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Development of a New Polymercement Waterproofing Screed with Secondary Materials

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Abstract: Throughout the world the issue of waste raw materials is still a very important topic. This paper is focused on the possibility of the use of waste raw material originated at high temperatures by the combustion of black coal as a partial substitution of filler component during the development of new waterproof levelling material designated for concrete constructions. The use of the fly-ash as partial substitution of the filler component has important ecological and economic contribution.

Key words: Fly ash, screed, filler, concrete.

1. Introduction

At present, the issue of waste production and subsequent handling of them is a very important topic, together with the ongoing search for new opportunities leading to the reduction in the production of waste materials, but also in supporting the origination of non-waste technologies. The originating waste raw materials can lead to, in most cases the development of secondary raw materials, and are, according to their material properties, used in various industries.

The largest producer of fly-ash achieved by high temperature combustion at a temperature of 1,200-1,700 °C in the Czech Republic is coal and heating power plants. One of the largest power plants of this type in the Czech Republic is the Detmarovice power plant. This power plant produces about 400,000 tons of side energy products each year, including 90% ash materials. One of the resulting factors of ecologic liquidation of this kind of wastes is, for example, use in the building industry.

Levelling of substances is mainly used as the part of the secondary protection of concrete construction and is placed in 0.3 to 3 mm layers. In addition to aesthetical unification of the surface of concrete constructions, it often fulfils some protective function. The selected diagram of the experimental testing was selected so as to cover basic requirements for waterproof levelling layers. It is evident that the basic criterion for the evaluation of the success of newly developed mixtures with partial substitution component by fly-ash was with a waterproof property [1-4].

2. Input of Raw Materials

The reference mixture was an REF, two-component permanently flexible waterproof substance consisting of a dry component on a cement basis and water soluble modified polymeric dispersion. The dry component was the combination of Portland cement CEM II/B-M 32,5 R, ingredients (such as foam remover, thinner, hardening retarder, inorganic die) and fillers consisting of silica sand and milled quartz rock. The dispersion then involves water solution of a copolymer of acrylic ester and acrylonitrile. The filler component was gradually substituted by a certain ratio of fly-ash within the range 10%, 20%, 40%, 50% and 60%.

Composition of the mixture is shown in Table 1.

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Table 1 Dosage of components per 1 kg of mixture.

Mixture	Dispersal (g)	Additives (g)	Cement (g)	Filler (g)	Fly ash (g)
REF	263	25	184	528	-
FASH 10%	263	25	184	475.2	52.8
FASH 20%	263	25	184	422.4	105.6
FASH 40%	263	25	184	316.8	211.2
FASH 50%	263	25	184	264	264
FASH 60%	263	25	184	211.2	316.8

The ratio of the dry component:liquid was 2.8:1.

3. Characteristics of the Fly-Ash Used

The fly-ash is the finest fraction of remainders from the combustion of coal with the graining 0-1 mm, which would have been processed in the separators. It is a heterogeneous material, its chemical, physical and technological properties depend on the quality of the combusted coal (combustible content, ash, water), and the technology of the combustion method, which differ in particular temperature combustion. Two different methods are used during the combustion. In the first instance it concerns fly-ash originated by the combustion of solid fuel, which is running under high temperatures of about 1,400-1,600 °C. These fly-ashes contain, in addition to β-silica and also such instances of a certain volume of mulite and more than 50 % glass phase. In the second phase it concerns a newer technology—fluid combustion of fuel. In this case the milled fuel with the additive of the calcite or dolomite is burned in the circulating layer. There is binding of the released SO_2 and CaO with the origination of calcium sulphate ($CaSO_4$). In the combustion process it performed at the temperature of 850 °C, which is an optimal temperature for the reaction of SO_2 and CaO. The main advantage of the fluid combustion is based on the use of a significantly lower temperature to which reactivity of β-silica relates. A lower temperature of the combustion process can affect a more reactive phase. Other advantages include the removal of SO_2 from the exhaust including the use of less valuable fuel and a relatively high efficiency of the combustion process with the prolongation of its time limit, which leads to a lower carbon content (combustible fraction) in the power plant ash.

Fly-ash is basically a waste, as with any waste, it may report variable chemical, mineralogical and granulometric composition by type of combustion of coal, location and method of separation. The produced fly-ash from black coal has a lower variability of properties and is qualitatively more favourable as an additive into the concrete than ash from brown coal usually. This type of fly-ash can be considered as a valuable secondary raw material due to its pozzolanic properties, which are particularly important for high-volume processing of fly-ash in the building industry.

Generally, we can use the name of pozzolans for materials which are able to react at room temperature with lime $Ca(OH)_2$ and to harden in water environment. The reaction creates stable non-soluble components, which have binding abilities. An ash pozzolanic reaction is defined as the reaction of silicic oxide SiO_2 and aluminium oxide Al_2O_3 from fly ash to calcium hydroxide $Ca(OH)_2$ while generating calcium-silicate and calcium-aluminate hydrating products. When evaluating the pozzolanic activity of fly-ash it is necessary to take into consideration not only the ability to bind $Ca(OH)_2$, but also the course of the reaction between the fly-ash and calcium hydroxide.

Properties of fly-ash are shown in Table 2.

Table 2 Properties of fly-ash.

Specific density	2,015 kg/m^3
Bulk density of aggregate in bulk	1,258 kg/m^3
Bulk density shaken down	1,385 kg/m^3
Modification before use	none
Mineralogical composition	mullite, β-quartz
Specific surface	< 300 m^2/kg

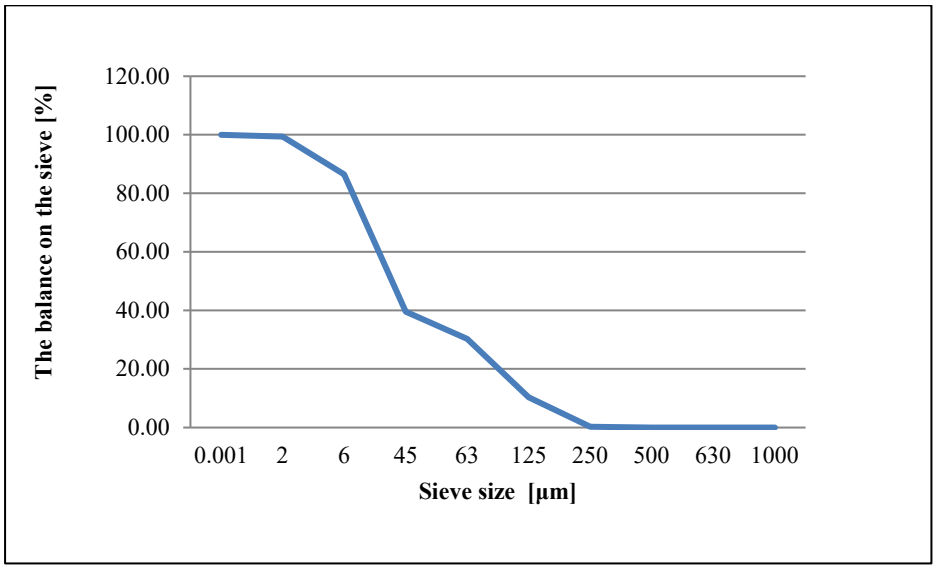

Fig. 1 Screen analysis of fly ash.

Table 3 Chemical composition of fly ash percentage of each element and compound.

SiO_2	Al_2O_3	Fe_2O_3	FeO	TiO_2	Cr_2O_3	P_2O_5	Cao	K_2O	MgO	MnO	Na_2O	S	C
52.4	24.2	6.4	0.3	1.0	< 0.1	0.4	0.4	2.8	2.8	0.1	0.3	0.8	4.5

4. Description of Tests Performed

4.1 Stating of the Consistence of Fresh Mortars (ČSN EN 1015-3)

A test of processability is performed immediately after the creation of a fresh mixture. A tin metal code is filled by fresh mortar twice so that the mixing is performed with a wooden bar with the square basis 30 × 30 mm, applying ten shocks across the diameter of the cone. The mortar must be the subject of proportional shakes on the shaking table by 15 lifts within the time 15 s. The diameter of the originated cake solution is always measured in two perpendicular directions with the precision of 5 mm. The result of the test is an arithmetic diameter from two performed measurements in mm.

4.2 The Depth of Absorption by the Compressed Water (ČSN EN 12390-8)

The concrete testing body with the levelling layer applied was clamped into the equipment and on the surface of the levelling layer water pressure affects 500 ± 50 kPa during 72 ± 2 h. Then the testing bodies were broken in half perpendicularly to the surface on which the water pressure was affecting. The result of the test was visual evaluation of the maximum depth of the penetration rounded to the nearest millimetre.

4.3 Determination of the Cohesion Breaking-Off Test (ČSN EN 1015-12)

The nature of the test is the adhesion and consequent breaking-off of the testing target with the diameter of 50 mm by means of special equipment from the concrete surface on which the tested material is applied. The measured value of the adhesion of the tested material to the concrete base is compared with the minimum requirements which are specified for the stated kind of the substance.

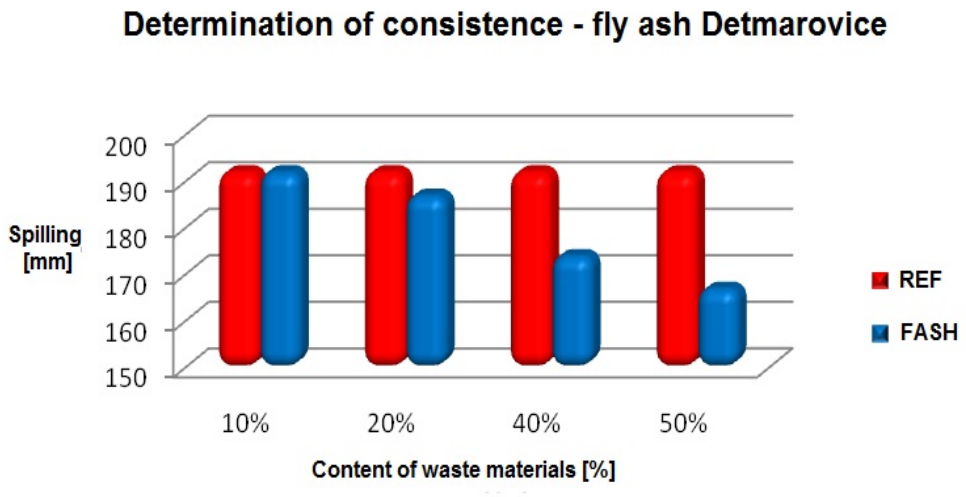

Fig. 2 Evaluation and comparison of the examined mixture workability.

5. Measured Values

5.1 Determination of Consistence

The determination of the consistence was performed after 25 shocks as the diameter of the originated cake of fresh substance in two mutually perpendicular directions. From the measured values in Fig. 1 it was evident that the content of fly-ash in the mixture influenced the value of processability. The increasing ratio of the waste raw material decreased the value of processability of fresh mixture. This status is caused by the high value of specific surface of waste raw material. On the basis of the evaluation of this test, it is possible to conclude all investigated mixtures for horizontal and vertical application.

5.2 Depth of the Penetration by Pressure Water

The waterproof test for the developed waterproof coat decisive criterion for the investigation of other physical and mechanical properties of the newly created formulas meet the waterproof requirements, resulting in measured values stated in Table 3 which shows the partial substitution of the filler by fly-ash is possible. The reference mixture, i.e. without fly-ash up to the mixture with the indication FASH 50% resisted the water pressure and it is possible to consider them waterproof. The evaluation of this test also stated the maximum limit value of the representation of the fly-ash in the formula of waterproof levelling layer which achieved a maximum 50%.

5.3 Determination of the Adhesion by the Break-Off Test

The graphic expression results in the fact that the quantity of waste material contained in individual modified mixtures has a negative influence on the measured values of cohesion of investigated waterproofing coatings on base concrete. The value of the force necessary for the breaking-off of the testing target decreased with the increased ratio of waste raw materials. The higher ratio of fly-ash binds liquid components which causes this effect. In the case of the limit value of the filling by fly-ash of 50%, the force necessary for the breaking of the testing target fulfilled requirements of the standard.

Table 4 Evaluation of the waterproof properties of stated mixtures.

Mixture	Evaluation
REF	allowed
FASH 10%	allowed
FASH20%	allowed
FASH 40%	allowed
FASH 50%	allowed
FASH 60%	failed

Fig. 3 Evaluation of the test for the determination of the depth of penetration by pressurised water on the broken testing bodies.

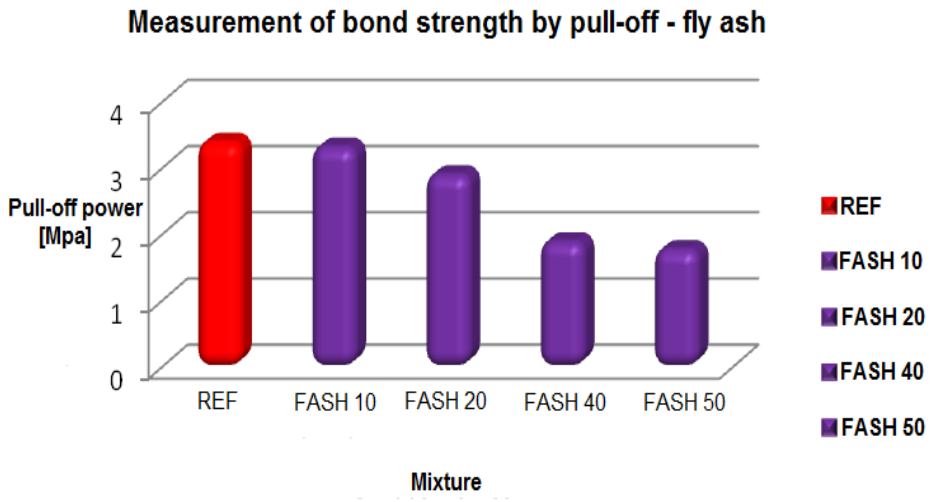

Fig. 4 Evaluation of adhesion of tested mixtures to the concrete base.

Table 5 Economic evaluation.

Mixture	Type of filler	Price of filler (1 t)	The amount of filler per tonne	Financial savings
REF	Silica sand and ground quartz	220 Euro	528 kg	0 Euro
FASH 10%	Fly ash	1.6 Euro	52.8 kg	11.7 Euro
FASH 20%	Fly ash	1.6 Euro	105.6 kg	23.4 Euro
FASH 40%	Fly ash	1.6 Euro	211.2 kg	46.8 Euro
FASH 50%	Fly ash	1.6 Euro	264 kg	58.5 Euro

6. Economic Evaluation

An integral part of this project is, in addition to the development of the levelling layer substance, also the economic evaluation in the instance of the use of waste raw material as the partial substitution of the filler component. The evaluation of the laboratory tests stated that the possible substitution of the siliceous filler by the waste raw material is up to the level of 50%. This phenomenon has important ecological, as well as economic influences whose evaluation is shown in Table 5.

7. Conclusion

The research focused on the development of a new type of two-component waterproof levelling substance for the concrete surfaces with the use of waste raw materials. The main thought of the project was the

verification of the possibility of partial or full substitution of the siliceous fuller component by power plant fly-ash. According to the mineralogical and chemical composition, it was possible to advocate this waste raw material without problem for the use of polymer-cement systems. The overall component of the filler represented 52.8% of the total volume of the material composition of the waterproof levelling layer and in the representative formula it was represented by the siliceous sand and milled silica. The evaluation of the group of basic tests verified the influence of the fly-ash on the resulting properties of the waterproof levelling layer. The main decisive criterion for the investigation of the further material properties of mixtures modified by the fly-ash was the positive evaluation of the waterproof properties according to ČSN EN 12390-8 "Depth of penetration by compressed water". The experiments uniquely state the maximum possible content of fly-ash in the modified formula at 50%. The influence of the fly-ash on the processability of modified mixtures was evident. With the increase of the fine fly-ash, the processability is decreased logically. The last performed test was the determination of the adhesion of surface layers according to ČSN EN 015-12. The adhesion to the concrete base was ensured mainly by polymeric components and the content of the fly-ash, which did not have principal influence on the measured values. The value of cohesion measured for the reference mixture was 3.4 MPa. This value was proportionally decreased depending on the increased ratio of fly-ash. The mixture with the content of fly-ash 50% achieved values of 1.75 MPa, which exceeds the minimum requirements of the standard 1.5 MPa for this type of substances.

A further issue was the performance of the financial calculation of newly proposed formulas. As the representative, the formula with the substitution of filler component at the level of 50% was used. According to the acquisition price of used fillers, it was proved that the substitution of the original filler by the fly-ash at the level of 50% saves up to 58.5 Euro from one ton of waterproof levelling layer.

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