Construction Materials

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Coating of concrete structures exposed to corrosive media

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Summary

The paper describes research and development of protective materials based on polymer resins. Instead of usual filler, ground quartz sand, several types of industrial wastes were used. Main aim of the research was to determine the most suitable type of industrial waste material, its treatment and last but not least amount of filler. On the contrary to silicate coatings the polymer-based coatings are not so "sensitive" to chemical composition of the filler. Paper describes methodology, carried out tests, results and possible outcome of the research.

Key words: concrete, corrosive media, protection, polymer coatings.

1. INTRODUCTION

The lifetime of reinforced concrete construction work is substantially limited by the amount of deterioration and chiefly by the corrosion of reinforcement. The causes of reinforced concrete deterioration can be various. In general, aggressive media can be divided according to the types that affect concrete:

- Aggressive gases and vapors with acidic character (CO_2, SO_2, N_xO_y, H_2S etc.),
- Aggressive waters and solutions,
- Hygroscopic solid substances,
- Microbiological effects,
- Mineral fats and oils,
- Stray current that effect reinforcement.

2. STRATEGY OF PROTECTION

The question of protection of reinforced concrete structures depends on the corrosive surroundings to which these structures are exposed to. Protection of concrete structures can be realized in different ways:

- Change of operational and exposure conditions
- Improvement of physical properties of repair materials for original concrete
- Influencing the electrochemical behavior

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- Application of different types of surface treatment

In this paper, the development of surface treatment is discussed. Several effective methods are; coatings, membranes, and impregnation paints. Surface protection of concrete structures is an expensive secondary measure.

A significant part of the costs is the price of the material. One of the possibilities to reduce the price is the choice of less expensive material, but which still provides sufficient protection to the structure. Another possibility is to replace part of the binder with filler. For further price reduction and for ecological benefits, the utilization of industrial waste materials as filler in coatings was suggested.

3. THE METHODOLOGY OF TESTS

At the Institute of Technology of Building Materials and Components, in the framework of research, the problems of the investigated protective coating types were tested. Those that utilize waste materials instead of usual fillers. Tested coatings can be divided into two main groups; silicate coatings and polymer coatings. Polymer coatings are based on polyester, vinyl-ester and polyurethane. They are designed for special applications where the concrete is exposed to a strong corrosive medium. The selection of materials was directed by local accessibility, by urgency of processing or liquidation, and by current known limits of utilization possibility. Admittedly, the waste materials are from local sources and their actual technical properties differ from all other materials, but on the basis of this research it is possible to deduce generally applicable dependences for the same waste materials from other localities.

3.1. Description of individual waste materials used in paints

Fly ash - Fly ash from electrostatic precipitators was used in this work. In this fly ash there are two main components: mullite and β-quartz. Chemical composition is relatively stable SiO_2 57%, Al_2O_3 29%, Fe_2O_3 6,2%, TiO_2 2% , CaO 1,7%, MgO , K_2O 1,8%. Bulk density: 2060 kg/m^3, specific surface: 270 m^2/kg

Slag - Ground blast furnace slag is a granulated material formed by quick cooling of blast furnace slag during the production of iron. The blast furnace slag is very important in the building industry. Chemical composition is variable CaO (30-50%), SiO_2 (30-43%), Al_2O_3 (5-18%), MgO (1-15%), Bulk density: 2810 kg/m^3, specific surface: 380 m^2/kg.

Wastes from the washing of crushed aggregates - In brief, this waste material called “washing waste” is formed during the washing of crushed aggregates in the

quarry. It is mainly the production of washed standard sand. The formed slurries accumulate and then are brought to a stock-pile.

The washing waste has the same mineralogical and chemical composition as the washed sand. The mineralogical and chemical composition depends on the locality of the source. The grain size composition depends on the kind of mineral, the crushing technology, and the method of treatment and separation. The chemical compositions of both samples of washing wastes are given in Table 1.

Table 1. Chemical analyses of waste washings

Compound	Sample 1 Amount %	Sample 2 Amount %
Insoluble material	59.5	91.47
CaO	0.82	1.19
Al_2O_3	0.4	1.39
Fe_2O_3	1.17	1.92
pH	8.5	8.2

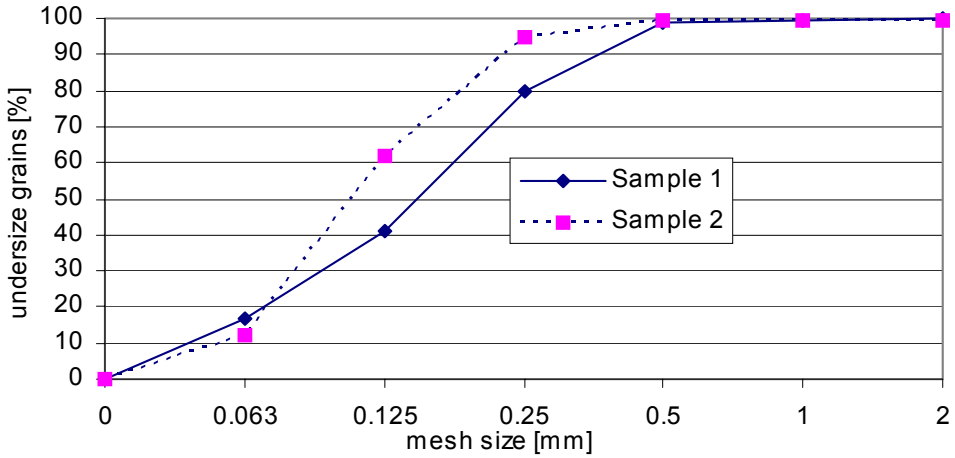

Figure 1. Sieve analysis of washing wastes

Properties of two kinds of material having different properties: Bulk density: Sample 1 = 2170 kg/m^3 Sample 2 = 2690 kg/m^3, Bulk density (jarred): Sample 1 = 1470 kg/m^3 Sample 2 = 1420 kg/m^3.

Minerals determined by X-ray analysis: Sample 1: β-quartz, feldspar, muscovite, kaolinite Sample 2: β-quartz, feldspar, muscovite, kaolinite, gehlenite, montmorillonite.

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3.2. Binders

The experimental work was divided according to three types of binders:

- Vinyl-ester (VE)
- Polyester (UP)
- Polyurethane (PUR)

3.3. Application of coatings and proposed proportions

For all proportions, the coatings were applied by a paint brush on vibro-pressed concrete paving bricks 200 x 200 mm. The composition of the vibro-pressed concrete paving bricks corresponds with requirements for concrete as substrate for testing surface treatment of building structures.

The methodology used for polymer coating is divided into two phases – the 1st phase is selection of most preferable proportions and the 2nd phase is determination of selected coating properties. In the 1st phase, proportions adjusted by the increasing quantity of filler by 5%, in order to determine the effect of filler quantity for constant quantity of binder on individual properties. The 1st phase includes also the testing of basic properties and the selection of most preferable proportions by means of an optimization process for further modification of coatings. In the 2nd phase – tests were performed with coatings following selected proportions to determine their properties.

The method was chosen in order to describe the changes in the coatings behavior, from the minimum up to the maximum percentage filling.

4. TEST RESULTS

The consistency of fresh coating is an important property. It is influenced by the properties of the binder and the amount of used filler. For consistency test results of polymer coatings filled with waste materials see Figure 2.

Very important property of coatings is bond to the substrate. All tested coatings had, due to high quality binder, very good results (see Figure 3).

The character of polyurethane coating significantly differs from polyester and vinyl-ester resin. The high viscosity of the binder limited the filling considerably. This caused a thick of the coating, which can be considered even as excessive. From another point of view this property can be evaluated very positively because the protective coatings perfectly cover small unevenness of the surface. With increasing quantity of filler, the coatings quickly lose their self-leveling properties after application. For this reason the maximum filling was only 30% in the case of

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a coating filled with slag, 20% with washing wastes, and 20% with fly ash, optimal filling was even lower (see Figure 2).

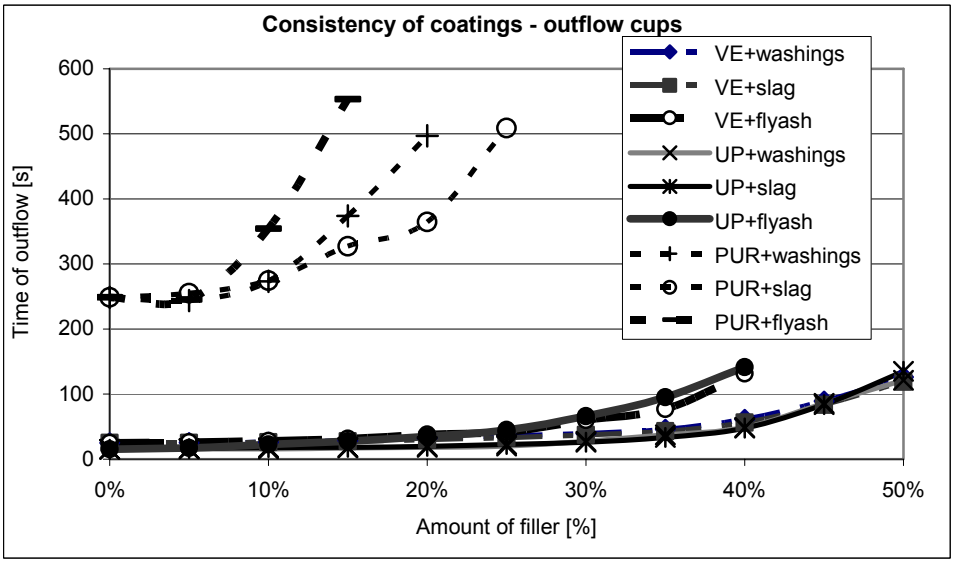
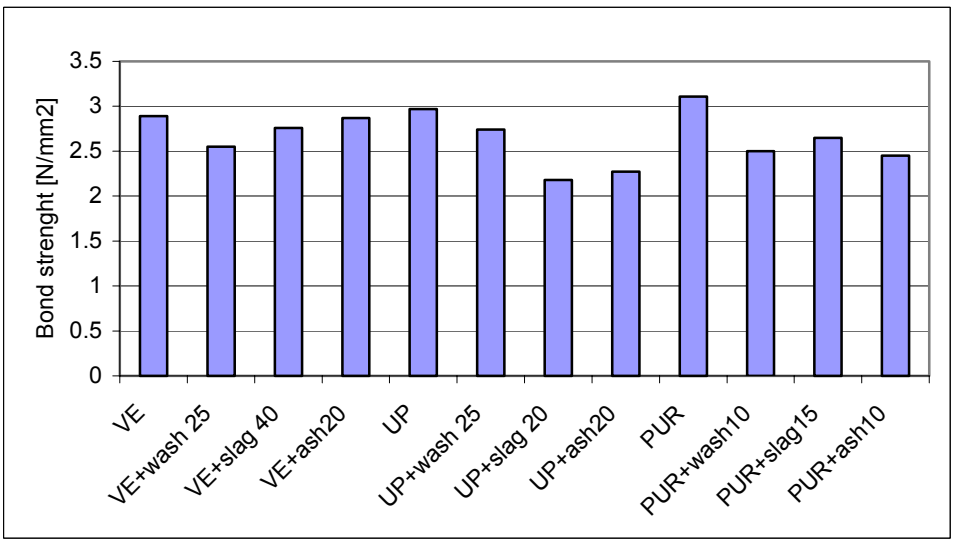


Figure 2. Consistency of polymer coatings in fresh state



Fifure 3. Bond strength of polymer coatings to concrete surface. VE+wash25 – VE binder filled with 25 % of waste washings. Other abbreviations are analogous

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The polyester and vinyl-ester coatings enabled maximum filling up to 50% owing to low viscosity. This meant in the case of transparent vinyl-ester that it obtained covering properties, became non-transparent. The micro-hardness of these resins significantly exceeds the micro-hardness of tested polyurethane. Results often exceed the values of reference samples. The vinyl-ester resin had self-leveling properties even with high percentage of filling with all types of binders and no traces after application with brush were formed.

It was found that if polyester and vinyl-ester were used without filler the gelatinization takes place as a rapid exothermic reaction. The temperature increases up to 60ºC and quick curing and considerable shrinkage takes place. When fillers are added, the curing reaction is not so rapid and the shrinkage is reduced. The shrinkage influence on thin-layer materials is not so significant and the shrinkage is further limited by the addition of fillers.

5. CONCLUSIONS

Filer materials commonly used in coating at the present time are fine ground limestone or ground pure quartz sand. The use of industrial waste materials as a substitute for these fillers was proven and verified for the development of protective coatings. Besides the environmental benefits, this would also have a positive economic effect.

The result of the work verified that the filling with selected raw waste materials has no significant effect on the properties of the coating itself up to a relatively high degree of filling. All test result values exceeded the values required for coatings by relevant standards or technical conditions. The limiting factor for filling the binder is the workability of the fresh coating. The research of long term durability of these coating applications on real structures is in progress.

For the most advantageous utilization of wastes the following proportions were selected:

- Vinilester + 40% slag, with similar properties as VE + 25% washing wastes
- Polyester + 25% washing wastes
- Polyurethane + 15% slag.

In contrast with silicate coatings, the noted proportions of polymeric coatings have more general validity because the polymer binders are not as sensitive concerning the type and the properties of fillers, except for significant changes of pH value. The mentioned proportions for polymer coatings can be used even for other fillers with similar grain size distribution.

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