TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 61, Issue Special, September, 2018

DEVELOPMENT AND TESTING OF MINERAL CASTING FOR USE IN STRUCTURAL ELEMENTS AND MOLD MAKING

Mihai CIUPAN, Marcel POPA, Ioan Pavel SOSA, Glad CONTIU, Emilia CIUPAN

Abstract: *The paper presents the making and the testing of different formulations of mineral casting, with the aim of identifying formulations with excellent mechanical properties for use in machine-tool structural elements and mold making. It describes the manufacturing process of this composite material from epoxy resin and granite. Specimens of different material formulations were cast and experimentally investigated by flexural testing. Individual stress-deformation graphs were plotted for each specimen and the average results for the many different formulations were compared.*
Key words: *composite material, mineral casting, structural elements, mold making*

1. INTRODUCTION

Mineral casting is a composite material and a type of polymer concrete used in building structural elements of machine-tools, such as beds, columns, portals and tables. It can also be used for mold making, used for example in thermoforming processes. The material has the advantages of being relatively low-cost, manufacturing requires a very small investment, it is safe to handle, requires much less energy than metal production and can easily be recycled.

It is mainly made of granite aggregate and casting epoxy resin. The aggregate gradation is important as it can lower epoxy resin content and improve mechanical properties such as tensile strength and compressive strength [1].

The paper presents the making and the testing of different formulations of mineral casting, with the aim of identifying usual properties and formulations with excellent mechanical properties. The manufacturing process started with the purchase of materials. From the many different types of epoxy resins which are available, one that satisfied the following criteria was chosen:

- casting type resin;
- long pot-life;
- low viscosity;
- room temperature curing.

Epoxy resins are well suited to machine-tool components because of their very good mechanical properties and excellent chemical resistance to the petroleum based products used in cooling liquids and lubricants. The chosen thermosetting polymer had a tensile strength of around 80 MPa and a Young’s modulus of 3 GPa when fully cured and heat-treated.

2. MANUFACTURING AND TESTING OF SPECIMENS

The mineral used was crushed granite from a nearby rock quarry. Aggregate sizes ranged from 0 to 4 mm. The mineral was further processed by drying and sieving into appropriate dimensions. The sieves were constructed from stainless steel mesh and wooden frames.

The molds used for the casting of specimens were built from easily available and relatively low cost chipboard fastened together with screws. Their disadvantages include the fact that their dimensions vary and are influenced by humidity; they have low strength and stiffness and can be used only for a limited number of parts. Alternatives to chipboard and wood for making molds include steel, aluminum and composites such as GFRP and CFRP. They are quick to make and can be taken apart after the epoxy curing so as to facilitate the demolding. The testing procedure was selected so as to suit the following criteria:

- small size of mineral particles;
- to mimic the stresses encountered during use of the structural elements;
- low consumption of mineral casting material.

The specimen size and flexural strength testing procedure followed the guidance of standard EN1015-11:1999: "Determination of flexural and compressive strength of hardened mortar" [2]. Accordingly, the specimen size was 40x40x160mm and the effective span was 140mm. The specimens were tested using a three-point flexural test. Figure 1 illustrates the standard shape and dimensions of the specimens used for bend-testing.

The testing procedure consisted in applying the load with a constant rate of approximately 0.25kN/sec, so the time period up to failure was between 30 to 90 seconds. For this purpose, a 400kN capacity hydraulic testing machine was equipped with a force sensor and connected to a computer. Moreover, a displacement sensor attached to the testing machine frame provided the displacement measurements. However, the displacement measurements included the deformation of the equipment in the first stages of the test. The displacement and force measurements were automatically stored on the computer via CatmanEasy, a data acquisition software widely use in engineering that also controls the loading rate.

Bend testing was chosen due to the fact that it represents stresses commonly encountered in the normal use of machine-tools. Even though bend-testing is a combination of two basic types of testing, compressive and tensile, it is a useful indication of the behavior of the material in use. In the case of polymer concrete, as in general with concrete, its compressive strength exceeds its tensile strength considerably.

Table 1: Mechanical properties of the constituents of mineral casting

	Granite	Epoxy resin
Elastic Modulus [GPa]	70	3
Poisson's Ratio []	0.25	0.35
Tensile Strength [MPa]	10	80
Compressive Strength [MPa]	2200	104

Table 2: Specific mechanical properties of mineral casting according to paper [5] and EN-GJL-300 cast iron

	Mineral casting	EN-GJL-300
Spec. Elastic Modulus [GPa*m³/kg]	15*10⁻³	16*10⁻³
Spec. Poisson's Ratio [m³/kg]	110*10⁻⁶	35*10⁻⁶
Spec. Tensile Strength [MPa*m³/kg]	9.25*10⁻³	38.46*10⁻³
Spec. Compressive Strength [MPa*m³/kg]	53.25*10⁻³	132.41*10⁻³

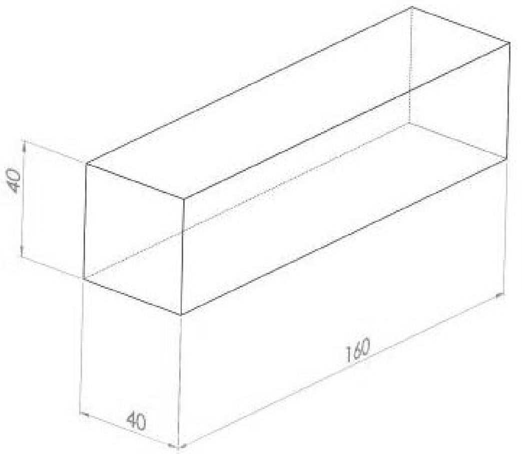

Fig.1 Standard specimen size in mm for 3-point bend testing

Table 1 lists the mechanical properties of the constituents of the mineral casting. It shows that epoxy resin has very low rigidity, only 3GPa, compared to an average value of 122 GPa for EN-GJL-300 cast iron [3], the reference material in machine-tool building. However, the epoxy quantity percentage is very small in the mineral casting as it only has to wet the surface of the granite particles and bond them together. This means that mineral casting has a much higher Young's modulus due to the properties of granite and its high percentage in the mix [4].

Also other measures often used in characterizing materials are the specific tensile strength and the specific Young's modulus. The measures are calculated based on the density of the material. Table 2 lists these properties as derived from data in paper [5]. From this information it is clear that mineral casting is an excellent match for cast iron.

After different formulations were created for mineral casting, specimens were cast using the chipboard molds. They were left to cure at room temperature for more than 72 hours, the time recommended by the resin manufacturer.

Testing took place at the Civil Engineering Testing Laboratory of the Technical University of Cluj-Napoca. The specimens were loaded at low speed and the following parameters were recorded: time, force and deformation. Figure 2 shows a picture of the testing equipment and figures 3 to 5 show pictures of the specimens and testing

3. RESULTS

Figures 6 to 21 present plots of bending stress vs. deformation for each of the specimens subjected to 3-point bend-testing. It can be seen that most materials exhibit an elastic deformation followed by a plastic deformation. Failure takes place suddenly when the maximum bending stress is achieved.

The bar chart in figure 22 displays a comparison for the average properties of each formulation. It shows that material properties vary a lot depending on the aggregates used and the resin content.

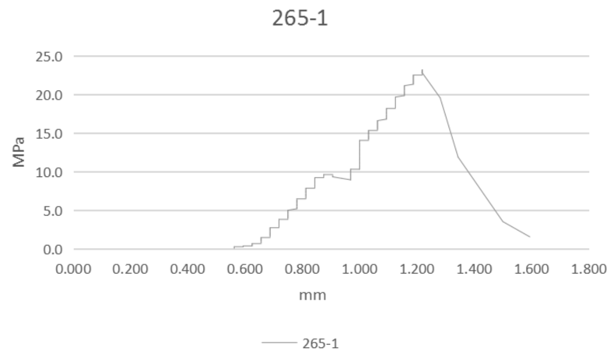

Figure 6: Bend-testing graph for material 265, specimen 1

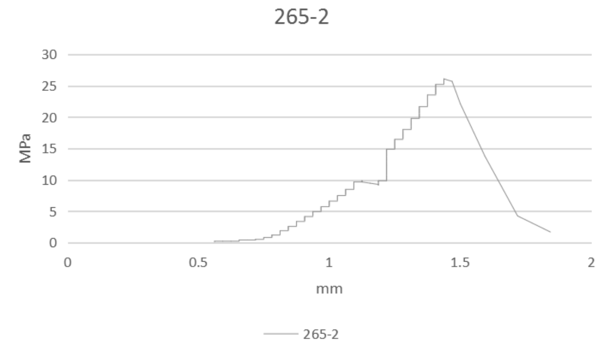

Figure 7: Bend-testing graph for material 265, specimen 2

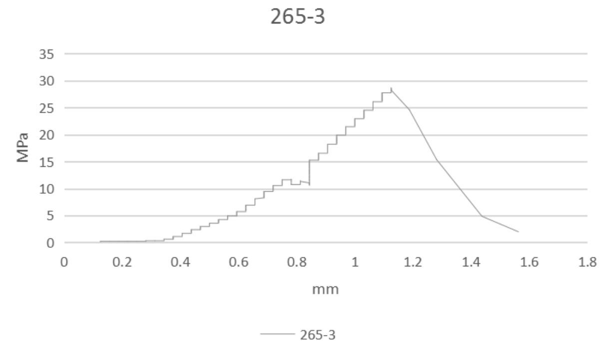

Figure 8: Bend-testing graph for material 265, specimen 3

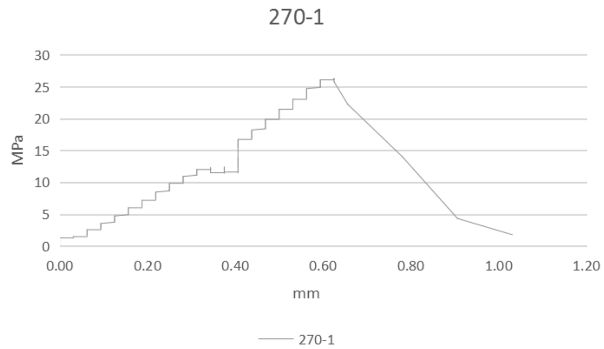

Figure 9: Bend-testing graph for material 270, specimen 1

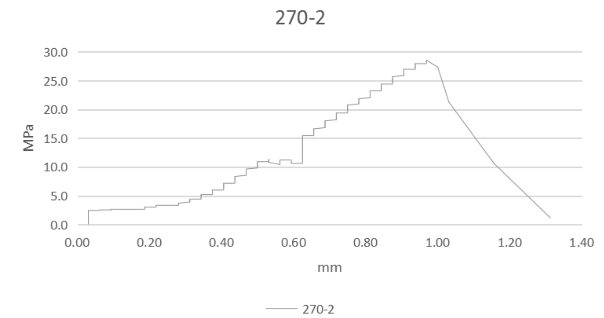

Figure 10: Bend-testing graph for material 270, specimen 2

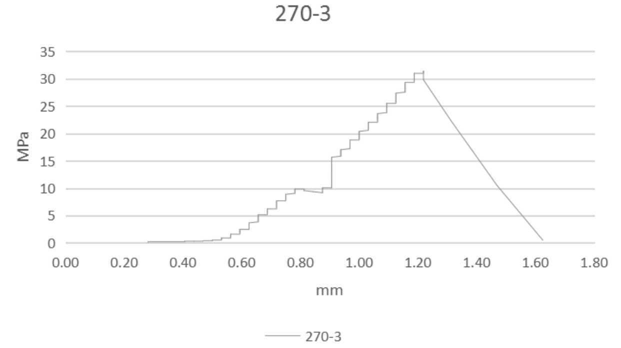

Figure 11: Bend-testing graph for material 270, specimen 3

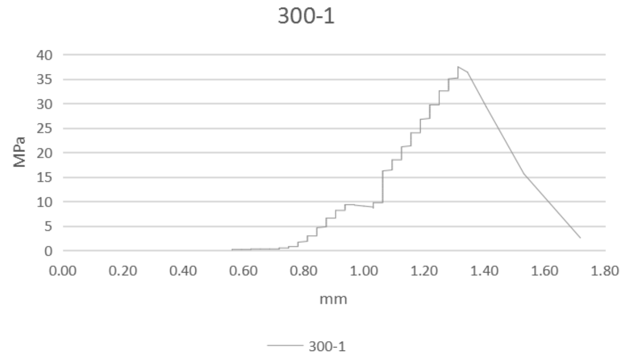

Figure 12: Bend-testing graph for material 300, specimen 1

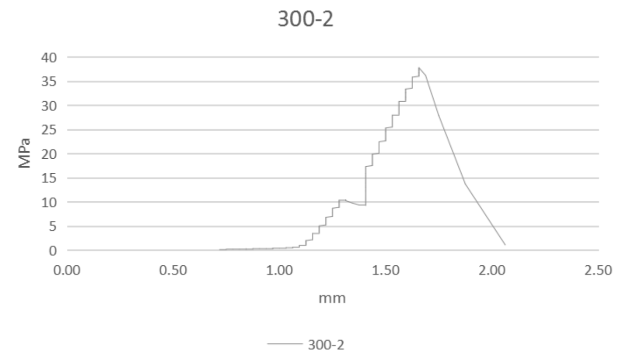

Figure 13: Bend-testing graph for material 300, specimen 2

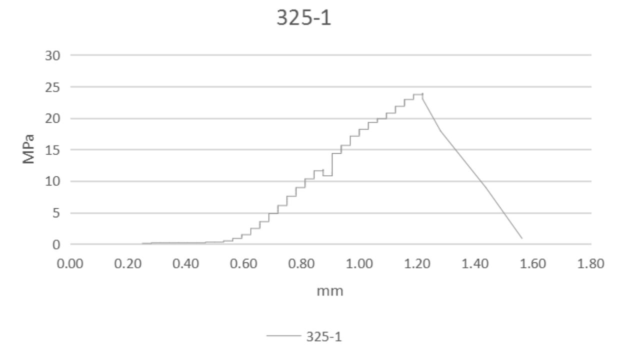

Figure 14: Bend-testing graph for material 325, specimen 1

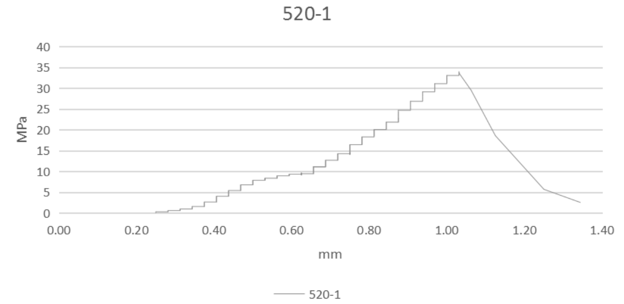

Figure 15: Bend-testing graph for material 520, specimen 1

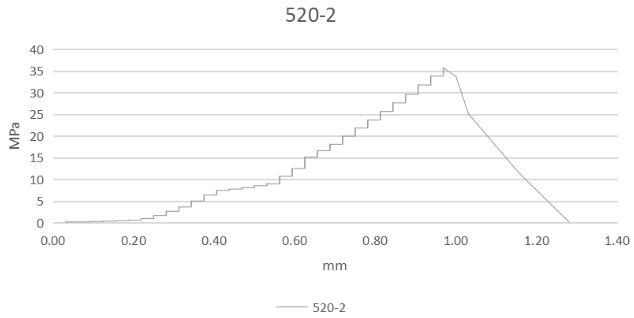

Figure 16: Bend-testing graph for material 520, specimen 2

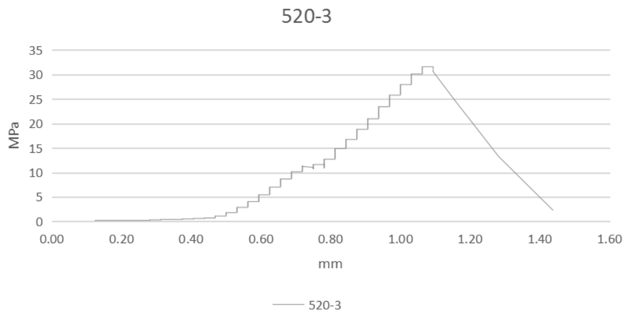

Figure 17: Bend-testing graph for material 520, specimen 3

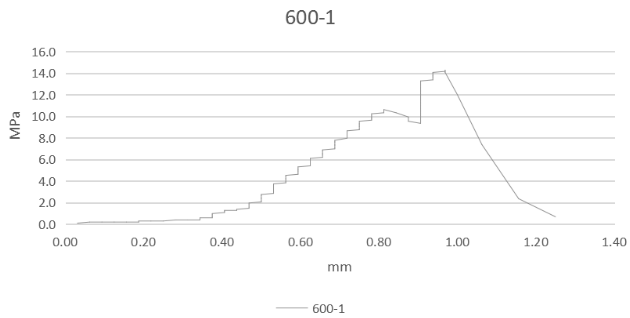

Figure 18: Bend-testing graph for material 600, specimen 1

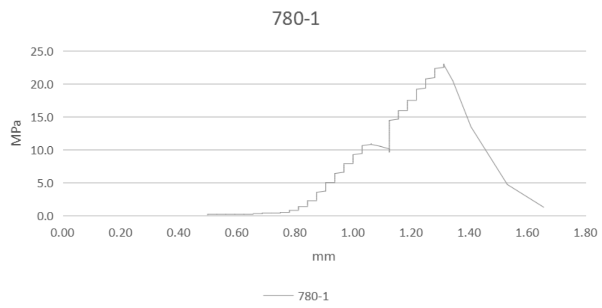

Figure 19: Bend-testing graph for material 780, specimen 1

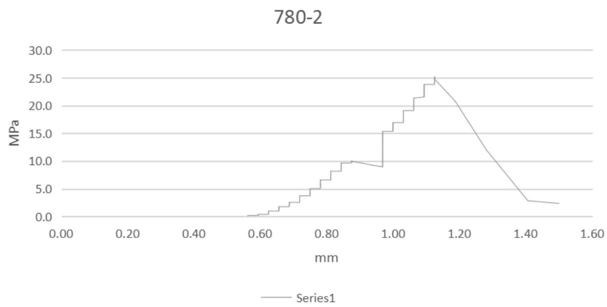

Figure 20: Bend-testing graph for material 780, specimen 2

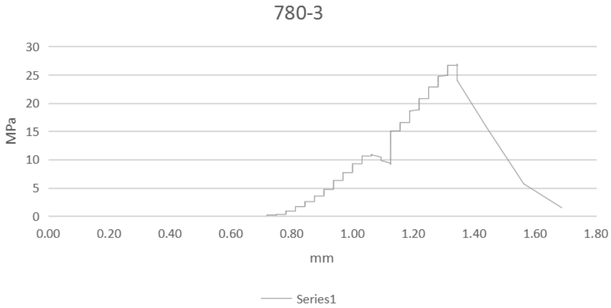

Figure 21: Bend-testing graph for material 780, specimen 3

Figure 19 shows that the best results for bending strength are obtained by formulations 520 with an average value of 33.8 MPa and 300 with 37.6 MPa. Even though material 300 has the largest value, if we look at their testing charts we can see that 300 exhibits plastic deformation, while 520 has mainly elastic deformation. This feature makes 520 a better choice for applications where not only ultimate strength is important, but also behavior up to that point.

The results show that mineral casting is a versatile composite material which allows the tuning of its properties in a great range:

- tensile strength and behavior can be influenced by different aggregate sizes and resin percentage;
- a higher Young's modulus can be obtained using stiffer mineral particles;
- castability / workability can be improved by coarser mineral particles and increased epoxy resin content.

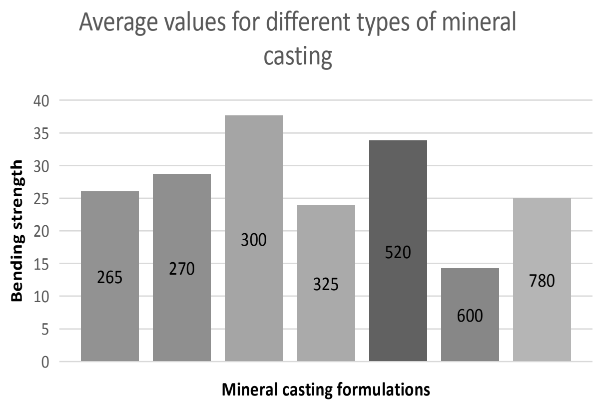

Figure 22: Bending strength of different types of mineral castings

4 CONCLUSIONS

The experimental results show that aggregate gradation and resin content influence the properties of mineral casting greatly. If these parameters are tuned properly, then mineral casting can become an adequate material for use in structural elements of machine-tools or in mold making.

Better mechanical properties can be achieved by applying post-cure heat treatment of the material or by integrating reinforcements such as steel or basalt rebar, glass fiber or carbon fiber. Prestressing of the castings could also lead to improvements, by taking advantage of the compressive strength of the material that is higher than its tensile strength.

Mineral casting is a composite material with many advantages: easy and low cost manufacturing, material low cost, quick production time and excellent mechanical properties. It can be cast and machined by drilling, milling and especially grinding.

The paper summarizes the manufacturing process, describes the testing procedure of mineral casting and compares detailed experimental results for the mechanical properties of different material formulations.

5 REFERENCES

1. Torsten, Erbe, József, Król, René, Theska, *Mineral Casting as Material for Machine Base-Frames of Precision*

Machines, Fakultät für Maschinenbau, Technische Universität Ilmenau, Ilmenau, Germany, (-).
2. Standard EN1015-11:1999: "*Determination of flexural and compressive strength of hardened mortar*", (1999).
3. Class Guss Gmbh, Grey Lamellar *Graphite Cast Iron*, Bielefeld, Germany, (-).
4. Jung Do, Suh, Dai Gill, Lee, *Design and Manufacture of Hybrid Polymer Concrete Bed for High Speed Cnc Milling Machine*. Int J Mech Mater Des, Vol. 4, pp. 113–121, (2008).
5. Norbert, Kepczak, Witold, Pawlowski, Wieslaw, Blazejewski, *The Study of the Mechanical Properties of the Mineral Cast Material*, Archives of Mechanical Technology and Automation,Vol.3, No.2, pp. 25 -32, (2014).

Dezvoltarea și testarea compozitelor minerale utilizate pentru elemente structurale și fabricarea matrițelor

Rezumat: Lucrarea prezintă realizarea și testarea diferitelor formulări de compozit mineral, cu scopul de a identifica formulări cu proprietăți mecanice excelente pentru utilizarea în elementele structurale ale mașinilor-unelte și fabricarea matrițelor. Aceasta descrie procesul de fabricare a materialului compozit din rășină epoxidică și granit. Epruvete din formulări diferite ale acestui material au fost turnate și investigate experimental prin testarea la încovoiere. Pentru fiecare epruvetă s-au trasat grafice de tip stres-deformație, iar valorile medii pentru diferitele formulări au fost comparate între ele.

Mihai CIUPAN, Department of Manufacturing Engineering, Technical University of Cluj-Napoca, Cluj-Napoca, Romania, mihai.ciupan@gmail.com.
Marcel POPA, Department of Manufacturing Engineering, Technical University of Cluj-Napoca, Cluj-Napoca, Romania, marcel.popa@tcm.utcluj.ro.
Ioan Pavel ŞOŞA, Department of Structures, Technical University of Cluj-Napoca, Cluj-Napoca, Romania, pavel.sosa@dst.utcluj.ro.
Glad CONŢIU, Department of Manufacturing Engineering, Technical University of Cluj-Napoca, Cluj-Napoca, Romania, glad.contiu@tcm.utcluj.ro
Emilia CIUPAN, Department of Management and Economical Engineering, Technical University of Cluj-Napoca, Cluj-Napoca, Romania, emilia.ciupan@mis.utcluj.ro.