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A study of the effect of corrosive solutions on selected physical properties of modified epoxy mortars

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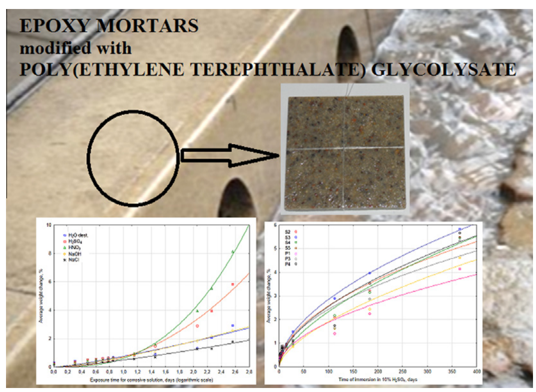
HIGHLIGHTS

- Investigated chemical resistance of epoxy mortars modified by PET glycolysate.
- The results obtained were shown as trend functions.
- Polymer mortars are excellent for use in the chemically aggressive environment.
- Application of plastic wastes allows making mortars of good chemical resistance.
- Investigated mortars are an innovative solution in construction materials.

GRAPHICAL ABSTRACT



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ABSTRACT

A partial replacement of resin binder in epoxy mortars by PET waste based glycolyzates makes these building materials ecologically and economically interesting. The article presents the results of the first phase of research on epoxy mortars modified with poly(ethylene terephthalate) (PET) glycolyzates. Changes of some chosen mortar parameters (weight change, appearance of mortar specimens) due to the effect of the solutions of five aggressive media were monitored for twelve months. It was established that unlike ordinary cement mortars, the building composites that were obtained showed very good chemical corrosion resistance. The results of the investigation were presented as the trend function.

1. Introduction

Nowadays, the list of requirements imposed on construction materials often includes, besides good strength characteristics, also that of high chemical resistance which should assure appropriate protection and prolong the lifetime of the structure. The innovative and modern material that perfectly meets all the strict standards in terms of lifetime, chemical resistance, environmental friendliness and high mechanical strength is resin concrete.

Resin concretes are cementless building composites obtained by mixing synthetic resins, polymers or monomers with an appropriately selected aggregate and then by curing the resin binder. These composites are grouped into resin concretes based on binder cured following the policondensation reaction (e.g.

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phenol–formaldehyde resins) with a by-product (e.g. water) or following the polymerisation reaction without a by-product (e.g. epoxy, polyester, vinylester and acrylic resins) [1]. Strength improvement, compared with ordinary concrete, and chemical resistance in particular depend first of all on the resin binder which has replaced the weakest component of standard concrete, i.e. hydraulic mineral binder. Given high mechanical strength, impermeability and first of all chemical corrosion resistance, resin composites can have the following application range [1–5]:

- Anticorrosive shields used to counter unfavourable weather conditions while building bridges, roads, hydro and sea structures and also in urban building.
- Parts of pipelines carrying highly corrosive materials (pipes, troughs).
- Sink basins, telecommunication chambers and their components.
- Constructions exposed to chemical hazard. Road surfaces exposed to heavy traffic (crossroads and parking bays). Windmill foundations, transformer station casings or trail cross-sills.
- Floors used in the electronic, food and pharmaceutical industries and in public facilities such as sports halls, gyms, and banquet halls.
- Making or repairing road, airfield or bridge surfaces, bridge heads, bank reinforcement and sea structure foundations.
- Parts of bridge drainage systems (bridge cornices, curbs, inlets, sewage pipes) production of linear drainage prefabricates, (ducts, troughs and gullies of linear drainage).

Resin concretes are used for repairs, first of all when previous functional ability has to be restored within a few days or even hours. They find their application in repairing structures made of upgraded strength concrete, in conditions of chemical aggression exposure (e.g. electrolytic tanks in the copper industry), in the manufacture of pipes for microtunnelling (ditchless pipe-laying to build underground water supply systems). Last but not least, resin concretes are used to produce prefabricated units of so-called synthetic marble (window sills, tiles, sanitary units, curbs, slabs, etc.) [1]. However, a universal application of polymers is limited due to the fact that the polymer composite production is more expensive than that of ordinary concretes, first of all because of high-priced polymer resins which are likely to be expensive also in the future as a result of possible crude oil crises.

Thus, it is vital that further research be conducted to find new possibilities of utilising polymer waste (mainly plastic waste) as a modifier of building materials. The constantly growing amount of plastic waste causes both ecological and economic problems, which results from its slow biodegradation pace. Reasonable waste management is one of the priorities of comprehensive environmental protection. Responsible recycling of such waste is also important for a sustained development of world's societies.

While assessing the usefulness of recyclable waste for concrete and mortar modification the authors turn their particular attention to poly(ethylene terephthalate) (PET). PET is the linear polyester of terephthalic acid ethylene glycol (or ethylene oxide). It is also a well-known packaging material used, among other things, to produce beverage containers. The popularity of packaging materials made of this plastic as well as the exceptionally short time of their original use make them an easy-to-get kind of recyclable waste. What is more, the fact that not all PET waste is recycled as well as slow biodegradation pace and big volume make it particularly harmful to the environment. Thus, ecological and economic reasons call for subjecting PET waste material to recycling. They also encouraged many researchers to look for a method of its effective utilisation. It can be seen from the literature that PET waste has also found its application in the production of building composites as a substitute of traditional aggregate [6,9–23] and as reinforcing fibres [24–30] in concretes and mortars.

This waste can also be used to synthesize epoxy or polyester resin which constitutes the binder in polymer mortars and concretes [7,8,31–40].

In recent years research work has focused on the modification of current materials and inventing new, better composites to achieve the ultimate goal which is longer durability and better corrosion resistance of building materials. Numerous research centres [5–8,41–52] try to make new polymer concretes which can successfully protect buildings against the adverse effect of aggressive media.

In the available literature it is possible to find only a few pieces of information on the research regarding the physical properties (% weight change, appearance of specimens) of resin composites exposed to different corrosive solutions. Most publications describe cement containing composites. Ribeiro et al. [52] determined, among other things,% weight change of polyester and epoxy mortars exposed to various weather conditions. Reis [50,51] studied the effect of some selected aggressive media on strength parameters as well as the% weight change of resin mortar specimens. The article presents the results of the study of the effect of corrosive solutions on some selected physical properties (change of weight and appearance of specimens) of epoxy mortars modified with poly(ethylene terephthalate)glycolyzates(PET).

The modification involved a partial replacement of epoxy resin in mortars with poly(ethylene terephthalate)glycolyzates. The poly(ethylene terephthalate) was retrieved, among other things, from waste plastic beverage bottles. They were first cleaned and shredded, then glycolyzed using an appropriate glycol. Before the chemical resistance tests it was decided that only those kinds of aggressive media which might potentially be in contact with finished products will be simulated. The possibility of epoxy mortar being used, among other things, for repair and manufacture of concrete floors or prefabricated elements exposed to a medium of intense chemical aggression inspired an attempt to define the change in the properties of the mortar specimens after exposing them to some selected corrosive media which were: 10% solutions of sulphuric acid, nitrous acid, sodium hydroxide and sodium chloride as well as water. The necessity to test a great number of varied content composites required an appropriate research plan. The use of a statistical algorithm enabled a remarkable reduction in the number of necessary specimens and, consequently, in the number of experiments. The Experiment Planning module from the STATISTICA programme was used in the research. The composition central plan with a repeat of the experiment in the central point was chosen. The distribution of the measuring points on the plan of the experiment is shown in Fig. 1.

A detailed description of the selection of the plan is described in [53]. In the case of the research on chemical resistance the plan took the form of a table (Table 1).

Each of the ten columns of the table presents one point of the plan and describes the composition of the mortars examined. The plan that was selected (Fig. 1) allowed for a repeat of the research at the central point, that is why the plan points denoted as 5 and 6 do not differ in composition. The results obtained during the experiment were analysed with the tools offered by the STATISTICA programme.

2. Experimental programme

2.1. Materials

Epidian 5 epoxy resin was used to obtain resin mortars. Z−1 hardener (trietylenotetraamine) whose amount was 10% (by weight) compared to the amount of resin, was used to cure the resin. The selected properties of the resin and the hardener are shown in Tables 2 and 3, respectively.