POLYMER CONCRETE MIXTURES – APPLICATION IN ENGINEERING INDUSTRY

Robert Poklemba*, Jozef Zajac, Darina Duplakova, Peter Cizmar, David Goldyniak

Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Institute of Advanced Technologies, Bayerova 1, 080 01 Presov, Slovakia, robert.poklemba@tuke.sk

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Corresponding Author:
Robert Poklemba, Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Institute of Advanced Technologies, Bayerova 1, 080 01 Presov, Slovakia.
robert.poklemba@tuke.sk

ABSTRACT

This article discusses the properties of concrete composite materials based on their contexture. Systematic and interactive approaches are required in order to achieve optimal material properties in the preparation of composite materials. In order to predict the physical and mechanical properties of each component of the composite material but also as a whole, its optimization, not only the mechanical but also the material properties under different working conditions, requires a combination of different methods and technologies. The advantage of each composite is its specific properties that cannot be achieved by any component of the composite material alone. The strength of the materials based on polymer concrete mixtures can be compared to the strength properties of metals. On the other hand, this material has elastic properties which give the material a high degree of flexibility. When compared to conventional materials, the value of polymer composites is assessed not only in terms of excellent mechanical properties but also in terms of their low weight and cost. The aim of the paper is to describe the advantages and disadvantages of composites based on polymer concrete mixtures.

Keywords: engineering industry, polymer concrete, manufacturing, concrete mixtures, polymer resins

INTRODUCTION

Today, a great deal of emphasis is placed on composite materials. In the last decades, they have become a subject of growing interest for all professions and industries. Without them, we can hardly count on technical progress (Hutyrova et al., 2016; Valicek, et al., 2012). Based on our experience, we try to construct new materials on different bases, which will have more and more special properties. Many composite materials are currently being invented. Progress depends mainly on the approach to the relationship between structure and properties of composite materials, which requires the involvement of different technologies. The investigation and development of these materials must be based on synergies between different disciplines. The polymer-concrete composite material itself brought even better and more efficient properties to the market. The development of these materials is constantly progressing and the possibilities of their use are increasingly affecting the engineering industry as well as other industries. Even though their cost is often high, they are economically more advantageous than various non-composite materials that do not offer as many specific properties as composite materials. The aim of this paper is to point out new trends in the field of composite materials based on polymer-concrete mixtures, investigate their properties, production and possibilities of their use in industry.

POLYMER CONCRETE MATERIAL AND ITS PROPERTIES

Composite materials are artificially engineered technical materials made from two or more basic constituents with significantly different physical or chemical properties, which remain separate and different in the final structure. Each composite material consists of a matrix and reinforcement. Both components must be present in the mixture. The matrix material surrounds and supports reinforcing materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the properties of the matrix. Due to the wide range of available matrix and reinforced materials, the design potentials are incredible. One suitable example of composite material is concrete, which is mainly composed of cement and gravel. The cement forms a matrix and gravel is reinforcement (Campbell, 2010). Polymer concrete is the composite material made by fully replacing the cement hydrate binders of conventional cement concrete with polymer binders or liquid resins, and is a kind of concrete-polymer composite. For hardening of polymer concrete, most liquid resins such as thermosetting resins, methacrylic resins and tar-modified resins are polymerized at ambient or room temperature. The binder phase for polymer concrete consists only of polymers and does not contain any cement hydrates. The aggregates are strongly bound to each other by polymeric binders (Ohama, 2014). Liquid resins for polymer concrete include unsaturated polyesters (UP), epoxy (EP), vinyl esters (VE), polyurethanes (PUR) and polymethyl methacrylate (PMMA). The universal polymers used in structural applications are unsaturated polyesters and epoxides due to their excellent mechanical properties and cost-effectiveness (Asif & Ansari, 2013). Thanks to high performance, multifunctionality and sustainability, polymer concrete composites have become innovative 21st-century building materials. Among the great advantages of properties of polymer concrete materials are high strength and rigidity, low weight, corrosion resistance, good static and dynamic load properties and also good damping properties. Table 1 shows comparison of basic strength characteristics of polymer composites with metals. Polymer composite materials are the most widespread of all types of composite materials, their greatest advantage compared to metal and ceramic materials with low density and corrosion resistance (Wahby, 2003).

Table1. Comparison of basic strength characteristics of polymer composites with metals

Material	Average density (g/cm^3)	Strength (MPa)	Specific strength (MPa. cm^3/g)	Normalized strength
Polypropylene / glass yarn	1.48	720	486	1
Steel	7.8	286-500	36-64	0.07-0.13
Copper alloys	8.3	60-960	7-116	0.01-0.24
Aluminum	2.6	40	15	0.03

The resulting properties of polymer concrete depend on the properties of individual components, their ratio as well as on preparation conditions. Figure 1 shows the cross-section of polymer-concrete product. The higher the polymer content, the higher the flexural strength and the flexural modulus, but its excess reduces the compressive strength. Other important properties of polymer-concrete include (Mráz & Talácko, 2006):

- Minimum stresses in polymer-concrete castings - when the casting is cooled from the casting temperature to the operating temperature, there is minimal shrinkage and cooling stress. High-quality polymer-concrete has a resulting shrinkage of 0.02-0.03%.
- Minimal impact of moisture on volume and dimensional changes - high-quality polymer-concrete is more hydrophobic than natural stone and is therefore used for the production of measuring instruments,
- Structural variability - a wide range of applications of polymer-concrete, where castings from several hundred grams up to several tons can be produced,
- Resistance to aggressive chemical influences - polymer-concrete with a suitable surface treatment is resistant to the effects of mineral oils, coolants, lubricants, hydraulic oils, cleaning agents,
- Dimensional accuracy of production - low internal stress and minimal shrinkage of polymer-concrete allow the production of castings with finite accuracy (so-called finished), which reduces machining costs. In practice, only working surfaces are used to achieve the required tolerances,
- Recycling - polymer-concrete is used as a building material after being crushed,
- Corrosion resistance,
- Possibility of integrating functional parts into castings - integration of distribution systems.

Figure 1. Cross-section of polymer-concrete product.

MANUFACTURING OF POLYMER CONCRETE MATERIALS

The polymer concrete is composed of three components: filler, binder and additives. The ratio of the individual components affects the resulting properties of this composite material. For the production of polymer-concrete products, demountable moulds are used, which are filled by casting technology. The whole process is carried out on vibration tables to improve compaction. Subsequently, the solidification process takes place, the exothermic reaction in which the material is heated to a maximum of 50 ° C to 55 ° C. (Yin, Zhang, Wang, Wang, & Ren, 2015)

Filler

Fillers of composite materials based on polymer-concrete mixtures are formed of natural minerals (SiO_2, Al_2O_3, TiO_2, Fe_2O_3, Cr_2O_3, CaO, MgO, Na_2O, etc.) or of artificial materials such as glass and metal fibres and balls or metal powder Inorganic fillers may have different structures. The filler constitutes 80% by volume of the mixture. The types of filler structures and their associated materials are shown in Table 2. On the basis of these components and their combination, the final properties of the polymer-concrete can be achieved (Mráz & Talácko, 2006):

- high compressive strength,
- good chemical resistance,
- low moisture absorption,
- good wettability to the binder.

Table2. Filler structure

Filler structure	Material
Powdered	glass, quartz, dolomite, feldspar, basalt, limestone and others
Platelet	mica, graphite, talc, kaolin and others
Fibrous	carbon, glass, aramid fibres and others

The quality of polymer-concrete and especially its strength is given by low porosity (the lower porosity, the better strength). This means that the resulting cavities between the coarse grains are filled with finer particles and binder. The lower the proportion of resin in the mixture ensures the better the strength parameters. Despite the use of very fine fractions, zero porosity will never be achieved. To put it simply, even the smallest particles cannot fill the gaps without residue (Patočka, 2007).

Important properties in the polymer-concrete mix design shape (granulomorphism) and size (granulometry), filler distribution and filler weight fraction. Fillers for polymer-concrete adapted for engineering use consist of three to four components. The dimensions of the individual filler components range from 0.1 mm (stone meal) to 2 mm (sand) to 16 mm (gravel and stones) (Mráz and Talácko, 2006).

Figure 2. Fillers

Binder

The binder, also called the polymer-concrete matrix, consists of two components, which are resin and hardener. They make up approximately 20% of the total volume and their proportion in the mixture should be as low as possible in order to achieve ideal properties. Therefore, when selecting a resin, it is also necessary to take into account its properties, whether technological – (viscosity, volatile content, shelf life, etc.) or utility (flammability, heat resistance, strength and others). Epoxy resins are most commonly used, but we can also use:

- Polyester,
- Polyurethane,
- Poly-Acryl.
- Phenol-formaldehyde,
- Methyl methacrylate and others.

Epoxy resin

Epoxy resin is a liquid viscosity substance and hardeners in liquid or powder form are used to cure it. The hardener is a solution or mixture of inorganic (for example polyamines, isocyanate) or organic acids (carboxylic acid) in various concentrations. Curing usually takes place at room temperature. Compared to polyester resin, epoxy resin is characterized by less volumetric shrinkage and longer pot life. It has good mechanical, chemical and electrical properties. Materials with these resin matrices are not suitable for operations above 80 ° C (Chwala, 2012).

Ingredients

Additives are agents added to the matrix that affect the final properties of the polymer-concrete mixtures such as mechanical and fire properties or corrosion resistance. With the correct combination of all components of the binder system, precise casting parameters can be achieved.

Additives used in the production of polymer-concrete include (Chwala, 2012):

- Dyes,
- Viscosity-reducing agents,
- Mould leakage, deaeration and adhesion promoters,
- Substances to facilitate mould removal (mould release agents).

APPLICATION OF POLYMER CONCRETE MATERIAL IN MANUFACTURING INDUSTRY

Polymer concrete is one of the most commonly used materials and ranks among particulate composite materials. Polymer concrete is used to produce castings weighing several kilograms up to several tons, offering a wide range of applications. Nowadays, bases for machine tools and measuring machines are used mainly in the machine, electrical, food and chemical industries. The process of manufacturing castings based on polymer concrete mixes consists of individual steps (Figure 3), resulting in a final material that meets predetermined parameters (Kender, 2016).

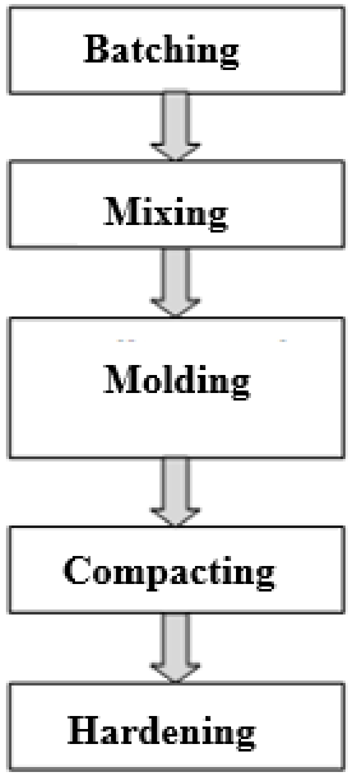

Figure 3. Casting production process

Batching

Batching is a process that is carried out by volume screw conveyors (loose materials), respectively, dosing pumps (liquid components), or weighing on precision scales. The exact weight fraction of filler and binder is derived from the manufacturer, application and recipe. Dosing is provided by automatic machines in order to achieve the exact ratio of the individual components (Figure 4). The advantage of automatic dosing machines is the speed that ensures that the individual components in the mixer become a homogeneous mixture. For batching they are used (Bratukhin, 1995):

- Screw conveyors – for bulk materials,
- Metering pumps – for liquid components,
- Accurate weight – gravimetric dosing.

Mixing

The mixing of polymer-concrete mixtures takes place in two phases (Bratukhin, 1995):

- The first phase – separate mixing of the filler of different fractions according to grain curve and type of resin with hardener
- The second phase – mixing of all components into the resulting mixture, in this phase, it is important that all grains are coated with a resin binder

Figure 4. Example of mixing and dosing machine

Figure 5. Molding

Moulding

The casting process takes place after the mixing phase by means of casting machines or the polymer-concrete mixture is poured directly from the mixer. From an economic point of view, it is advisable to cast several castings at once if they are not oversized, saving time - the machine is in operating mode and does not need to be cleaned. The casting is followed by a compaction process and vented (Buksa, 2008).

Compaction

Compaction is used to reduce the volume of air pores that can increase during previous steps. The two principles that work best have been used for compaction:

- Shaking tables
- Vibration motors mounted on the outer mould wall

As a general rule, large and heavy moulds use a low speed with high force, and light and table mould the opposite. When vibration is oversized, particle resonance can occur, turbulent flow occurs and the air is absorbed. In some cases, raising the temperature can help prevent it (Buksa, 2008).

Figure 6. Vibrating table (platform)

Hardening

During curing there is an exothermic heat escape reaching a temperature of up to 50 ° C, at least after 12 hours it is possible to remove the casting from the mould. After 24 hours, the casting has final properties and can be further machined. Hardened polymer-concrete should be seen as a synthetic stone. Accordingly, the polymer-concrete can be processed by natural stone processing methods: polishing, drilling, sandblasting, cutting and the like. However, further processing is inefficient. It is more economical to achieve the desired moulding properties. Materials used in the manufacture of moulds (Snoeck et.al., 2015):

- Cast iron
- Aluminium
- Wood
- Foam plastics
- Steel

Processing of polymer-concrete after its wear

Polymer-concrete meets all the requirements for environmentally friendly material. The cured material is chemically inert and free of health risks. Unnecessary castings or parts of them can be stored in construction waste dumps. The concrete blocks can be processed by crushing into mixtures for road construction and other construction needs after separation of the other parts. Polymer-concrete can be recycled at the end of its useful life and is also called a modern unconventional material (Yin et al., 2015).

CONCLUSION

Quality, economic aspects, durability have a very important role to play in materials. In the context of industrial engineering practices, innovation, development and composition of materials are increasingly emphasized. Competition in the field of materials is very demanding, but there is still a need to market new materials that will have better properties and will not be expensive. Polymer concrete is one of the most commonly used materials and ranks among particulate composite materials. Polymer concrete is used to produce castings weighing several kilograms up to several tons, offering a wide range of applications. Nowadays, polymer concrete materials are used for the production of bases for machine tools and measuring machines, which are used in the engineering, electrical, food and chemical industries. The aim of this paper is to give the most comprehensive overview of the materials and technologies used for the production of polymer concrete and its use in construction practice.

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