# HEAT INSULATION MATERIALS OF POROUS CERAMICS, USING PLANT FILLER

**Aleksandrs Korjakins*, Liga Upeniece**, Diana Bajare*****
Riga Technical University, Chair of building materials and wares
E-mail: *aleks @latnet.lv, **liga.upeniece @rtu.lv, ***Diana.bajare@rtu.lv

**ABSTRACT**

*Constantly growing energy prices and concerns about energy supplies in the future, as well as the requirements for regulating gas emissions that produce the greenhouse effect, directs us to search and realize activities allowing the reduction of energy consumption and to reach a higher energy efficiency level.*

*Heat insulation is one such procedure for energy efficiency improvement, by reducing energy consumption in the construction field. New ecological heat insulation materials, which are made from local raw materials, can serve as an alternative for heat insulation materials already existing in the market, using clay as a binder in its production, but hemp and flax and shove are used as burnable fillers, thus obtaining material with the necessary heat and acoustic insulation qualities, as well as fire-resistance and chemical stability in an aggressive environment and providing to the development of industries in Latvia.*

*In order to reduce thermal conductivity of ceramic materials, it is necessary to increase its porosity which can be realized by the usage of gas forming additives, for example, calcite and magnesite, but the second variant is to add burned out additives thus forming porous ceramics. Within this research, agricultural waste is used for the production of porous ceramics, which have not been sufficiently used for the production of construction materials with high added value in Latvia.*

*The aim of the research is to develop porous ceramic materials, using plant burnable filler with certain properties due to their resistance and density, based on world achievements, as well as the experimental investigations. In the present paper, the evaluation of practically obtaining material which could be used for heat insulation of buildings has been done.*

*The porous ceramic materials with burnable plant filler are being developed in the present investigation. The dependences, the mechanical and physical properties of porous ceramics are defined in accordance with the amount of filler, glass and the amount and size of pores, have been performed.*

**Key words:** porous ceramics, ecological materials, insulation materials, agricultural waste, plant filler

## INTRODUCTION

In the result of energy demand growth, power dependence from countries which supply primary power resources, is also increasing both in Latvia and in other European countries. Besides the growth of power dependence, worries about an unstoppable increase of energy costs in the future also extend, as well as an increase of gas emissions creating the greenhouse effect. This leads us to the realization of events that would allow us to reach an adequate level of energy efficiency, as well as promote the decrease of energy resources consumption in all sections of economic activities, including the construction branch where a greater part of energy resources are consumed for creating heat supply.

Although the speed of construction in the Baltic States has significantly slowed down during recent years, the interest in increasing the energy efficiency for building refurbishment in the public and private sector is growing.

Besides the above mentioned, society's interest about environmental and health are also issues. Understanding the importance of the quality of their surroundings, people are beginning to pay more attention towards their consumption patterns and the related potential impacts on the environment and their health, with concerns for the wellbeing of the current as well as future generations. (Indriksone et al., 2011)

Considering both of the above mentioned modern tendencies, selection of "green" or ecological materials in the building of new houses and the building renovation process, serves as a solution for energy resource reduction not being harmful to the human health.

Municipalities and other public bodies in the Baltic States also increasingly often consider including environmental criteria or requirements for construction materials in public procurements.

Responding to this interest, producers and retailers of materials offer a wide selection of different materials to try and satisfy this demand.

Thus "*ecological*", "*environmentally friendly*", "*sustainable*", „*green*" - are popular terms used frequently nowadays by producers/retailers of materials to advertise their products. (Indriksone et al., 2011).

Using green building materials and products promotes conservation of dwindling nonrenewable resources internationally. In addition, integrating green building materials into building projects can help to reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials. All the materials used for construction of buildings must not harm the environment, pollute air or water, or cause damage to the earth, its inhabitants and its ecosystems during the manufacturing process, and also during use or disposal after their end of life. Materials should be non-toxic and contribute to good indoor air quality.

Using environmentally friendly building materials is the best way to build an eco-friendly building.

The following criteria can be used to identify green materials:

a) Local availability of materials.
b) Embodied energy of materials.
c) Percentage of recycled/waste materials used.
d) Rapidly renewable materials.
e) Contribution in the Energy Efficiency of buildings.
f) Recyclability of materials.
g) Durability.
h) Environmental Impact (Tudora, 2011) .

Porous ceramics can be uses as one such ecological materials produced from local raw materials, where macro-pores are obtained using plant scorched fillers, thus the clay, hemp and flax shoves which are agricultural waste-products are mainly used for the production of material.

Flax is a versatile crop that supplies both fiber and seed for important industrial applications (Domier 1997). Flax shive is the woody, lignified inner tissues of the stem and is a by-product of fiber production. Flax fiber constitutes about 25 – 30% of the stem. Therefore, a large amount of shive is available after fiber processing. (Marshall et al., 2007). With estimates of 1 million tons of flax straw available from linseed production (Dormier, 1997) about 700.000 tons of shive could be available for a variety of uses. (Marshall et al., 2007). Traditionally flax shive is considered a waste product and as such has a limited value or is used in low-value applications such as animal bedding and burning for thermal energy (Sankari, 2000, Sharma, 1992)

Hemp is a fast growing, multi-purpose, annual herbaceous plant and almost all parts of this plant are used for processing different products. Up to now the most commonly produced and used parts are the fibers and seeds, but shoves in most cases are considered as by-product and burned or used as animal bedding, mulch, compost or a chemical absorbent.

However, in recent years, investigations of hemp shoves showed that the usage could be much wider and that they could be used in new, more high-quality products with higher added value.

Nowadays hemp shoves are used in a wide range of applications such as paper, packaging, plastics and polymers, building materials (insulation, fiber board, hemp concrete) and construction products etc., which create a more viable market with new and high-quality products from hemp shives.(Stikute et al., 2012)

Besides hemp and flax shoves, wood chips, chaff, straw, wheat bran, bark and others (Kumaoka et al., 2000) also can be used as scorched fillers, in order to produce porous ceramics. Kumaoka, 2000).

Porous ceramics are now expected to be used for a wide variety of industrial applications from filtration, absorption, catalysts and catalyst supports to lightweight structural components. (Ohji and Fukushima, 2012). Therefore their usage is natural also in the production of building materials, which has been researched in Latvia and the whole world, but has not been sufficiently and highly evaluated where the determinant role of the sphere of porous ceramics is directly related to its qualities.

The properties of porous ceramics can be tailored for specific environmental application by controlling the composition and microstructure of the porous ceramic. Changes in open and closed porosity, pore size distribution and pore morphology can have a major effect on the material's properties. All of these microstructural features are in turn highly influenced by the processing route used for the production of the porous material. For the mechanical properties, porous ceramics are determined by their structure parameters, such as porosity, pore size and pore structure (Hong et al., 2012, Gough et al., 2004). Additionally,the microstructure of the solid phase related to neck growth and solid phase continuity strongly affect the mechanical properties. (Studart et al., 2006, Koh et al., 2006, Hong et al., 2012).

By the production of porous ceramics within the scope of this research, its qualities are regulated by varying the amount and type of the material used which has an impact on the structure of this ceramics. Planned pores are obtained in an irregular, elongated form because of the usage of hemp and flax shoves. Wood chips are historically the most popular and widely used burn-out filler.

Usage of woodchip as the burnable filler in the production of porous ceramic has been widely researched in Latvia, obtaining samples with a strength of 10 to 12 MPa in a density up to 1.5 g/cm3, by using 25% woodchip and burning the clay at a 950 – 960 °C temperature, (Sedmale et al., 2009), as well as elsewhere in the world, e.g., studies in order to assess the impact of the porous ceramic material porosity were performed at the Federal University of Kazan.

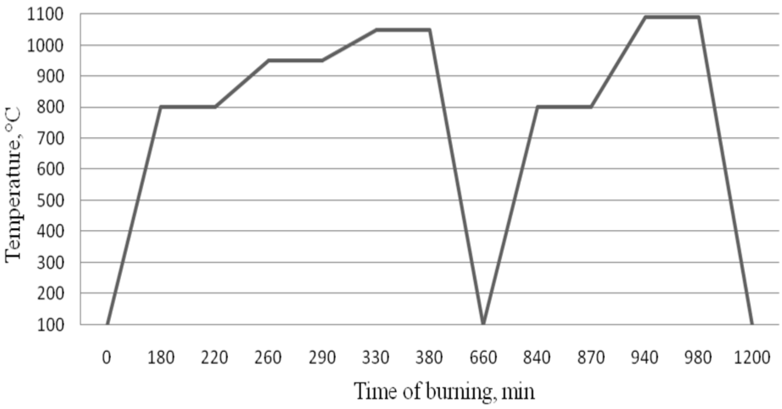


**Figure 1a.** The regime of sample burning 2 times

During this study, multiple samples were obtained for the purpose of pore formation, additives such as woodchips and cottonstone were used.
in series, obtaining samples that were up to 17 MPa strong upon compression (Salahov A. et al., 2011)
Production of a porous ceramic material with specific features of strength and density, achieving a material that could be used to insulate buildings is the main aim of this research.

## MATERIALS AND METHODS

During the stage of the sample preparation process, ceramic slurry was made, Lode clay with a humidity level of 24 % as well as ground glass and organic filler – hemp and flax shoves were used.

By preparing samples using plant fillers, such as burnable fillers, wood chips and hemp/ flaxen shoves from Kraslava region Piedruja parish, which were sieved beforehand in order to deselect admixtures of large scale, like flinders, shingles, chunk wood, as well as admixtures of organic and mineral origin, like soil and sand were used. The size of shoves used in the survey did not exceed 5 mm. Characteristics of shoves:

- Poured volume density range from 50 kg/m$^3$ to 80 kg/m$^3$;
- Admixture of long grain in shove mass does not exceed 8 % of the volume unit;
- Colour: Greyish green for hemp shoves, greyish yellow for flax shoves;
- With humidity level not exceeding 12 % of mass;
- There are no signs of mold on the shove surface or signs of biological degradation of shove mass.

In the beginning Lode cay was dried in a drying oven, and ground in RETSCH PM 400 mill for 30 minutes in dry condition.
When the all required components – clay, glass and hemp and flax shoves are prepared, they are dosed in the required amount and mixed in dry condition, gradually adding water until a sufficiently homogenous mixture for sample making is obtained.

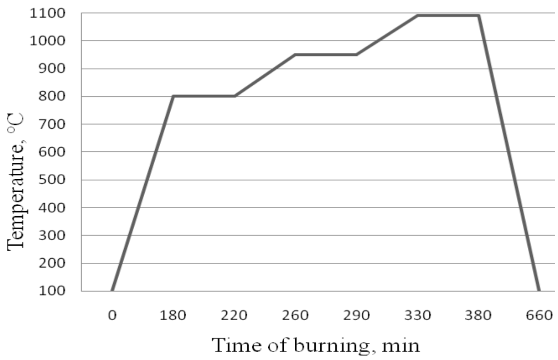


**Figure 1b.** The regime of sample burning 1 time

Proportion of dry clay, glass, burnable filler and water used in the investigations varied, changing the amount of glass, and amount of shoves in order to obtain larger amount of shoves in the mixture – resulting in samples with greater porosity.

Components of dry mixture are dosed according to mass, where dry, milled clay is 50 – 65 %, glass 15 – 25 %, but the burnable filler 20 – 25 %. When the dry mixture has been mixed, water is added in the amount of 35-45% from the mass of mixture.
The volume of added water shall be chosen so that it provides both the viscosity of the required mixture and strength of the obtained samples as well as probably decreasing shrinkage and energy consumption for the sample drying.
Squared samples with the side length of 100x100mm and height of 30 – 35 mm were made, which were dried without additional loading under pressure for 8 hours at a temperature of 60 °C.
By the analysis of the information available in the literature and foreign researches, it was selected that samples were burned gradually one or two times at a temperature of up to 1090 °C, for 11 – 20 hours in total.
The regime of sample burning one time is presented in Figure 1b. The regime of sample burning two times is presented in Figure 1a.
The regime of sample drying as well as burning was chosen so that time and energy resources required

for material development are minimal, but sufficient enough to provide obtaining the of material with certain properties in the end result.

Verification of samples developed using plant fillers was realized by ZWICK Z100 perpendicular to the formation direction of the samples, thus providing the establishment of a mean strength in the cross section, reducing the influence of certain weakening, which could have been formed while the samples were removed from the moulds and a non-homogenous structural density in the direction of cross section formation.

## RESULTS AND DISCUSSION

The results of the research reflect on the existing and common raw material in Latvia – clay and its broad application opportunities for building material production by regulating its mechanical and physical properties with the addition of burnable plant fillers and ground glass.

Used raw materials provide acquisition of necessary properties of porous ceramics where clay serves as a cohesive substance, but glass provides higher strength and better cohesion between mixture and plant fillers within the sample formation process.

The samples with the amount of shoves 5-30% were made. The main aim of the experiment was to improve compressive strength parameters, which resulted in higher density. Maximum and minimum values of density of samples depending on the amount of used shoves are summarized in Figure 2.

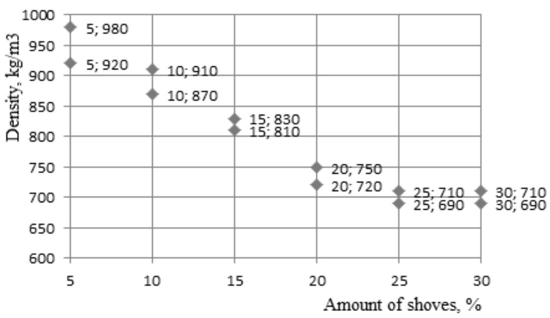


**Figure 2.** Volume density of samples depending on the amount of used hemp/flax shoves

Density of samples can be easily regulated, by changing the amount of fillers used. But increasing the quantity of shoves, the amount of water needed for the mixture, in order to obtain a plastic mass also increases, and in the result the time and contraction necessary for drying increases but reduces compressive strength.

Samples, in which the quantity of shoves reaches 25% - 30% and more, have low compressive strength, and a respective amount of ground glass must be chosen in further researches, in order to increase it. Compressive strength also can be increased by double burning of the samples, choosing a higher temperature and shorter period i the second time. This topic will be studied more widely in further researches.

Weight of samples decreased per 32.1% to 38.7%, after burning. Size of samples, comparing it before and after burning, decreased per 8-12% per edge length and per 2-6% per thickness.

By comparing sample compressive strength, higher strength was observed for the samples where amount of used glass filler reached 25-30%. The highest compressive strength was 2.28 MPa for samples with content 20% of hemp/flax shoves In comparison with previous researches, where compressive strength is 0.97MPa, using 15% of glass, it can be seen that a greater amount of glass provides higher compressive strength. By using 40% of grinded glass in previous research for making of samples, compressive strength was 3.95 MPa was obtained, but porosity of the samples was too low.

During the control of ceramic material, water-absorption varied from 25.8% to 29.3 %.

Using hemp and flax shoves as burnable filler, macropores (Fig.3.) and micropores, shown in figure 4, can be seen within the structure of porous ceramics, where macropores have an elongated irregular form and the measure of pores in obtained the plant matrix samples is 0.033 – 1.7 mm.

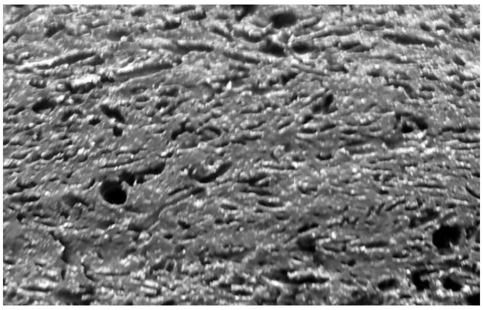

**Figure 3.** Macropores of porous ceramics

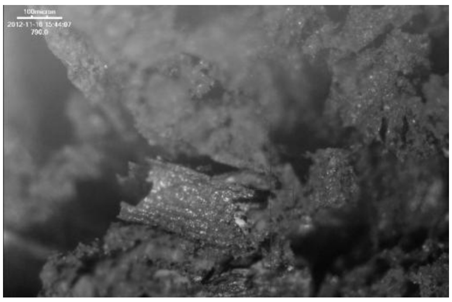

**Figure 4.** Micrograph of pores for samples which are made by plant fillers burning method

In comparison with the other methods for obtaining porous ceramics, this method is technologically the simplest one and has been researched more widely, allowing samples to be produced with definite porosity, but not reaching the regular form of pores.

The greater advantage is the availability and wide distribution of these raw materials.

Hemp and flax shoves used in this research which are burned during the process of burn, allow porous ceramics to be obtained with a heterogeneous porous structure, which is linked to the complex additive distribution and orientation in the volume of the sample.

By comparing this method with the other methods for obtaining porous ceramics, we can see that this method minimally limits the sizes and dimensions of obtainable samples, thus allowing production of outsized blocks, but the variation of form is not so wide as in the case when scorched filler polymer sponge is used.

In further studies of this research it is important to study and compare the impact of the sample burning regime and number of burning times and their strength, as well as to reach a higher level of sample strength without a significant increase of their volume-mass.

Usage of hemp and flax shoves in the production of porous ceramics allows us not only to produce the material itself, but also to utilize agricultural waste, which serves as the reason why hemp and/ or flax fiber is used in this research, which is a valuable raw material for the production of materials with high added value in the heat insulation plate manufacturing, the textile industry and other branches.

In line with the conducted research, the addition of ground glass improves the strength of the obtained samples. Moreover, it reduces the temperature necessary for burning as well as the amount of clay required, thus enabling to save on natural resources through an effective recycle of the glass waste.

## CONCLUSIONS

Within this research samples of porous ceramics were made using clay as a matrix and scorched hemp and flax shoves in the process of pore creation.

Weight of ceramic samples decreased per 32.1% to 38.7% after burning process. Shrinkage of samples was in the range per 2-6% per thickness to 8-12% per edge length that may be explained by influence of orientation plant fillers in the samples after mixing process.

The highest compressive strength was 2.28 MPa for samples with content 20% of hemp/flax shoves and 25-30% ground glass fillers.

Water-absorption of the porous ceramic samples varies from 25.8% to 29.3 %.

Using hemp and flax shoves as burnable filler, created micropores and macropores have elongate, irregular form with sizes in the range 0.033 – 1.7 mm

Obtained samples of porous ceramics are ecologic, produced from local raw materials and waste, breathable, resistant against aggressive environment and durable.

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