ISSN 2347 - 3983
Volume 8. No. 10, October 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter988102020.pdf
https://doi.org/10.30534/ijeter/2020/988102020

# Filler amount impact on the composite material properties based on ceramic and polymer waste

**A.S. Uvarova[1], I.A. Vitkalova[2], E.S. Pikalov[3], O.G. Selivanov[4]**
[1] Vladimir State University named after A. G. and N. G. Stoletovs, Vladimir, Russian Federation
astorlova@mail.ru
[2]Vladimir State University named after A. G. and N. G. Stoletovs, Vladimir, Russian Federation,
iavitkalova@gmail.com
[3] Vladimir State University named after A. G. and N. G. Stoletovs, Vladimir, Russian Federation
evgeniy-pikalov@mail.ru
[4] Vladimir State University named after A. G. and N. G. Stoletovs, Vladimir, Russian
Federation,selivanov6003@mail.ru

**ABSTRACT**

This paper presents the research results dealing with the main physical and mechanical properties dependence of polymer composite material on the filler amount in the raw material mixture. To develop the studied composite material, the scrap full-bodied ceramic brick is used as filler, and polystyrene is used as binder, which is formed as a result of polystyrene waste dissolving in carbon tetrachloride. The research results allowed determining the filler amount for the most effective application of the developed composite material in the construction materials production for external wall cladding of buildings and structures.

**Key words:**scrap brick, expanded polystyrene, polymer composite material, facing material, carbon tetrachloride

## 1. INTRODUCTION

All types of production and human household activities are inevitably associated with the waste, which accumulation negatively affects the environment and human life quality. In this regard, it is relevant to develop methods and technologies for waste disposal not only reducing its amount, but also reducing the primary natural resources consumption[1-3].

Among the most effective ways of waste processing is its utilization as a component for the construction materials production, since this trend permits to dispose almost all types of waste in large amounts and manufacture high-quality products at low production costs [4-6].

In turn, the most promising direction of waste disposal for the construction materials is the production of composite materials, including the application of polymer binder [7-9]. On the one hand, it depends on the fact that polymer composite materials combine light weight, strength, low water absorption and chemical resistance, being an advantage in comparison to most other construction materials. On the other, it is possible to use some types of waste as fillers, and others as binders, thus allowing for its comprehensive disposal [10-12].

The research authors have previously developed polymer composite material where scrap brick served as the filler, and polystyrene as the binder, received at dissolving polystyrene waste in carbon tetrachloride. The best compressive strength and the lowest water absorption were found to be achieved at the ratio of polystyrene : carbon tetrachloride equal to 1 : 1.4, with the introduction of 45-55 wt. % of scrap brick and samples forming at 8 MPa pressing pressure [13].

The research objective was to study the dependence of the main physical and mechanical properties of the developed composite material on the filler amount and the choice of its concentration in the raw material mixture, which ensures material properties meeting the regulatory requirements for the external cladding materials.

## 2. RESEARCH OBJECTS AND METHODS

In this research common ceramic scrap bricks from various sources were used to make the filler. They were crushed into max 0.63 mm particle size and dried to constant mass. To make the binder, waste polystyrene foam was used in the form of waste packaging elements for household appliances, equipment, etc. collected from various sources. Styrofoam waste was also crushed and dried to a constant mass. Pure carbon tetrachloride according to GOST 20288-74 was used to dissolve Styrofoam waste.

The samples of the developed material were manufactured by dissolving Styrofoam waste in carbon tetrachloride, followed by mixing the binder solution and scrap brick into a homogeneous raw material mass. The samples were formed from the developed raw material mass at 8 MPa pressing pressure, at the heat treatment temperature of 85-90°C with 45 minutes exposure time for solvent removal [13].

The samples were tested to determine: density ($\rho$, kg/m$^3$), water absorption (WA, %), open ($P_{opn}$, %), closed ($P_{cl}$, %) and total ($P_{totl}$, %) porosity, compressive strength ($\sigma c_{mp}$, MPa) and bending strength ($\sigma_{bnd}$, MPa), frost resistance (FR, cycles) and thermal conductivity ($\lambda$, W/(m·$^o$C)) applying standard methods for construction materials.

## 3. RESEARCH RESULTS AND DISCUSSION

The experiments results revealed that density and water absorption of the developed composite material increase alongside the increase of the filler amount in the raw material mixture (Fig. 1).

Such dependence character depends on the fact that the scrap brick density is higher than polystyrene density, and that the increase of the scrap brick amount increases the developed material porosity. It is confirmed by research data addressed to the porosity dependence on the filler amount (Fig. 2).

The developed material porosity increase can be explained by the voids in the scrap brick particles, the pores formed at the contact points with filler particles and the binder solution because of the air bubbles, remaining on the scrap brick surface during mixing, due to the imperfect wettability of the filler particles with the binder solution, as well as open pores formed at solvent removal during heat treatment. The received data demonstrates that when total and open porosity is increasing, the proportion of closed pores is decreasing. It is associated with polystyrene amount decrease which serves as a binder, filling not only some part of the pores and voids, but also transforms open pores into the closed ones.

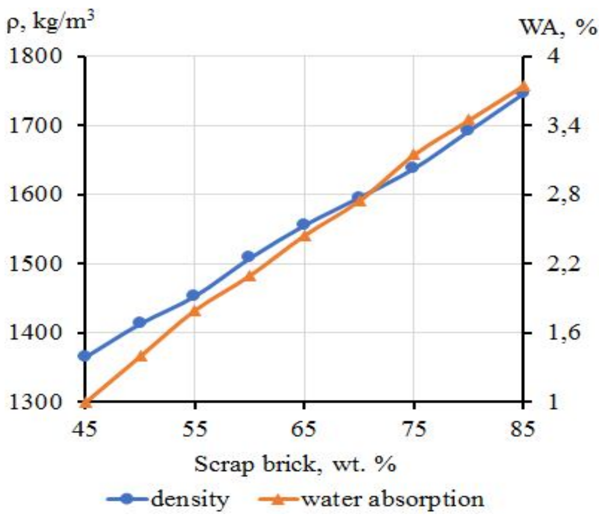


**Figure 1.**Dependence of density and water absorption on the filler amount in the raw mixture

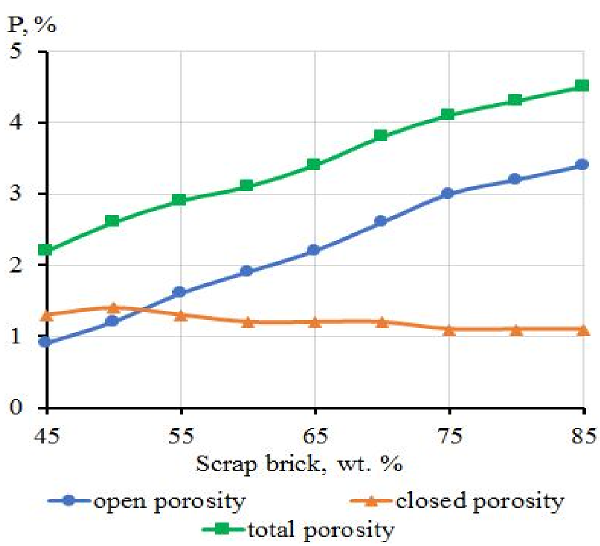


**Figure 2.**Dependence of porosity on the filler amount in the raw mixture

The experiment results also stated that the dependences of compressive strength and bending strength are similar and the considered properties reach their maximum when the filler amounts 45-55 wt. % (Fig. 3). As previously revealed, it depends on the fact that this amount of filler makes polystyrene perform its binder function most effectively [13].

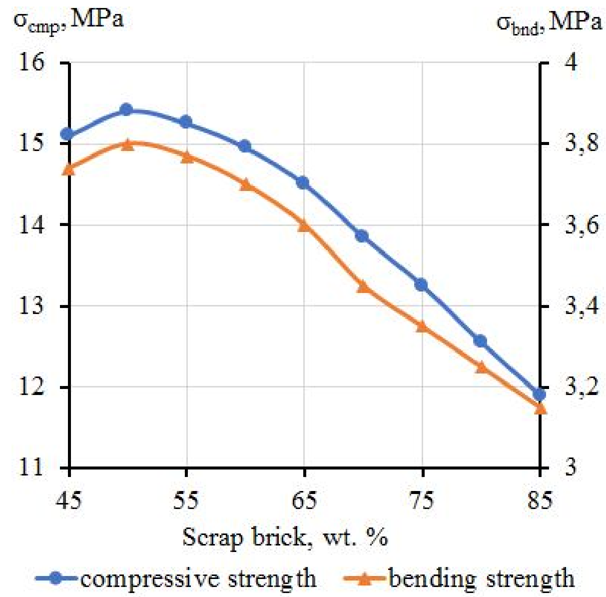


**Figure 3.**Dependence of compressive and bending strength on the filler amount in the raw mixture

The experimental data dealing with frost resistance and thermal conductivity prove that filler amount increase causes the decrease in the material frost resistance, and increase in thermal conductivity (Fig. 4).

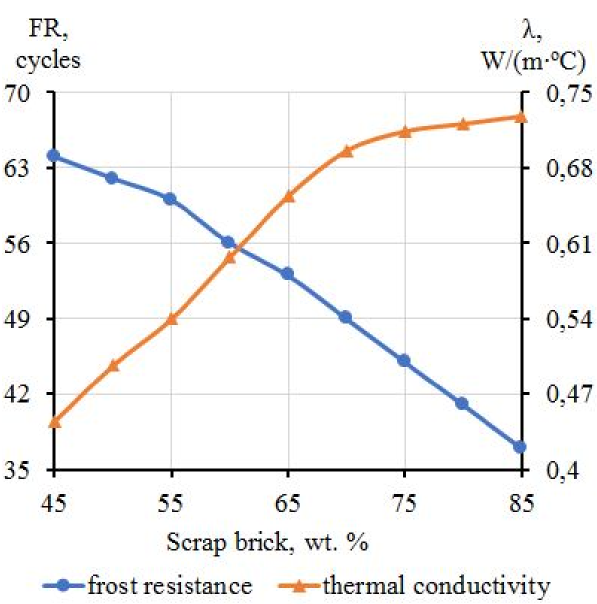


**Figure 4.**Dependence of frost resistance and thermal conductivityon the filler amount in the raw mixture

The frost resistance decrease is caused by the water absorption increase, since these properties are inverse related. The thermal conductivity increase can be explained by the fact that the porosity increase slightly weakens this property, and thermal conductivity of scrap brick (≈0.85 W/(m·°C)) significantly exceeds polystyrene thermal conductivity (≈0.093 W/(m·°C))[13].

Thus, the maximum strength of the composite material for the developed raw mixture composition is achieved at 50 wt. % of scrap brick. It is worth considering that alongside the filler amount increasing the material density increases, causing the products mass increase, the conductivity increase, which reduces material the efficiency, and closed porosity decrease, which reduces frost resistance. In this regard, it was decided to introduce 50 wt % of the scrap brick into the raw mixture.

## 4. CONCLUSIONS

The experiments results revealed that the scrap brick in the max amount of 50 wt. % increases compressive strength and closed porosity ratio of the developed composite material. Higher amount of the filler causes the lack of binder, resulting in strength reduction and open porosity share increase, which in turn causes increased water absorption and reduced frost resistance.

Composite material possessing sufficiently high strength and frost resistance can be produced applying the selected amount of filler in the raw material mixture, thus allowing for the manufacture of products used for external wall cladding of buildings and structures. Thus, the developed raw material mixture makes it possible to comprehensively dispose two large-capacity waste products to manufacture high-quality construction products.

## REFERENCES


1. I.A.Vitkalova, A.S.Uvarova, E.S.Pikalov, O.G. Selivanov**"Lanthanum oxide application for modifying the properties of chemically resistant ceramics produced with galvanic sludge additive."***International Journal of Emerging Trends in Engineering Research*. 2020, Vol. 8,Iss. 8, pp. 4544 - 4547.
2. A.Erdoğan, M.S.Gök, V.Koç, A.Günen**"Friction and wear behavior of epoxy composite filled with industrial wastes."***Journal of Cleaner Production*. 2019, Vol. 237, 117588.
3. P. Sharma, V.K. Gaur, S.-H. Kim, A. Pandey**"Microbial strategies for bio-transforming food waste into resources."***Bioresource Technology*. 2020, Vol. 299, 122580.
4. A.S. Uvarova, I.A.Vitkalova, E.S.Pikalov, O.G. Selivanov**"Application of tripolite in the production of facing ceramic material using cullet."***International Journal of Emerging Trends in Engineering Research*. 2020, Vol. 8,Iss. 9, pp. 6042-6044.
5. A. Mohamed, G. Jacek, N. Marian, P. Jan, G. Małgorzata**"Recycle option for metallurgical sludge waste as a partial replacement for natural sand in mortars containing CSA cement to save the environment and natural resources."***Journal of Hazardous Materials*. 2020, Vol. 398, 123101.
6. S. Liuzzi, S.Sanarica, P.Stefanizzi**"Use of agro-wastes in building materials in the Mediterranean area: a review."** *Energy Procedia*. 2017, Vol. 126, pp. 242-249.
7. A. Saccani, S. Manzi, I. Lancellotti, L. Lipparini**"Composites obtained by recycling carbon fibre/epoxy composite wastes in building materials."***Construction and Building Materials*. 2019, Vol. 204, pp. 296-302.
8. C.A. Echeverria, W.Handoko, F.Pahlevani, V.Sahajwalla**"Cascading use of textile waste for the advancement of fibre reinforced composites for building applications."***Journal of Cleaner Production*. 2010, Vol. 208, pp. 1524-1536.
9. J. N. Asaad, S. Y. Tawfik**"Polymeric composites based on polystyrene and cement dust wastes."***Materials & Design*. 2011, Vol. 32, Iss. 10, pp. 5113-5119.
10. A.Torlova, I. Vitkalova, E. Pikalov, O. Selivanov**"Development of polymer composite facing material using anthropogenic waste."***Advances in Intelligent Systems and Computing*. 2020, Vol. 1116, pp. 544-551.
11. I. Vitkalova, A. Torlova, E. Pikalov, O. Selivanov**"The Development of Energy Efficient Facing Composite Material Based on Technogenic Waste."***Advances in Intelligent Systems and Computing*. 2019, Vol. 983, pp. 778-785.
12. A.S. Kolosova, E.S. Pikalov, O.G. Selivanov**"Heat-insulating composite material based on wood and polymer waste."***Ecology and Industry of Russia*. 2020, Vol. 24, Iss. 2, pp. 28-33.
13. A.S. Torlova, I.A. Vitkalova, E.S. Pikalov, O.G. Selivanov**"Recycling of Ceramic and Polymeric Wastes in the Production of Surfacing Composite Materials."***Ecology and Industry of Russia*. 2019, Vol. 23, Iss. 7, pp. 36-41.