw from the process of combustion. Higher temperature in the combustion chamber significantly enhances the value of heat transfer. The formation of soot and tar is less and glass fireplaces remain cleaner.
- **Visual effect.** Light beige form surface of the vermiculite plate is uniform and smooth, with no discoloration at the surface. Edges are cut or processed, and never crumbled. Cover of these panels improves the look of the fireplace and achieved very good thermal radiation of space is achieved.

2.2. Agrivermiculite

The main raw material of vermiculite is mined in open pits and it is subjected to thermal treatment at approximately 1000ºC. In doing so, the material is autoclavable, i.e.. becomes aseptic. Due to the porous structure of vermiculite, this mineral is very suitable as a means for the retention of water.

Mixed with the garden soil, land becomes loose, while airflow is improved. The used binders contain phosphate and silicon dioxide as well as potash. These are valuable nutrients for plants. Phosphates are needed for the growth of plants and in particular for the formation of the root, while potash facilitates growth of a flower and fruit (Fig. 7).

Figure 7. Vermiculite as fertilizer.

Therefore, it is recommended that the remains should not be thrown away or deposited, but to be used as an aid for processing the flower garden or land. For this purpose, it is enough to just chop material into approximately 5 mm granules and mix with soil. The best results are achieved with the addition of (5-10) volume %.

Agrivermiculite is a 100% natural product, sterile, free from pathogenic bacteria, seeds, insects and has excellent water absorption.

Vermiculite is a good addition to substrates, and it serves to cover the land after sowing as a substrate for growing hydro plants, for the transmission of microorganisms, increases the capacity of the air and water when the plant needs. It allows the plants easier access to potassium, calcium and magnesium. It is resistent to the attack of rodents and insects and will not rot as stable.

2.3. Thermal insulation materials in civil engineering on the basis of vermiculite

2.3.1. Thermal insulating concrete

Vermiculite is used for thermal and sound insulation of floors, roofs and attics (Fig. 8).

Figure 8. Floors thermal insulation.

By installing insulating concrete based on vermiculite, space quickly reaches the desired temperature and maintains it. It can be used as a dry fraction and for the thermal insulation of floors (Fig. 9).

Figure 9. Example of use of dry vermiculite.

2.3. 2. Thermal insulation mortar

Vermiculite is a special, unique thermal and sound insulator for interior and exterior insulation of walls. By application of these insulating materials, thermal insulation with unlimited shelf life is obtained. While other insulation materials after 10-12 years loose their properties, this plaster becomes even more stronger and better thermal insulator.

2.3.3. Insulating plasters

The plasters contain expanded perlite, and so it gives a certain degree of thermal insulation (Fig. 10).

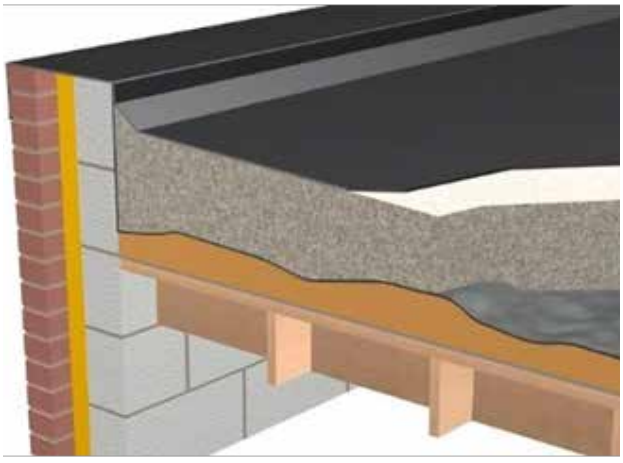

Figure 10. Vermiculite as plaster.

3. Conclusion

The nature offers the materials and regulations, and the inventiveness of a researcher gives possibilities of utilization.

The generated heat, if it is necessary to keep from scattering, is a feature that characterizes vermiculite as an insulating material for use on low and high temperatures.

Mechanical properties of vermiculite dominate among the other heat insulators. Inflammability of vermiculite secures its use even in very difficult places such as vessels.

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DOPRINOS VERMIKULITA UPRAVLJANJU ENERGIJOM U GRAĐEVINARSTVU

Sažetak

Komunikacija sa prirodom i htjenje da se iz ponuđenog upotrijebi materiajl koji ima povoljnije karakteristike od saznatih, niklo je upotrebljavanjem vermikulita. Otkriven u prirodi kao sirovina i pružio je široki spektar fizikalnih veličina za upotrebu u građevinarstvu. Dominatna karakteristika ovog materijala je toplotna izolacija i na visokim i na niskim temperaturama.Rad ima za cilj da da pregledno svojstva vermikulita i njegovu upotrebu.

Ključne riječi*: vermikulit, temperatura, građevina.*

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