Polymer Concrete Composite – Preparation of Testing Samples

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***Abstract* – Presented article is focused on manufacture of composite materials based on polymer concrete mixtures. Article describes the very essence of polymer concrete as well as the properties of its individual possible components. In the second part, the paper deals with specific materials, machines and utilities, which are used in the manufacture of composite. The third part of the article describes the manufacturing process itself and the individual stages of production. Conclusion includes the acquired knowledge of the production as well as other possible improvements of the process.**

***Keywords* – polymer concrete, manufacturing, composite material, filler, binder, matrix.**

1. Introduction

Polymer concrete is a new, modern composite material that has found its application in various industries. It consists of a matrix (binder), filler and suitable additives. The main component of the polymer concrete is the filler that forms up to 80% of the volume of the mixture. [1]

It can be organic (natural) or inorganic (artificial). Of the organic, the most commonly used are silica, granite, calcite, basalt and dolomite. In the production of polymer concrete, it is suitable to use several filler fractions to reduce the porosity of the material. The fraction is a part of the filler of the same grain size. In most cases, 2 to 3 fractions are mixed, from powder, through the sand to the coarse gravel. The most used inorganic materials are carbon, glass, steel and in the form of fibers. [3]

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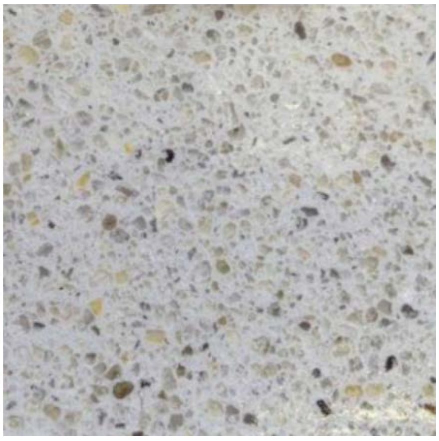

Figure 1. Polymer concrete structure [2]

Figure 2. Carbon, steel and glass fibers [2]

Fibers fulfill the role of dispersed reinforcement. The matrix of polymer concrete is two-component and consists of resin and hardener. For optimum mechanical properties the proportion of the resin in the mixture should be as low as possible. When selecting a suitable resin, the following properties must be observed [4]:

- technological – viscosity, volume shrinkage, reaction rate, shelf life,
- utility – strength, toughness, modulus of elasticity, flammability, heat resistance.

The most commonly used resin for precision casting into complex molds is epoxy resin thanks to low volume shrinkage. Further, the epoxy resin is characterized by resistance to water, alkaline solutions, acids and some solvents. [5]

Table 1. Properties of epoxy resin [6]

Properties	Epoxy resin
In the uncured state:	
Density [kg.m^{-3}]	1100 – 1250
Color	light yellow
In the cured state:	
Volume shrinkage [%]	1 – 5
Compressive strength [MPa]	90 – 150
Tensile strength [MPa]	60 – 80
Modulus of elasticity [10^{3}.MPa]	3 – 4
Coefficient of linear extensibility [10^{-6}/°C]	60 – 65
The softening temperature according to Martens [°C]	90 – 115
Absorption in 7 days [%]	0,1

To the resin a hardener in a specific ratio is added. Hardener contains active hydrogen ions, which react with epoxy groups and an exothermic reaction occurred. [7]

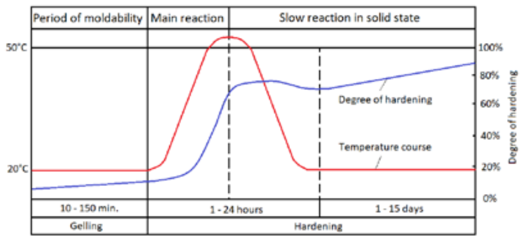

Figure 3. Exothermic reaction [2]

The process for the production of polymer concrete is divided into the following phases: batching, mixing, casting, compaction and hardening. [4]

The most positive property of polymer concrete is damping. [8] According to the available literature, it is possible to state that polymer concrete has 8 to 10 times more damping than cast iron. [9] Using this material for the production of machine tool frame as compared with conventionally used cast iron can reduce the number of oscillations, shift natural frequencies outside the critical area, reducing the amplitude of oscillations at resonance and reduce noise. This should be reflected in a better quality of machined surfaces and a longer tool life. [10]

2. Materials, machines and utilities

The following materials were used to make the polymer concrete:

- fillers
  - silica sand **STJ 25** – grain size 0,06 – 0,31 mm, location of mining – Mladějov, Czech Republic,
  - silica sand **ST 06/12** – grain size 0,63 – 1,2 mm, location of mining – Mladějov, Czech Republic,
  - silica sand **ST PBT 4** – grain size 2 – 4 mm, location of mining – Skalná pri Chlebe, Czech Republic,
  - chopped glass fibers – length 6 mm,
- matrix (binder)
  - epoxy resin **CHS-EPOXY 324**. The resin is designed to bond composites, ceramics, wood, metals etc. It is also suitable for use in sealants, polymer concrete and gravel masses.

Table 2. Properties of CHS-EPOXY 324

Viscosity at 25°C	20 – 60 Pa.s	ČSN 64 0349
Epoxy index	3–3,4 mol.kg^{-1}	ČSN EN ISO 6271-2
Epoxide mass equivalent	294 – 333 g.mol^{-1}	ČSN EN ISO 3001
Color	max. 300 j.Hazena	ČSN EN ISO 3001

  - hardener **TELATIT 0492**. Hardener for two-component epoxy resins.

Table 3. Properties of TELATIT 0492

Viscosity at 23°C	15 – 30 mPa.s	DIN 53015
Density at 23°C	0,93 – 0,96 g.cm^{-3}	ČSN EN ISO 2811-1
Amine number	550 – 600 mgKOH.g^{-1}	PI 627/915
Hydrogen equivalent	min. 49 g.mol^{-1}	
Color	ma. 3 Gardner	ČSN EN ISO 4630-2

Benefits of this system:

- perfect adhesion,
- high toughness,
- high thermal and chemical resistance,
- has no hygienic limitations such as phthalates modified with epoxides.

Table 4. Application properties of the system

System	Max. exotherm	Gelling time	Moldability time
	[°C]	hours [23°C]	min. [23°C]
CHS-EPOXY 324/ TELATIT 0492	118	3	50-70

The mixing ratio between CHS-EPOXY 324 and TELATIT 0492 is 100:16.

Table 5. Properties of the hardened system

System	Shear strength	Peel strength	Maximum temperature	Tensibility
	ČSN EN 1465	DIN 53 282		
	[MPa]	[N.cm^{-1}]	[°C]	[%]
CHS-EPOXY 324/ TELATIT 0492	25	14	80	3

Chemical resistance of the system CHS-EPOXY 324/ TELATIT 0492:

- the system resists dilute mineral acids (hydrochloric acid 10%, nitric acid 10%, sulfuric acid 30%),
- the system resists alkaline solutions (sodium hydroxide 40%, ammonia 10%), water, detergents, oils, mineral oils, gasoline,

- the system does not resist organic acids (acetic acid 5%, lactic acid 10%),
- the system does not resist organic solvents (ethanol, xylene) mostly acetone and butylacetate.

For the production of polymer concrete, these machines were used:

Electric stirrer **Makita UT1200.** Properties of Makita UT1200: input power = 960W, maximum diameter of the stirrer = 120 mm, fastening system = M14, operating speed = 0 – 360 min^{-1}, weight = 3,2 kg.

Figure 4. Makita UT 1200

Vibration table **Lievers LTT 40/40.** Properties of Lievers LTT 40/40: voltage = 220V, engine type = ETR 65/3, operating speed = 3000 min^{-1}, centrifugal force = 0 – 66 kg, weight = 29 kg.

Figure 5. Lievers LTT40/40

A plastic mold was used for the production of polymer concrete castings. The mold has two holes in the shape of a cube and dimensions 100x100x100 mm.

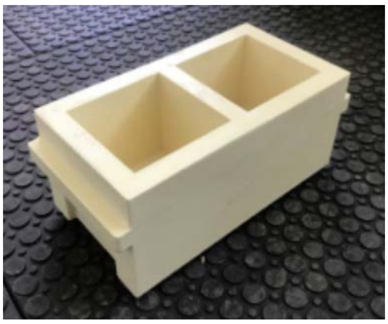

Figure 6. Plastic mold

Other utilities were: ladle, pail, measuring cups, vaseline, paintbrush, protective equipment, thinner.

3. Manufacturing process

Polymer concrete samples were produced in workroom at the Faculty of Manufacturing Technologies of the Technical University of Košice with a seat in Prešov.

Date of manufacture: 14.08.2018
Room temperature: 24,8°C
Relative humidity: 55%

First, the mold was properly cleaned and lubricated with vaseline. This ensures a simple removal of the polymer concrete cube from the mold.

Figure 7. Mold lubrication

After that the necessary quantities of individual components of the mixture were measured.

Table 6. Ratio of components in a samples

Sample no. 1	
Filler 75%	50% silica sand STJ 25
	50% silica sand ST PBT 4
Binder 25%	100 parts CHS-EPOXY 324
	16 parts TELATIT 0492
Sample no. 2	
Filler 50%	1/3 silica sand STJ 25
	1/3 silica sand ST 06/12
	1/3 silica sand ST PBT 4
Binder 50%	100 parts CHS-EPOXY 324
	16 parts TELATIT 0492
Sample no. 3	
Filler 60%	40% silica sand ST 06/12
	40% silica sand ST PBT 4
	20% chopped glass fibers (6 mm)
Binder 40%	100 parts CHS-EPOXY 324
	16 parts TELATIT 0492

Figure 8. Measuring the volume of components

These components were poured into pail and thoroughly mixed. The result of mixing was the best distraction of all components.

Figure 9. Filler before and after mixing

After preparation of all the necessary components, the resin and hardener were mixed with the electric stirrer in the prescribed ratio. This process was performed for five minutes. Thanks to that the active hydrogen ions react with the epoxy groups and the exothermic reaction began. After five minutes a filler was gradually sprinked with constant stirring. The filler and the binder were mixed together for an additional 5 minutes to achieve the best possible interconnection of the components. The resultant mixture is a compact moldable mass of dark gray color.

Figure 10. Mixing the matrix and the filler into the resulting mixture

After mixing, the mixture was given into the prepared mold. For filling the mold the trowel was used. The mold was filled up to the top with a trowel. With a trowel we tried to compress the mixture to avoid air bubbles.

A vibration table was used after filling the mold. The mixture was vibrated for 3 minutes. Vibration on the table causes compaction of the mixture and removes any possible air bubbles. After proper vibration, the surface of the mixture is smooth and glossy from the binder ascended to the top.

Figure 11. Filling and vibration

The mold was postponed. After 24 hours the polymer concrete sample was removed from the mold.

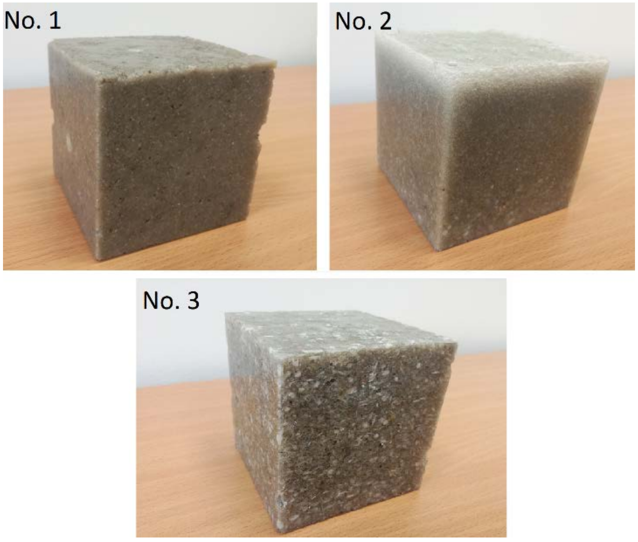

Figure 12. Polymer concrete samples after removal from the mold

4. Conclusion

Manufacture of polymer concrete is a complex process. It consists of several phases, which must be observed. The most important is to determine the correct ratios of filler and binder. Too much binder will cause the filler to set on the bottom of the mold and not fill its volume uniformly. Then a layer of binder is formed on top of the sample, which is not filled with filler but only by bubbles. This problem can be seen on top of the sample number two. In contrast, too little binder will cause a very dense mixture and even after vibration does not fill the entire volume of the mold. It can be seen on imperfect edges and uneven surface of the sample number one. Visually sample three looks the best. The sample number three with a ratio of filler and binder 60/40 has faultless shape. Edges are almost ideal and the surface on the top is the straightest of these samples. This means that the ratio of 60/40 is ideal for the used resin. The resin CHS-EPOXY 324 was very dense and was hard to work with it. Therefore, it was no longer possible to produce a sample with a ratio greater than 75/25. Thanks to this knowledge, the lower-density resin will be used in the future. Lower-density resin should allow a higher ratio of the filler in the mixture and to fill the mold better. These three samples as well as samples from future production will be tested for compressive strength, tensile strength and modulus of elasticity. Test results will be published in the following articles.

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