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The effect of the type of curing agent on selected properties of epoxy mortar modified with PET glycolisate

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HIGHLIGHTS

- Epoxy mortars modified by PET glycolisate were obtained.
- Epoxy mortar was hardened using three different amino curing agents.
- Selected physico-mechanical properties of modified mortars were determined.
- The curing agent that allows the obtainment of the best composites was indicated.
- A significant impact of the type of curing agent was confirmed.

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ABSTRACT

In the area of chemical applications in construction they are new materials, which do not have equivalents in nature. Polymers can be used to successfully replace traditional materials of the wood, metal or ceramics types. Among the polymers, one of the most important groups are epoxy resins, whose popularity stems from a combination of excellent mechanical and chemical properties. At the same time, the characteristics of epoxy resins are strongly dependent on the type and quantity of curing agent. The article presents the results of research on epoxy mortar modified with PET glycolisate, hardened by using three different amine curing agents. Characteristics such as flexural and compressive strength and water absorption were determined. The results were subjected to statistical analysis and compared, indicating the curing agent that allows the obtainment of a composite that is characterized by the highest values of the tested parameters.

1. Introduction

Building chemistry is now to a large extent the chemistry of polymers. Polymeric materials engineering has become an indispensable part of modern construction, because it allows for the designing of products with desired properties and reductions in the cost of their manufacture and use. The most popular group of polymers in the world are the thermosetting polymers. This is due to their wide range of application possibilities. They are used for the production of varnishes and waterproofing and sealants, laminates and binders to rock wool [1]. They are used in coating and assembly materials, and key importance is attached to insulation products produced with them [2]. They are a popular component of paints. They are also used to modify the autoclaved concrete and sand-lime bricks [3]. They are used as a main ingredient in adhesives [4], as well as a matrix of composite materials on a micro-scale (nano-composites) [5] and macro-scale (mortars, concretes) [6–14].

In turn, among the thermosetting polymers, one of the most important groups are epoxy resins, which have been used in many industries since the nineteen-fifties. The popularity of epoxy resins stems from a combination of excellent mechanical and chemical properties that can be adjusted to the required value, depending on the specific application. The characteristics of epoxy resins are strongly dependent on the type and quantity of curing agent, as well as the processing parameters, such as the time and temperature of curing [15–16].

Epoxy resins are compounds containing more than one epoxy group (oxiranes) per molecule, which are capable of poly reactions (also called curing reactions), in which across-linked, insoluble and infusible material is obtained. Typically, this name also refers to hardened resins, despite the fact that they no longer include epoxy groups of the form shown in Fig. 1 [17–18].

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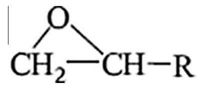

Fig. 1. The epoxies group of epoxy resins.

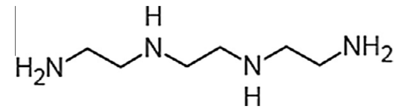

Fig. 4. General formula of triethylenetetramine.

The most commonly produced epoxy resin is the so-called bisphenol epoxy resins. They are obtained from the p, p-hydroxy phenylpropane (Bisphenol A or BPA) and 1,2-epoxy-3-chloropropane (epichlorohydrin) in an alkaline medium. The general chemical formula for epoxy resin shown is in Fig. 2.

Uncured epoxy resins are viscous liquids or solid bodies with a molecular weight of not more than 4000 g/mol. In this form, however, they do not have practical applications. Only their cross-linking in the so-called curing process allows the obtainment of a material with excellent application properties. The cross-linking process gives the resin usable properties, the material becomes resistant to melting and insoluble. Design and manufacture of high-performance epoxy resins is therefore possible by understanding the changing behaviour of monomers, from the unhardened to hardened state [16,19–24].

The epoxy resin curing process is a chemical reaction of resin molecules present in the function groups with active curing groups. The structure of epoxy resins contains two types of function groups participating in the cross-linking, i.e. epoxy groups, which are located at the ends of the chain and hydroxyl groups, attached along the chain macromolecules. As the amount of epoxy groups does not depend on the degree of polymerization of the resin, so with increasing molar mass the number of hydroxyl groups increases. Cross-linking is polyaddition or ion polymerization, and is without the secretion of low-molecular-weighty-products, which distinguishes the polycondensation reaction [25]. For epoxy resins, there are many possibilities for the selection of curing agents, which are at the same time modifiers of the properties of the binder. The parameters of cured resin are affected not only by the qualitative selection of curing agent, but also the determination of the optimal amount. Changing the amount of curing agent in some cases is possible in a wide range, causing a gradual change in the properties of the binder. Often, however, the amount of curing agent is due to the stoichiometric calculations related to the course of the reaction, and changing the fixed quantity can cause significant deterioration of properties of the obtained composite and interfere with the curing process [26].

Anhydrous and amino curing agents are of primary significant economic importance. In the case of multiple resin composites, it is possible to carry out the process of curing only at room temperature "cold", then aliphatic amines are most commonly used.

The reactions of amines with epoxy compounds run by the addition of an amine to the epoxy group with the creation of amino alcohol, which in turn reacts with the next epoxy group. A simplified mechanism for curing of epoxy resins with primary amines is shown in Fig. 3.

The catalysts of these reactions are the hydroxyl groups that arise in this process. Cross-linking reactions occur until depletion of the function groups in the resin and the curing agent. In practice, one of the most widely used curing agents for epoxy resins is triethylenetetramine (TETA), with a general formula as shown in Fig. 4.

This is an aliphatic amine, which contains 6 active hydrogen atoms. Ethylene diamines cross-link extremely quickly and with small distances between the centres of active curing agent, causing dense cross-linking of the resin.

Due to the extremely significant influence of the type of hardener on the final properties of the composite, the authors of this study have already started to determine which of the available curing agents will allow the obtainment of the best performance epoxy mortar, if it is modified. In previously conducted studies [11–14] a curing agent recommended by the manufacturer for commercial epoxy resin was used. The tests described in this article have shown that use of a different curing agent for modified resin allows the obtainment of better results. The article presents a comparison of selected technical characteristics of hardened epoxy mortars using three different amino curing agents. To produce the mortar glycolisate of poly(ethylene terephthalate) was also used, which partly replaced the resin. This modifier allows

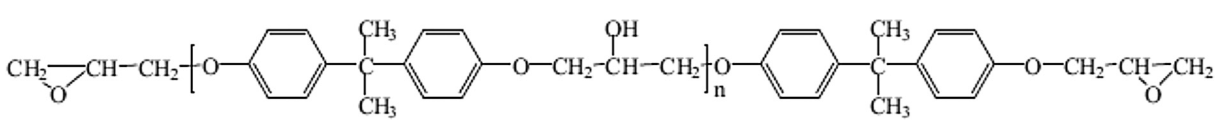

Fig. 2. Chemical structure of epoxy resin.

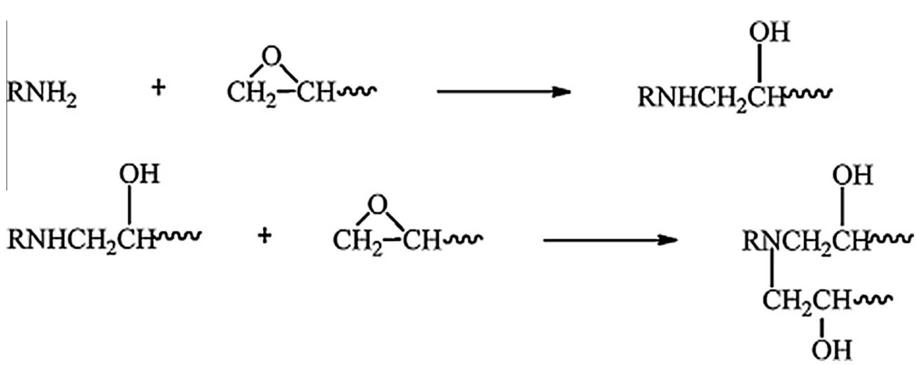

Fig. 3. Cure reaction mechanism of amine and epoxide.