STRENGTH PROPERTIES OF MOULDING SAND FOR THIN-WALLED CASTING PRODUCTION

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Abstract

In the article the results of testing the moulding sand based on alumino-silicate microspheres matrix with organic binder - epoxy resin were presented. Developed moulding sand is intended to serve in the role of moulding or/and core, is supposed to be used for the implementation of thin-walled casting, which examples are so-called skeletal castings (3D), characterized by a small thickness of wall and strongly developed heat transfer surface in the process of crystallization. Castings of this type are the original development of the Department of Foundry, in Silesian University of Technology. The matrix is characterized by good thermal insulation properties and a small particle size, while synthetic organic binder utility preferred properties, among the others the delayed setting time and good rheological properties should be distinguished and high chemical resistance. Moulding or core sand should also provide a low surface roughness of the casting and the preservation of close tolerances on shape and dimensions. At the moment there is no normative regulations for the design of casting process and technology of preparation of moulding and/or core sand used in the production of castings with extremely small dimensions of the wall or of a particularly high surface area heat dissipation during crystallization. The subject of researches is compressive strength depending on the amount of selected binders for foundry advanced application. The results confirmed the benefits of the newly developed technology of the moulding sands.

Keywords: Alumino-silicate microspheres, organic binder, moulding sand, core sand

1. INTRODUCTION

Among existing in nature, as well as in various technical fields of porous bodies molding compound belongs to the group having the highest degree of complexity [1]. Utilizing many years of experience and laboratory tests identified a number of technical characteristics, which should have a molding compound to comply with the cast of established quality. In the literature [2, 3] is given 21 properties, which should have the moulding sand. One of them is the strength at room temperature and at elevated temperature, so determining the binding strength, so-called "bridges" formed of binder material and occurring in the interfaces between the matrix grains. A separate group having particular importance for the quality of the cast are thermophysical properties of material, which responsible i.a. for the rate of heat removal from the casting mould, directly influencing the resulting microstructure of the original casting. In case when the mould is homogeneous throughout its volume, or almost uniform it is assumed to be equal the capacity of all of its fragments into the casting heat storage, the properties of thermophysical as if they are subordinated to the type of technological properties [1]. However, the utility fundamental properties are mechanical and thermal properties.

2. STATIC COMPRESSION TEST

Problems the testing of compression strength of moulding sands standardized laboratory samples Ø 50x50 mm size are described in the specialist literature [4, 5] and in the document [6]. They predict that the strength of the test material attached in a universal apparatus for testing mechanical properties of moulding in the type of LRu does not exceed the value of 2.1 MPa. At the majority determination of case, such as claybonded sand, where bentonite is used, it is a sufficient value. For the moulding sands, whose strength exceeds 2.1 MPa it is properly to use other (preferably standardized) measurements allow the determination of that size. One of them is the use of standard [7].

3. ALUMINO-SILICATE MICROSPHERES AS A MATRIX OF MOULDING SAND

Microspheres are spherical particles of aluminum silicate filled with carbon dioxide and nitrogen from the combustion of coal in power equipment [8].
As a result of the coal combustion process in the power boiler in the high temperature zone of the site of the plastic slag as a result of presented in the furnace gas formed inside the gas-filled granules. Shaped particles together with the remaining slag are transported away into the pond, and then float to the surface. Fished out of the water microspheres are directed to the drip chamber. The collected material is subjected to long-lasting seasoning period until the particles reach about 20 % moisture. The final stage of production is packaging. A characteristic feature of this material is its structure (**Fig. 1**) and the physical properties shown in **Table 1**.

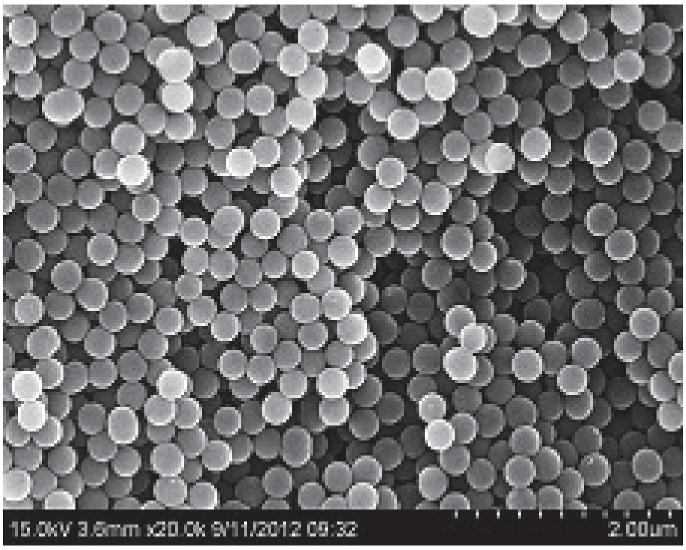

Fig. 1 Microstructure of microspheres [9]

Table 1 Physical properties of microspheres [10]

Properties	Volume	Unit
Apparent density in a dry condition	400 ± 30	kg/m^3
Density of alumino-silicate envelope	2200 ± 200	kg/m^3
Relative density	690 ± 50	kg/m^3
Thermal conduction	0.07 ± 0.03	W/(m·K)
Melting point	1495 ± 10	^{o}C
Softening point	1220 ± 10	^{o}C
Internal pressure in microsphere	0.02 to 0.10	MPa
Water contents in dry microsphere	< 0.5	%
Hardness in Mohs scale	6 ± 1	
pH factor of water extract	7 ± 1	
Colour	light to dark grey	

Microspheres, with its spherical construction, are characterized by high volume and low mass density.

4. EPOXY RESIN AS A BINDER

The term epoxy compounds is determined in the molecule containing more than one epoxy group, which are capable of polyreactions (also called crosslinking or curing reaction) to give the crosslinked, insoluble and infusible materials. By convention, this name is also referred to resins cured, even though they no longer contain epoxy groups [11].

The diverse range of products for each producer makes that quite often you can find products with similar ranges of the number of epoxy and other of chemical and/or physical properties. Some manufacturers produce different types of resins in a fairly narrow limits the number of epoxy, while others bring a wide range, which does not provide preferred the stability of the production process [11].

For the resin curing process, performed at room temperature (cold) are the most frequently used aliphatic polyamines. Very important is their stoichiometric dosage, because excess or too little amount have negative impact on the properties of materials. About 80 % of the mechanical properties of epoxy compositions typically achieve after 24 hours of bindings. A full mechanical strength, thermal and chemical hardener composition is achieved after several days [11].

4.1 Diluents

The main objective of lowering the viscosity of the diluent agents is cold-curable compositions. There are usually difficult to volatile organic compounds, liquid, mostly of low viscosity and construction of polar, well dissolving resins and significantly increase their liquidity [11].

There are two basic types of diluents [11]:

a) inactive, which do not have functional groups participating in the reaction with the base resin or hardener and do not participate in the curing agent and remain in the cured plastic material chemically unbound,
b) the active, which chemically bind to the curing process, and are incorporated into the polymer formula spatial:

- diluents with one epoxy group,
- diluents of epoxy resin types,
- diluents which do not contain epoxy groups.

In range of own studies were used active diluents in form butyl glycidyl ether.

5. OWN RESEARCH

In the study were used position and methodology in accordance with *PN-EN 12290:2007* Standard. It is consistent with the *PN-H-11073:1983 Foundry moulding materials. Measurement of strength.*

The aim of the study is the analysis of the compressive strength of the moulding, in which the matrix is gray microspheres, while as an adhesive epoxy resin was used.

During the study were used the following materials and equipment:

a) gray microspheres F150;
b) epoxy resin, LE: 0.510 ÷ 0.550 mol/100 g;
c) laboratory mixer ML-92M type;
d) laboratory manual rammer LU-1;
e) testing machine WPM.

Stages of preparation of moulding:

a) weighing the ingredients in the required proportions,
b) mixing the ingredients until a uniform consistency,
c) curing and post-curing samples.

Table 2 Composition of moulding during the compressive strength analyzed

Designation	Matrix	Binder*
A-1	100 %	5 %
B-2	100 %	10 %
C-3	100 %	15 %
D-4	100 %	20 %

*mass fraction calculated to matrix weight

6. RESULTS

Compressive strength testing were subjected to the six samples of each type of mass, the obtained results are shown in **Figs 2** to **6** and **Tables 3** to **4**.

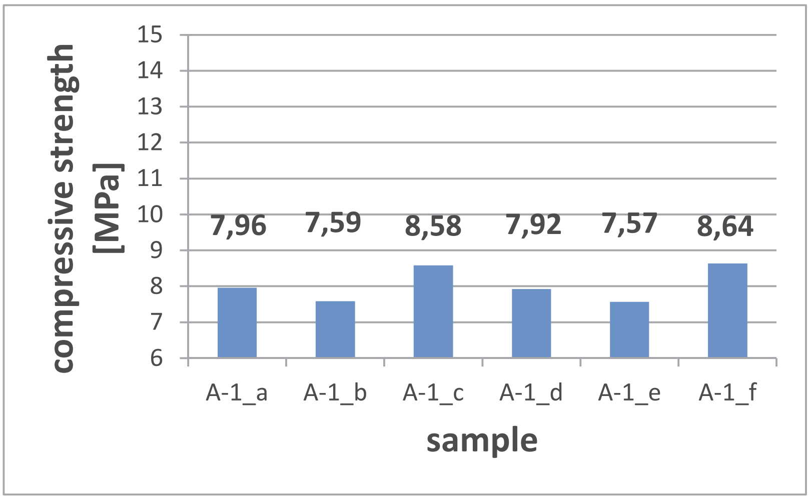

Fig. 2 The compressive strength of samples with 5 % of binder

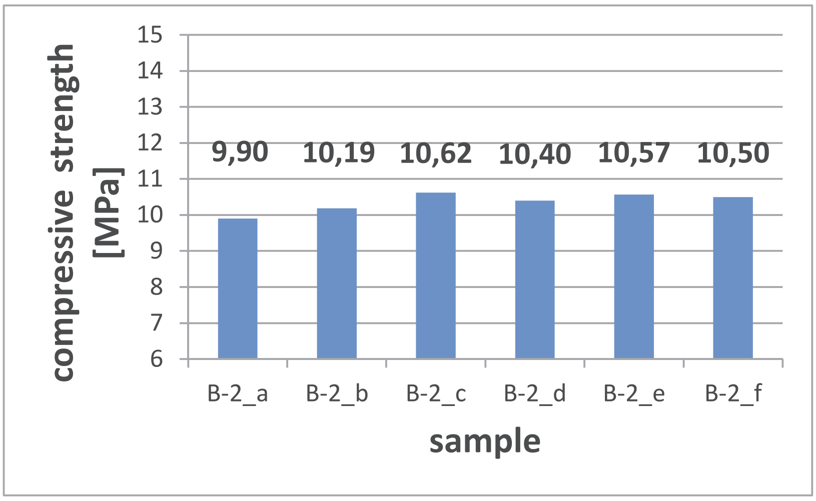

Fig. 3 The compressive strength of samples with 10 % of binder

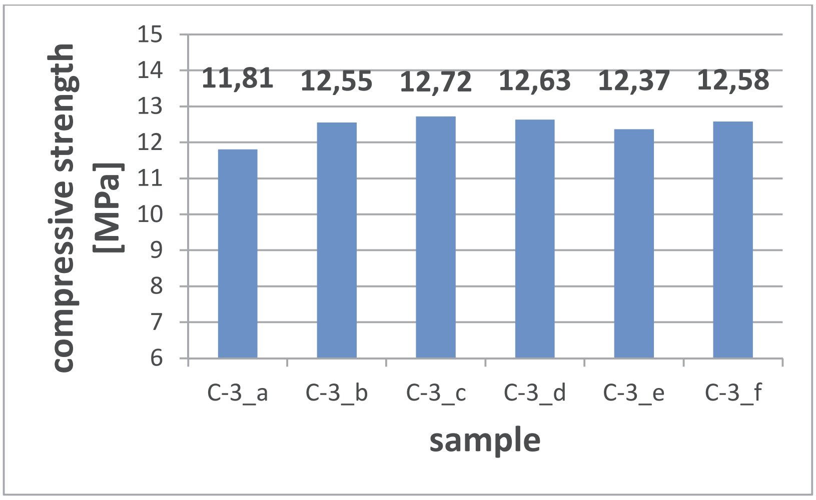

Fig. 4 The compressive strength of samples with 15 % of binder

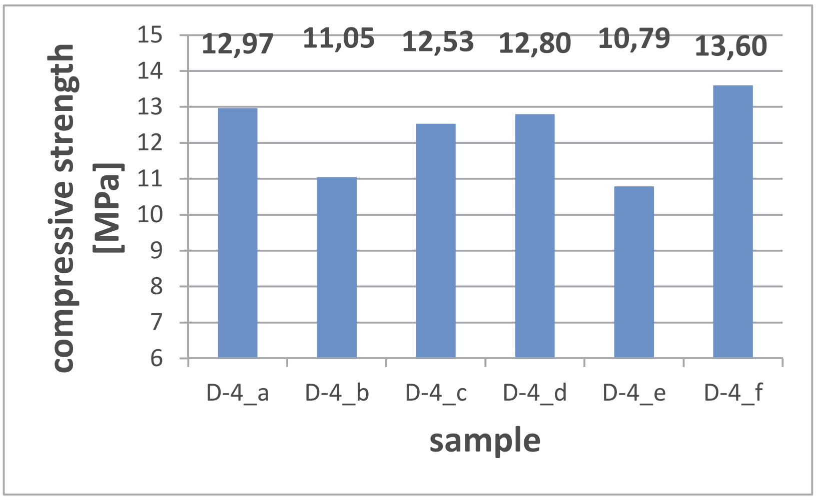

Fig. 5 The compressive strength of samples with 20 % of binder

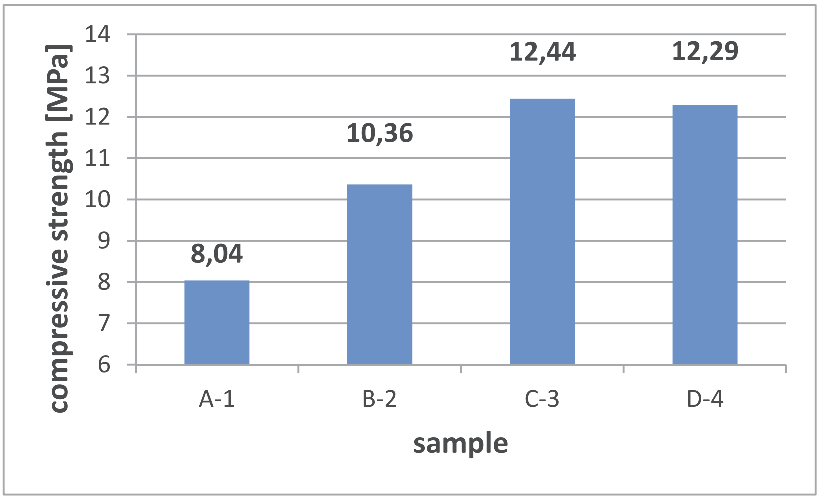

Fig. 6 Mean values for the compressive strength of developed moulding sand

Table 3 Statistics research

Participation of binder (%)	5	10	15	20
average	8.04	10.36	12.44	12.29
variance	0.22	0.07	0.11	1.26
standard deviation	0.47	0.27	0.33	1.12
standard deviation (%)	5.82	2.64	2.66	9.12

Table 4 The conversion of mass fraction to volume fraction for alumino-silicate microspheres and quartz sand

Mass fraction	Alumino-silicate microspheres	Quartz sand
	Volume fraction	
5 %	1.87 %	11.68 %
10 %	3.52 %	23.38 %
15 %	5.36 %	35.08 %
20 %	7.16 %	46.86 %

CONCLUSION

Based on conducted studies following conclusions have been formulated:

a) elaborated moulding sand have very good strength properties that exceed several times than currently used moulds and / or cores sand,

b) the content of the resin has an influence on the strength properties of the analyzed moulds, the differences between C-3 and D-4 are smaller than those between the other moulds,

c) sample A-1 were characterized by the lowest strength of a fairly large distribution between 7.57 and 8.64 MPa,

d) sample B-2 were characterized by fairly uniform strength in the range of 10.40 ÷ 10.62 MPa and a slight deviation of the weakest sample not exceeding 10 %,

e) the sample C-3 showed a uniform level of mechanical properties at about 12 ÷ 13 MPa, in contrast to D-4 with a rather large scatter of about 2 MPa,

f) despite the use of 5 to 20 % of the mass fraction of resin binder used is relatively small when converted to the volume fraction that results from a small bulk density of the microspheres,

g) a ratio of microspheres and the bulk density of quartz sand is 1 : 6.5, which allows for multiple reduction in volume fraction of the binder,

h) the use of advanced, active diluent can contribute to reduce the amount of binder used by a significant decrease in viscosity; different from the typical uses of compositions in the case of epoxy molding also seems justified use of inactive diluents,

i) the results indicate a utilitarian need for further research to identify other functional properties developed moulds.

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