SUSTAINABLE DEVELOPMENT THROUGH THE USE OF INNOVATIVE, HIGH PERFORMANCE, "GREEN" CONSTRUCTION MATERIALS

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Abstract. The goal of this paper is to analyse the defining characteristics of today's construction materials and focus on an innovative, heat-insulating material with a cellular structure and closed pores, obtained from basalt powder. It also has a completely non-polluting production technology, an abundant raw material and is called "Basalt foam". It is anticipated that "Basalt foam" will have superior characteristics compared to the materials currently used both in terms of overall performance and imbeded energy. Analyzing the properties of the basalt rock and the characteristics of other ceramics foams, it is anticipated that the new material will have the following characteristics: • Low density (< 600 kg/m³); • Resistance to chemical agents, • High hardness: 5-7 Mohs; • Temperature for use max. 800 °C; (the glass foam has around 400 °C) • Thermal factor (thermal conductivity): < 0.07 W/mk (BCA has around 0.1 W/mk); • compression resistance: > 25 N/mm² (the brick has 20 – 40 N/mm²). Having a very good compression resistance, better than that of ceramic blocks and at the same time better insulating properties, this new material could be used as a viable replacement. Regarding the impact on the environment, this material can be fully recycled through a simple technology: grinding at appropriate granulation and reintroducing it in the manufacturing process, thus completing its "green" characteristics.

Keywords: sustainability, basalt, construction materials, recycle, embedded energy

INTRODUCTION

Due to ever more visible climate changes during the last century, as well as the increased attention given to continuous and sustainable development, the process of replacing currently used materials and raw resources, in different areas of activity, has dramatically accelerated on a national and international level.

The construction materials industry, through its dynamics, has generated a growing expansion in the use of polymeric thermoplastic materials, polymer diversity, introducing new polymer and composite materials with better performing and more efficient characteristics, in general low density materials with high mechanical resistance. The use of an unconventional, abundant, pollution free raw material is considered to be the solution for today's ever more demanding construction industry.

Basalt is a volcanic rock, widely spread in nature, generally having an ashy color towards black with different nuances, created by oxides in different proportions. It is exploited in surface quarries through simple methods (and therefore reduced costs) that do not generate pollution. The general chemical composition is presented in Table 1, the variations of the components being determined by geological conditions specific to the area where the basalt has been formed.
Table 1

<table>
<thead>
<tr>
<th></th>
<th>SiO₂</th>
<th>TiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>FeO</th>
<th>MnO</th>
<th>MgO</th>
<th>CaO</th>
<th>Na₂O</th>
<th>P₂O₅</th>
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<tr>
<td>43,5 - 47</td>
<td>2 - 3,5</td>
<td>12 - 13</td>
<td>4 - 7</td>
<td>5 - 8</td>
<td>0,2 - 0,3</td>
<td>8 - 11</td>
<td>10 - 12</td>
<td>1 - 2</td>
<td>0,5 - 1</td>
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Physical-chemical properties: (low density: 2,9 g/cm³, resistance to temperature, thermal shock, chemical agents, not affected by moisture and water, does not favor the development of microorganisms of any kind, with no impact on people’s health), mechanical (high hardness, 5-7 Mohs, good mechanical resistance) and technological (can be processed through moulding, sintering and metal cutting) convert basalt from an ordinary rock used especially to manufacture blocks for street paving into a raw material for numerous superior utilisations. By melting, basalt may be cast into metallic moulds thus producing pipes, sleeves, vessels, coating for cement industry. They are three times lighter and twice cheaper and more resistant than the ones made of cast-iron or steel. In any raw material a significant factor is the assessment of its availability and the intricacy of the extraction and processing process.

**MATERIAL AND METHODS**

**Material.** The above-mentioned qualities brought basalt in scientists' attention and they deem it to be a material for the future with great perspective. There are worldwide level researches for utilisation of basalt in niche domains such as aeronautics, conquest of space and nuclear power plants.

Within this context, of avant-garde materials and technologies corroborated with basalt features, came up the idea of using it to produce closed cell basalt foam upon the pattern of metallic foams. Metallic foams, (fig.1) are materials that are obtained through foaming a metal (or any material that can be melted) in melted state with the use of a foaming agent.

![Metallic foam](image-url)

Briefly, the procedure of producing foams develops as follows: the basic material, under powdery shape, is mixed with the foaming agent forming a so called forerunner for foaming. Next it is heated, the foaming agent decomposes and releases gas that penetrates the mass of the basic material as bubbles. The cooling phase is next, the gas bubbles being
integrated in the material. It results in a porous stiff structure that is very light (it can float on water). They have good properties of shock resistance, absorbing impact energy, which is due just to this sponge-like structure. Due to the fact they incorporate air, they are good thermal and phonic insulators.

Methods. Similarly to the production of metal foams, the production of ceramic foams has been conceived within which glass foams stand for a distinct class. There are two different obtaining technologeies for producing a ceramic foam of basaltic nature: foaming under the melting temperature, and foaming after melting.

A. Foaming under the melting temperature (the dipping is followed by an increase in volume);

In this sense the following will be done: The rock extracted from the quarry will be crushed and grinded at a granulation of a few tenth microns. Following a study, one of the following foaming agents will be chosen (calcium carbonate, coal, silicon carbide, etc.), in powdery shape and will be mixed in cold conditions, in a certain proportion with the basalt powder, according to the degree of foaming that is desired. In this phase the behavior of different foaming agents will be determined, as well as the optimum proportion, choosing the one that has the lowest influence on the people and the environment.

In this manner the forerunner for foaming will be realized. It will be compacted through pressuring, extrusion and roller burnishing, after it had been laid in a closed or opened matrix and heated until a temperature whose optimum values can be determined, considering the used foaming and the sintering temperature of the basic material. This temperature is usually around 1200°C. The necessary time for maintaining this temperature will be determined in order to finalize the decomposition reaction of the foaming agent and to allow the resulted gas enough time to integrate in the basalt mass. The cooling phase follows, at a faster rate at first in order to interrupt the ascension of the gas bubbles with the purpose of preventing the formation of channels and obtaining a closed cells foam and then at a slower rate until around the temperature of 600 °C, the limit at which the cooling will be done at room temperature. This technology is presented in fig. 2.

![Fig. 2 Foaming under the melting temperature](image-url)
In a first phase the cold mechanical mixing of the foaming agent and the basic material powders is realized. This is followed by a compaction of the mixture which can be done by squeezing, extrusion or rolling. The purpose of this job is to get a compact mass that should not allow for an “escape” of the released gas out of the foaming agent during heating. The so compacted material is put into a closed or open die and the foaming treatment goes further on. In case that the die is closed an equivalence shall be done of volumes under the circumstances of having gotten a certain degree of foaming. The degree of foaming, and therefore the porosity of the resulted material, is determined by a series of factors such as: the degree of the basalt granules and of the foaming agent and its type, quantity of foam, degree of compacting the foaming precursor, heating temperature. The increase in volume may be up to 5 times the initial volume while the foaming degree may be up to 80 %.

B. Foaming after Melting (melting followed by an increase in volume). The basic material is melted a the foaming agent is added in the molten mass while continuously stirring.

![Fig. 3 Obtaining of foams in melting state](image)

*In the first phase, 3a, in the molten material a melt fluidiser is introduced; in phase 3b the foaming agent is entered under continuous stirring; in phase 3c in isothermal conditions foaming commences; in phase 3d cooling is done at a certain speed.*

This method is used to produce metallic foams prevailingly if compared with the first method that is especially used in producing ceramic foams.

**RESULT AND DISCUSSION**

In general, it can be stated that man spends 90 % of a day time inside closed space. This, indoor spaces have to meet a minimum set of conditions in order to avoid negative consequences on human health. The buildup of a toxic atmosphere in an indoor environment starts mainly from the use of synthetic materials that act as air exchange barriers with well known consequences: dampness, mildew, occurrence of microorganisms, etc. Currently existing solutions consist in plating indoor or outdoor walls with materials pertaining to polystyrene family, mattresses made of mineral wool or autoclaved cell concrete (BCA).

**Polystyrene** is a waterproof material obtained from styrene grains that by expansion or extrusion generate air micro-spheres inside the core material. The volume of such spheres varies depending on temperature and generates expansions or shrinkage of material leading to an alteration in dimensions, loss of thermally insulating properties and
occurrence of cracks in the grouts of thermal coat with time elapsing. On the other hand styrene is obtained from dehydrogenation of ethyl-benzene substance framed within directive 65/548/CEE as being hazardous for health or environment. Temperature-resistance is relatively low, approx 70°C. Once ignited it releases a choking toxic smoke. Polystyrene is an oilfield product - a non-renewable resource, thus the impact on human health and the environment is a serious issue.

**Mineral wool** is a material that has good insulating properties, it has however the great disadvantage of being **water sensitive**: when it comes in contact with water it behaves sponge-like, induces undesired phenomena and may stand for favourable environment for micro-organisms development. It lacks rigidity, it is necessary to have supplementary structure for its fastening. It is known that small and light particles of wool spread in the air during use and handling and these particles, once inhaled, are particularly harmful to lungs. The influence is contentious on human health of the substances used as binding and hydrophobic agent in the manufacturing process of mineral wool.

**Autoclaved cellular concrete, BCA**, is composed of a mixture of slurry (very fine granules of sand, having 0.009 mm in diameter, high content of SiO₂) and lime. Swelling (formation of bubbles giving that cellular appearance) is accomplished by adding in this mix (fresh slurry, water and lime) a certain amount of aluminium powder. By the chemical reaction between aluminium and lime onto the thermal support generated by the “extinction”of lime in water hydrogen release takes place. At microscopic level each granule of aluminium powder releases a very small amount of hydrogen that determines the occurrence of a “bubble” in the material. Hydrogen migrates to the surface of the swollen material. Migration towards surface generates between the hollows (bubbles) of material small channels (capillary cracks) with permanent character. Such capillaries have negative impact on the autoclaved cell concrete impermeability as well as on thermal conductivity coefficient thus forming an open space foam. The autoclaved cell concrete, due to lime presence as raw material is by excellence hygroscopic, naturally absorbing and retaining water. The presence in the autoclaved cell concrete of these capillaries increases water absorption up to a level of about 45-50%. A block of autoclaved cell concrete laid on a water film is capable to absorb it quickly just due to these capillaries and of the natural hygroscopic feature of lime. The autoclaved cell concrete cannot cure under natural conditions of temperature and pressure “in the cold” as it does not contain any binder (cement). In absence of cement, curing of autoclaved cell concrete (generation of its resistance matrix) may only be achieved under certain conditions of temperature (200°C) and pressure (12 atmospheres) following a pre-heating procedure, isothermal treatment and then cooling during 16 hour time. This thermal treatment takes place by continuous pumping of saturated steam into autoclaves (pressurized cylinders). The above outlined result in the fact that the technology of producing autoclaved cell concrete requires complex equipments and is laborious. On the other hand hygroscopic feature becomes an actual problem.

The innovative degree of the paper is that it tackles the up to date, less explored field of foaming materials and the degree of originality consists in the expansion of the research area over a non conventional material for such aplications - basalt. The consequence of a world policy for conservation of natural resources and the environment, made the whole world develop, at the moment, research programs with objectives that consist of producing new materials with superior characteristics, low production costs, minimum energy consumptions and impact on the people and the environment. By finalizing this research a new material will be obtained in an important field of activity,
relatively new, such as the field of foaming materials. The technical solution generated by this project facilitates the realisation of a national and world premiere in the field of these types of materials by realizing a new material with remarkable proprieties. The products obtained from implementing the new technology will have a major impact on the national economy due to the specific characteristics presented. The foaming materials represent a relatively new field of material sciences. These are materials are characterized through a reduced weight and a high absorption capacity of energy on impact. The originality of the proposed project consists in the expansion of the research regarding foams towards a non conventional material that has remarkable mechanical, thermal, chemical proprieties, that can be recycled 100% - basalt.

CONCLUSION

The theme of the project is almost limitless, as it can be continued through research activities, in view of diversifying the characteristics of basalt foam through combining it with different elements. It is estimated that there is the possibility of obtaining basalt foams with controlled proprieties. On the other hand research activities can be developed in order to realize structures from basalt foam, plated on one or several sides with metallic or non-metallic materials. By continuing the research of enlarging the characteristics of basalt foam, new opportunities are discovered for introducing it in the economical circuit of a material that is little researched such as basalt, a material with proprieties that situate it among the materials of the future. When finalizing the project, the following results are expected:

- Designing and realizing the technology needed to obtain the basalt foam
- Realizing testing lots from basalt foam with the following characteristics:
  - Reduced density ( < 600 kg/m³);
  - Resistance to chemical agents,
  - Increased hardness: 5-7 Mohs;
  - Temperature for use max. 800 ºC;
  - Thermal transfer factor (thermal conductivity): < 0.07 W/m² K
  - Resistance to compression: > 25 N/mm².

Basalt foam is a new product with adequate proprieties for its use in the field of constructions materials, as a thermal sound insulated material. Presenting a very good compression-resistance and very small thermal conductivity compared to that of bricks its utilisation could be expanded even as replacement in some areas of the mentioned material.

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