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Obtaining Porous Ceramics Using Shredded Paper and Foamglass Pellets

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Obtaining Porous Ceramics Using Shredded Paper and Foamglass Pellets

Aleksandrs Korjakins*, Liga Upeniece, Liga Tomase

Riga Technical University, Institute of Materials and Structures
Department of Building Materials and Products
Kalku Street 1, LV-1658, Riga, Latvia

*Corresponding author: **aleksandrs.korjakins@rtu.lv**

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Within this research, carbonized clay, chamotte, as well as burn–out additives – widespread fillers (shredded paper and foamglass pellets) are used for the acquisition of porous ceramics, despite the fact that these fillers are not frequently used as burnable filler in traditional ceramics. The investigation of optimal mix content of raw materials, burning treatment was developed for obtaining improved mechanical properties of porous ceramics. The physical-mechanical properties of obtained ceramics were evaluated.

Proportion of dry clay, shredded paper, foamglass pellets, chamotte and water used in the investigations varied, changing the amount of fillers in order to obtain the samples with better mechanical properties.

Components of dry mixture for samples with shredded paper are dosed according to mass, where dry, milled clay was 63 – 69 %, shredded paper 2 – 12 %, water – 25%, but chamotte 0 – 4 %. When making porous ceramics using foamglass pellets as burnable filler, clay and water were used, where dry, milled clay was 57 – 69 %, water – 25 %, but foamglass pellets 6 – 18 %.

Following results were obtained for the samples with shredded paper used as a filler: shrinkage after the drying from 1.33 % up to 8.78 %, shrinkage after burning – 3.33-11.56%, density – 1256.64-1567.97 kg/m^3, water absorption – 9.23-16.70 % and compressive strength – 1.17-4.66 MPa.

While for samples with foamglass pellets used as a filler following results were obtained: shrinkage after the drying – 2.22 – 3.08%, shrinkage after burning – 5.44 – 6.11 %, density – 861.71 – 1178.34 kg/m^3, water absorption – 8.33 – 10.21 % and compressive strength – 1.15 – 1.94 MPa.

Porous ceramic materials obtained within this research are breathing; they are not only thermally stable materials, but also resistant to thermal impacts, corrosion and are easy in processing.

Obtained results of the research testify that these porous ceramics materials have great potential of application, but speaking about the material usage for load-bearing constructions, strength indicators must be improved by following researches using nano- additives, the fillers such as glass and fire clay, developing the technology of producing (mix contents, drying and burning processes) ceramics which improve compressive strength indicators of the sample.

The following investigation will be devoted to developing more effective material with relation density/stiffness by controlling thermal conductivity properties.

KEYWORDS: : ecological materials, insulation material, ceramics, production waste

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Introduction

Within last hundred years, ceramics as the material has changed a lot due to the modernization of traditional ceramics industry and implementation of new and unusual functions in modernized ceramics.

Nowadays ceramics is modern material which can be successfully used in numerous spheres – from materials of ceramics up to social life, construction and other traditional products of ceramics up to the present time miniature computers, television, cars, planes and spacecraft and other modern technique developments. Current general civilization progress is not conceivable without ceramics (Sedmale 2010).

Due to its unique featured, modernized ceramics can and could be used as replacement material instead of other usual materials in building sector and as the material of new possibilities for innovative technology systems.

In order to provide successful operation of those materials, ceramic constructions must be suitable for particular materials and production processes. From the point of perspective of ceramics materials, it is planned not only to replace traditional ceramics, but to develop completely new solutions from traditional materials. Ceramics materials are not used in construction very frequently, but in electric and thermal isolation because it has high resistance indicators and very low thermal expansion. On the contrary characteristics of ceramics materials are particularly stable because plastic deformations almost do not exist. Strength in a compression can be reached ten times more than in the bend and tension. In comparison with metals, ceramics materials are suitable for high temperatures because only particularly high temperatures can affect ceramics materials. Those materials offer equally perfect features for corrosion and wear resistance (Indriksone 2013).

Regardless of the modernization of ceramics and numerous changes, it is well known and used from ancient times and its raw material – clay is widely spread in the upper seams of Earth (Kurshs and Stinkule 1997).

Porous ceramics nowadays are successfully used in the filtration and has a high potential of usage also in the production of heat insulation materials thus obtaining the material which combine high resistance that can compete with other heat insulation and constructive materials.

Problem of house renovation is very actual in Latvia and other Eastern Europe countries, and it requires not only enormous investments but also evaluation of different benefits. Besides economically opportune heat insulation materials which are flammable, less respiratory and produced abroad, we can also place materials of porous ceramics which have been produced from local raw materials, are inflammable, do not mildew, rot, are respiratory and harmless for the environment and people living in a house.

Nowadays porous ceramic can be obtained in several ways: using contents of monofraction raw materials, foam formation method, using burn-out additive method and forming of pores in a chemical way.

Within this research, burn-out additive method is used. The basis of this method is mixing fire-resistant material with hard and burn-out organic substances.

Sawdust is traditionally burnable filler used for production of the porous ceramics. It is widely researched both in Latvia by obtaining samples with a strength of 10 MPa to 12 MPa in a density up to 1.5 g/cm^3, by using 25 % woodchip and burning the clay in a 950 – 960 °C temperature (Sedmale *et al.* 2009) as well as in leading Russian scientific centers, where samples were obtained that were up to 17 MPa strong upon compression (Salahov *et al.* 2011).

Comparatively low resistance at the high porosity can be mentioned as obstacle for the development of porous ceramics heat insulation, but application of nanotechnologies can be considered as solution thus forming ceramic solid matter nano-crystals (Salahov *et al.* 2008).

It is known that mechanical strength can be significantly improved when grain size is reduced to nanometer scale. Composites with nanograins have several advantages in that they possess improved properties (such as mechanical, electrical, thermal, ionic conducting, catalytic, and optical).

Besides, nanoscale ceramic powders offer the possibility of manufacturing dense ceramics at low sintering temperature (Khalil 2012).

Within the research widespread fillers – shredded paper and foamglass pellets, which are not frequently used as burnable filler in traditional ceramics, were used for the acquisition of porous ceramics.

Used materials

Carbonized clay with volume mass – 1600 kg/m^3 and humidity level of 24 % as well as ground chamotte were used for sample preparation, where the organic filler – shredded paper and non-organic foamglass pellets are used as burnable filler.

The chemical composition of clay is given in **Table 1**.

Table 1

Chemical composition of clay

Component	SiO_2	Al_2O_3	Fe^2O^3	MnO
Amount, %	49.5	13.04	5.14	0.071
Component	MgO	Na_2O	K_2O	P_2O_5
Amount, %	3.68	0.63	3.64	0.138
Component	TiO_2	CaO	Cr_2O_3	SO_3
Amount, %	0.757	8.69	0.008	0.05
Component	Other			
Amount, %	14.656			

The regular foamglass grain size used in present research was in the range 4-8 mm. The bulk density of these pellets is 150 kg/m^3 and volume density is 270 kg/m^3.

Paper is shredded in 7mm wide strips, grammage - 80g/m^2.

Proportion of dry clay, shredded paper, chamotte and water used in the investigations varied, changing the amount of shredded paper, and amount of chamotte in order to obtain the samples with better mechanical properties.

Components of dry mixture were dosed according to mass, where dry, milled clay was 63 – 69 %, shredded paper 2 – 12 %, water – 25%, but chamotte 0 – 4 %.

When making porous ceramics using foamglass pellets as burnable filler, clay and water were used. All the components were dosed according to mass, where dry, milled clay was 57 – 69 %, water – 25 %, but foamglass pellets 6 – 18 %. For greater visibility the composition of the samples is shown in **Table 2**.

Mould at the size 5x5 cm for sides was used for samples (6 samples of each composition) where foamglass pellets and shredded paper was utilized as burnable filler.

Table 2

Composition of the samples

Abbre-viation	Clay, %	Water, %	Shredded paper, %	Chamotte, %	Foamglass pellets, %
SP6	69	25	6		
SP2C4	69	25	2	4	
SP12	63	25	12		
FP6	69	25			6
FP9	66	25			9
FP12	63	25			12
FP18	57	25			18

Methods

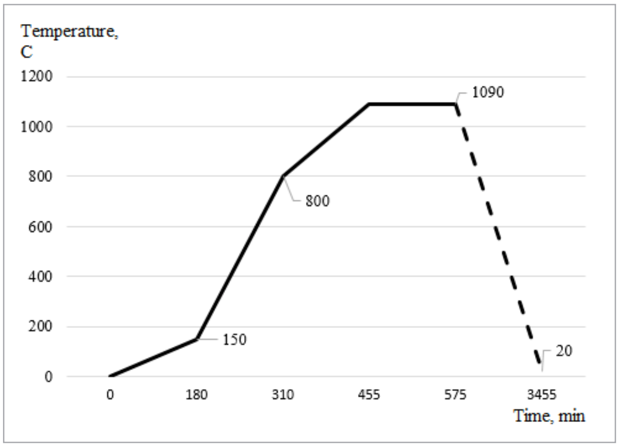
When making the porous ceramic material, great attention has been paid to the raw material in the clay and mineralogical and chemical composition. During the presented research quartz has been not used in porous ceramics producing. Since it reduces the technological characteristics – complicates sintering process, also reduces strength and, in certain cases, frost resistance of the samples as well. As well quartz worsens the plastics of ceramic mass, but reduces the contraction of the sample after drying and burning. CaO and MgO (Table 1) existing in their composition promote sintering of ceramics mass, advancing formation of pores.

In the beginning, clay was dried in the drying oven and ground in RETSCH PM 400 mill for 30 minutes in dry condition. When all of the required components are prepared, they are dosed in the required amount and mixed in dry condition, gradually adding water till the sufficiently homogenous mixture for sample making is obtained.

Samples were dried in two different ways: using the dry in natural conditions for 7 days and artificial drying in BINDER FED drying-case for 48 hours at 70°C. Shrinkage of samples was evaluated for each of the above mentioned cases. After drying samples were burnt one time by gradual increase of temperature. Within the range of temperature 0 °C up to 150 °C, samples were kept for 3 hours in order to ensure that upon the vaporization of excessive water there are no cracks in the porous ceramic samples. Temperature in the range from 150-800 °C was increased per 5 °C/min or 130 min in total, but from 800-1090 °C - per 2 °C/min or 145 min in total. At the maximal temperature 1090 °C, samples were kept for 2 hours in order to completely burn all of them (see Fig.1).

Fig. 1

Sample burning graph



After burning samples were refrigerated for 48 hours by gradual decrease of their temperature from 1090 °C to 20 °C .

Sample preparation process is summarized in Table 3.

Table 3

Sample preparation process

Abbreviation	Preparation of the components	Dosage and mixing	Burning	Refrigerating
SP2C4	Clay was dried in drying oven and ground for 30 minutes. Chamotte was dried.	All the components were dosed according their mass and mixed in dry condition, gradually adding water	All the samples were burnt 1 time by gradual increase of temperature. Max. temperature was 1090°C	48 hours by temperature dechease to 20 °C.
SP6	Clay was dried in drying oven and ground for 30 minutes.			
SP12				
FP6				
FP9				
FP12				
FP18				

Water absorption, volumetric mass and compressive strength were stated for the obtained samples. Water absorption of the samples was evaluated using standart test method for water absorption of plastics ASTM D570but compressive strength of the samples were tested in accordance with Latvian Standart (LVS) EN 679:2005 “Determination of the compressive strength of autoclaved aerated concrete”.

Results

The goal of the given research is to obtain a porous ceramic material with specific features of strength and density, thus achieving a material that could be used to insulate buildings and burnable fillers, such as shredded paper and foamglass pellets were used for its production.

To achieve the goal of the research it was necessary to select the composition of formation mixture, drying and burning regimes and determine the physical – mechanical and structural parameters of ceramic samples and to select the best composition of formation mixture and drying/ burning regimes in order to obtain porous and at the same time resistant materia using the local clay as the main material.

Several types of porous ceramic materials were obtained during research. Compressive strength tests were performed, as well as their density and water absorption was determined.

Volumetric mass of samples where shredded paper was used as the burnable filler in the amount of 2-12%, reached 1256.64 – 1567.97 kg/m^3, by respective decrease of volumetric mass if the amount of burnable filler are increased.

While the volumetric mass of samples where foamglass pellets were used as the burnable filler was from 861.71 kg/m^3, if the amount of filler is 18 %, to 1178.34 kg/m^3, if the amount of foamglass pellets is 6 % (see Fig. 2).

Shrinkage of samples was stated after their drying and after burning. For samples where foamglass pellets were used as the burnable filler, shrinkage after the natural drying was from 1.33 % up to 6.89 %, and the least shrinkage was recognized at the greatest amount of paper 12 %, but the greatest shrinkage at the amount of paper 6 %. After the natural drying the shrinkage was from 2.22 % up to 8.78 % accordingly and the least shrinkage was recognized upon the usage of 12 % of shredded paper, but the greatest upon the usage of 2 % of shredded paper and 4 % of chamotte.

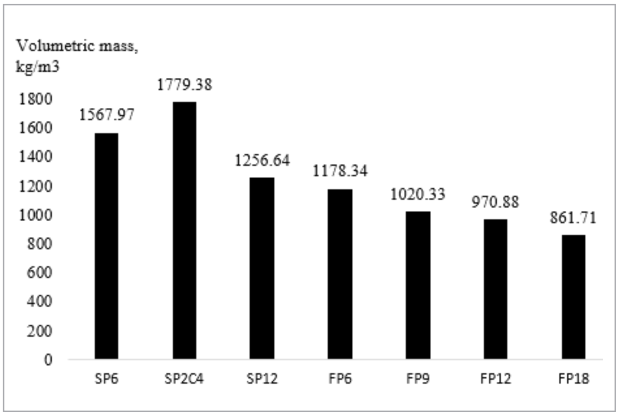


Fig. 2

Volumetric mass of the samples

By the summarization of obtained results it can be seen that shrinkage after the natural drying is 1.1 – 1.7 less that shrinkage after the artificial drying.

Shrinkage after the natural drying of samples where foamglass pellets were used as burnable filler, is from 2.22 % up to 3.08 %, and the least shrinkage was recognized for the samples with greater content of foamglass pellets (18%), but the greatest – for the samples with least content of foamglass pellets (6%).

Shrinkage after the burning of samples where shredded paper was used as burnable filler was from 3.33 % to 11,56 %, but for the samples, where foamglass pellets was used – 5.44 %– 6.11 %, in both cases the least shrinkage was recognized for the samples with greater content of the burnable filler (see Fig.3.).

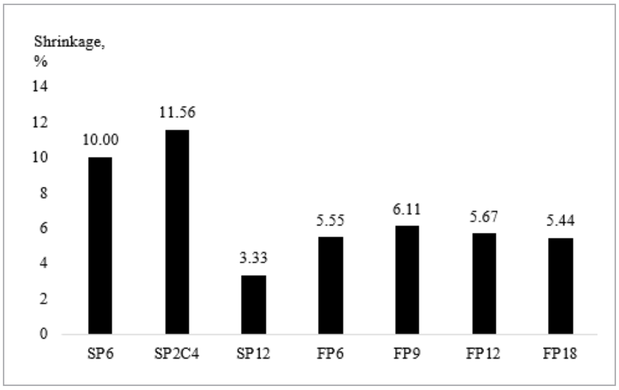
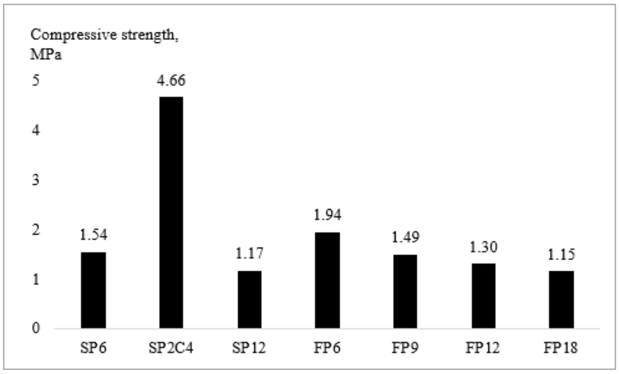


Fig. 3

Average shrinkage after the burning of the samples, which were dried for 48 hours at 70°C

Fig. 4

Compressive strength of the samples, MPa



Compressive strength was determined for all the samples, the resulting values can be seen in Fig.4.

Greatest compressive strength – 4.66 MPa has been stated for the samples, where 2 % of shredded paper and 45 % of chamotte were used as a filler, where chamotte provides necessary stiffness by making stable frame during the sample burning process.

Compressive strength of other samples where shredded paper was used as a filler, was from 1.17 MPa to 1.54 MPa, by respective increase upon decreasing of the amount of filler. In samples where foamglass pellets were used instead of shredded paper, the compressive strength is from 1.15 MPa up to 1.94 MPa by respective increase upon decreasing of the amount of filler.

Table 4

Water absorption of the samples

Amount of filler	Water absorption, %
6 % shredded paper	9.23
2 % shredded paper, 4 % chamotte	10.70
12 % shredded paper	16.70
6 % foamglass pellets	9.55
9 % foamglass pellets	10.21
12 % foamglass pellets	9.11
18 % foamglass pellets	8.33

Water absorption of the samples was obtained during the research, which is summarized in Table 4.

Obtained data demonstrates that the greatest water absorption – 16.70 % is for the samples with filler of 12 % paper, but the least – 8.33 % for samples with 18 % of foamglass pellets. Totally the difference between the volume of water absorption for samples with shredded paper filler and foamglass pellet filler is 4.58 % – 50.12 %.

Discussion

During the research the acquisition of porous ceramics was practically demonstrated by using shredded paper and foamglass pellets as the filler upon changing the amount and type of filler and obtaining the material with various physically mechanic features.

Volumetric mass of samples where shredded paper was used as the burnable filler in the amount of 2-12 %, reached 1256.64 kg/m^3 – 1567.97 kg/m^3, while the volumetric mass of samples where foamglass pellets were used as the burnable filler was from 861.71 kg/m^3, if the amount of filler is 18 %, to 1178,34 kg/m^3.

The efficiency of application a shredded paper is very low, since reducing volume density to about 20 %, the strength of the ceramics is reducing for almost 10 times. It may be explained by chips form of paper particles that create a lot of plain voids in the specimens destroying homogeneity of material structure. At the same time particles of paper absorb the water from the mix and worse plasticity of this one.

Density of porous ceramics samples can be easily regulated by changing the amount and type of foamglass pellets, but if the amount of filler is increased and amount of water is kept at the same level, plasticity of the mixture decreases and it is more difficult to get homogeneous mixture as well as to work it in the moulds.

Besides the decrease of plasticity we must also consider the decrease of compressive strength which is obtained by increasing the porosity of sample (decrease of density) therefore recognition and acquisition of mutual proportion between the density and resistance of sample plays essential role thus ensuring the acquisition of optimal material.

Resistance indicators for the samples where shredded paper is used as the filler, are from 1.17 MPa up to 4.66 MPa, but for samples with foamglass pellets – 1.15 MPa up to 1.94 MPa. There were a lot of shrinkage cracks in the specimens with foamglass pellets as fillers. This fact can explain low strength properties of the ceramic specimens.

Obtained results of the research testify that these porous ceramics materials have great potential of application, but speaking about the material usage for load-bearing constructions, strength indicators must be improved by following researches using nano- additives, the fillers such as glass and fire clay, developing the technology of producing (mix contents, drying and burning processes) ceramics which improve resistance indicators of the sample.

Shrinkage of obtained samples with foamglass pellets after the drying is from 1.33 MPa up to 8.78 % which due to the information mentioned in literature sources (Рыбьев *et al* 1987) means that listed clay is less plastic (shrinkage less than 6 %) and medium plastic (shrinkage from 6 % up to 10%).

Total shrinkage of the drying and burning for both samples is from 4.66 % up to 12.11 % which confirm to the total shrinking level from 5 % up to 18 % mentioned in literature sources (Higerovics *et al.* 1972).

By the application of natural drying the main advantages are the less shrinkage, less consumption of resources and more easy technological process if we compare with the artificial drying. But at the same time artificial drying provides essential decrease of drying time thus speeding up the process of material production.

Water absorption for both types of obtained samples was from 8.33 % up to 16.70 % which confirm to the total shrinkage level from 8 % up to 20 % mentioned in literature sources (Higerovics *et al.* 1972).

Decreasing water absorption with increasing volume of glass pellets in ceramic may be explained by decreasing permeability of materials for water due to covering inner surface of voids by glass. It means the obtained material should improve the thermal insulation properties by saving breathing possibility.

If we compare foamglass pellets and shredded paper fillers, the second one has the deficiency of heterogeneous structure of pore which is related to the orientation of shredded paper and its disposition in the sample that has negative effect to the physical and mechanic features of samples by decreasing their compressive strength. But the following must be considered – usage of shredded paper in the production of porous ceramics can be more effective by additional treatment before mixing with clay and other fillers. The following investigation will be devoted to developing more effective material with relation density/stiffness by controlling thermal conductivity properties.

Conclusions

Within the research samples of porous ceramics were developed upon application of two different burnable fillers – foamglass pellets and shredded paper by stating the shrinkage (after the artificial and natural drying), density, water absorption and compression strength of acquired samples.

Following results were obtained for the samples with shredded paper used as a filler: shrinkage after the drying from 1.33 % up to 8.78 %, shrinkage after burning – 3.33-11.56%, density – 1256.64-1567.97 kg/m3, water absorption – 9.23-16.70 % and compressive strength – 1.17-4.66 MPa.

While for samples with foamglass pellets used as a filler following results were obtained: shrinkage after the drying – 2.22 – 3.08%, shrinkage after burning – 5.44 – 6.11 %, density – 861.71 – 1178.34 kg/m^3, water absorption – 8.33 – 10.21 % and compressive strength – 1.15 – 1.94 MPa.

By comparing the features of both obtained materials we can see that samples with shredded paper used as the filler have better compressive strength indicators, but samples with foamglass pellets – less density. If we compare the shrinkage, samples with the paper used as the filled have less shrinking of the dry after the burning. Therefore for the acquisition of necessary strength and density indicators of the material, in the following researches it is essential to find the optimal filler and its amount.

Porous ceramic materials after improvement of their strength properties can be used as constructive building materials, they are breathable, do not rot and they are resistant against heat and thermal impact, corrosion, deterioration and aggressive environment.

Production of porous ceramics materials where foamglass pellets are used as the burnable filler, allows create more effective ceramics, creating high added value for the final product.

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About the authors

ALEKSANDRS KORJAKINS

Professor

Riga Technical University, Institute of Materials and Structures, Head of Department of Building Materials and Products

Main research area
Building materials an building technology

Address
Kalku Street 1
LV-1658, Riga, Latvia
Tel. +371 26422442
E-mail: aleks@latnet.lv

LIGA UPENIECE

PhD student

Riga Technical University, Institute of Materials and Structures, Department of Building Materials and Products

Main research area
Ecological materials, ceramic

Address
Kalku Street 1
LV-1658, Riga, Latvia
Tel. +371 26356332
E-mail: liga.upeniece@rtu.lv

BRIAN O'ROURKE

Ms. student

Riga Technical University, Department of Building Materials and Products

Main research area
Building materials an building technology

Address
Kalku Street 1
LV-1658, Riga, Latvia
Tel. +371 28635851
E-mail: liga.tomase@rtu.lv