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INFLUENCE OF ALTERNATIVE BINDERS ON PROPERTIES OF CEMENT COMPOSITES

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ABSTRACT

The paper deals with utilization of secondary products as a substitution of Portland cement in cementitious composites. This is a research focused on application of secondary products in building industry. Series of specimens were manufactured with partial substitution of Portland cement by micro-grounded recycled material, fly-ash, or their combination. Specimens with dimensions 40x40x160 mm were subjected to flexural loading and fragments from flexural tests were tested in compression.

Keywords: Fly Ash, Mechanical Properties, Micro-Ground Recyclate, Recycled Materials, Substitute Binder

I. INTRODUCTION

Utilizations of recycled materials is one of European Community priorities. Waste management plans established in the Czech Republic aim to achieve re-use of 75% volume of the construction waste. The 7th Environmental Action Programme for Europe promotes increase of recycling and re-use of materials. In accordance with these requirements utilization of the secondary raw materials is investigated, such as recycled concrete. Crushed concrete is a typical example of construction and demolition waste it is generally used as substitution aggregate. It appeared that recycled concrete after grinding to very fine particles has also hydraulic properties. So that it could be used as an alternative binder. There are other alternative binders as geopolymers – slag, fly ash, etc. Questionable matter is influence of particular binders, their interference or synergy. The investigations focused on effect of micro-ground recycled concrete, fly ash and cement and their proportioning on mechanical properties of resulting composite.

II. EXPERIMENTAL PROGRAM

The experimental program relates to previous investigations concerned in utilization of secondary waste products in cementitious composites [1, 2]. Experiments focused in determination of basic mechanical properties of cement composites with partial substitution of Portland cement by micro-grounded recycled concrete and its combination with fly-ash. The specimen sets with substitution from 10% to 50% were manufactured. Each set comprised three specimens with dimensions 40x40x160 mm which were at the age 28 day tested in bending. The fragments from bending tests were used to determine compressive strength. The results showed influence on compressive strength decrease both for micro-grounded recycled concrete and combination of micro-ground recycled concrete and fly-ash. Flexural strength for combination of substitutive binders increased compared both to Portland cement and micro-grounded recycled concrete.

This part of investigations focused in substitution by fly-ash only. Five sets of specimens were manufactured with substitution of Portland cement from 10% to 50%. Prism specimens 40x40x160 mm were after 28 days of maturing in water dried, measured and weighed. The flexural strength was measured on prisms in a three-point bending test; compressive strength was determined on fragments of prisms in a similar way as in previous investigations.

2.1 Origin of Alternative Binders and their Properties

For manufacturing of specimens a micro- grounded recycled concrete from railway sleepers was used and fly-ash from electrical power plant Mělník. Description of both materials' properties follows.

2.1.1 Micro-ground recyclate

The input material for manufacturing of micro-ground recyclate was crushed concrete from railway sleepers. The sleepers originate from cancelled precast-plant railway. A jaw crusher Metso Nordberg LT 105 was used for crushing of sleepers.

Manufacturing of the micro-ground recyclate was performed in research centre of the company Ecological Investment Group s.r.o. using self-designed and self-built device TRITON M – II. The device is a common contra-rotating grinder with two vertical-axis rotors – so called disintegrator. The diameter of grinding rotors is 395 mm. Grinding was executed in two stages under different conditions. The main reason was that the rotors were not intended for grinding of concrete and were made from relatively mild steel. With bigger grains the abrasion of rotors was significantly higher. The first stage – rough grinding with the aim to decrease the grain size to less than 1 mm was performed with relative circumferential speed of rotors 160 m/s. The relative circumferential speed in the second stage – fine grinding was 215 m/s. Micro-ground recyclate prepared with this procedure was analyzed using laser granulometry (Fig. 1) to determine grain size distribution and X-Ray diffraction (XRD) analysis (Table 1) to identify particular phases in the fine–ground material.

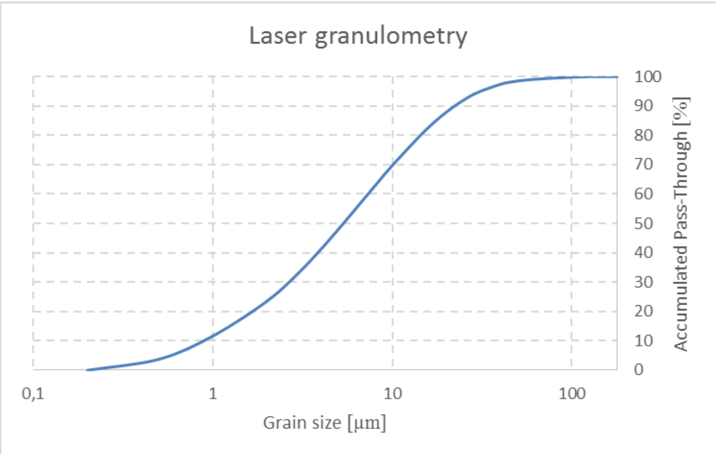

Figure 1: Laser granulometry of tested micro-ground recyclate

Table 1: XDR phase analysis

Compound name	Semi quant [%]

Quartz	63
Calcite	2
Portlandite	2
Chlorite-serpentine	2
Albit low	20
Gypsum	-
Muscovite	11

2.1.2 Fly Ash

In the investigation program fly ash from power plant Mělník was used. The Mělník fly ash is composed of 50.3% Silicon dioxide SiO_2, 31.5% Carbon dioxide (Al_2O_3), 2.33% Calcium oxide (CaO), 6.96% Iron(III) oxide (Fe_2O_3), 4.06% Titanium dioxide (TiO_2), 1.02% Potassium oxide (K_2O), 1.16% Magnesium oxide (MgO) and less than 1 percent of other oxides.

2.2 Composition of Specimens

Particular mixtures comprised Portland cement, water, fly-ash, eventually micro-grounded recycled concrete. Water/binder ration is same for all mixtures and equals 0.4. Composition of mixtures is given in Table 2.

Table 2: Composition of mixtures with water/cement ratio 0.4.

Blue	B0	B10	B20	B30	B40	B50
Portland Cement	100%	90%	80%	70%	60%	50%
Micro-ground recyclate	0%	10%	20%	30%	40%	50%
Fly ash	0%	0%	0%	0%	0%	0%
Green	G0	G10	G20	G30	G40	G50
Portland Cement	100%	90%	80%	70%	60%	50%
Micro-ground recyclate	0%	0%	0%	0%	0%	0%
Fly ash	0%	10%	20%	30%	40%	50%
Red	R0	R10	R20	R30	R40	R50
Portland Cement	100%	90%	80%	70%	60%	50%
Micro-ground recyclate	0%	5%	15%	25%	35%	45%
Fly ash	0%	5%	5%	5%	5%	5%

2.3 Results

Results of the bulk density, compressive strength and flexural strength are bellow. The blue line states for mixture with addition of micro-grounded recycled concrete, the green line for mixture with fly-ash, the red line for combination of alternative binders.

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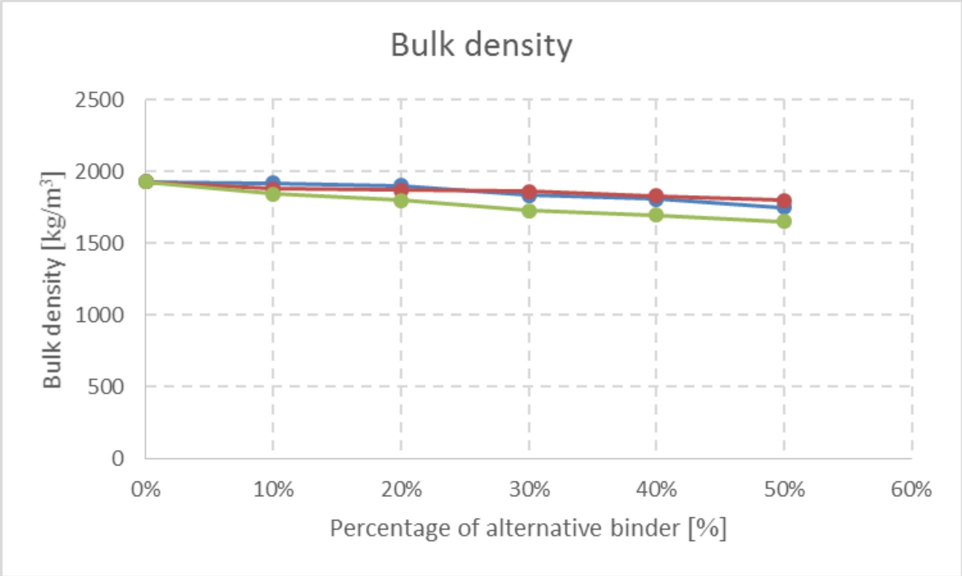

Figure 2: Relation of bulk density on alternative binders content

Specimens with alternative binders have lower bulk density compared to specimens with Portland cement only. The mixtures with fly-ash have lower bulk density than specimens with micro-grounded recycled concrete.

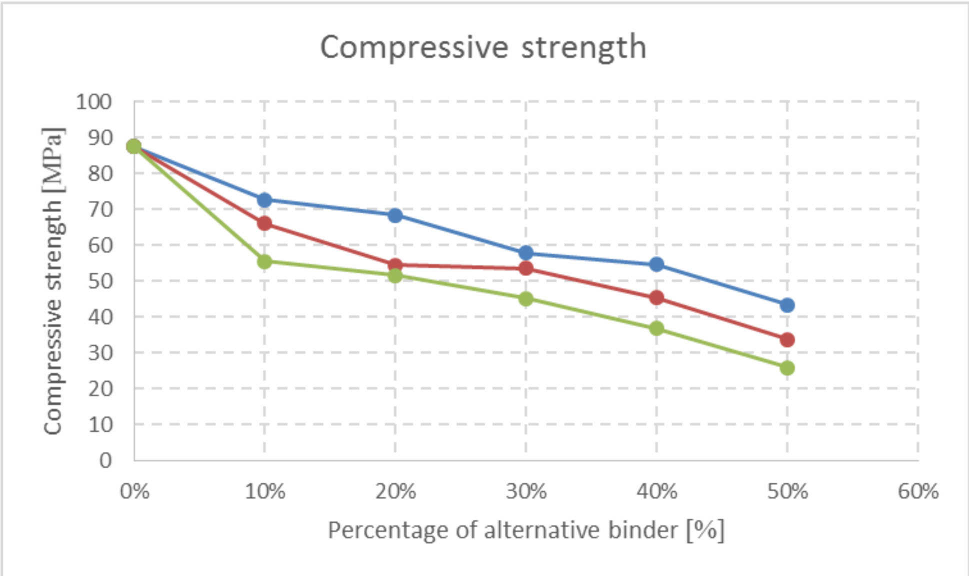

Figure 3: Relation of compressive strength on alternative binders content

From the graph follows that utilization of alternative binders lead to decrease of compressive strength, for fly ash the decrease is more significant.

Flexural strength increases for any type of alternative binders compared to specimens made from Portland cement. Fly-ash effect on strength is higher than effect of micro-grounded recycled concrete, their combination shows also good results. Combination of micro-grounded recycled concrete and fly-ash (substitution 30% and 40%) provided high scatter caused obviously by shrinkage of the cement paste. This is proved also by nonstandard fracture plane (see Fig. 5). Further research of properties of combination of alternative binders is needful; it will provide larger set of results to investigate its effects on cement composite.

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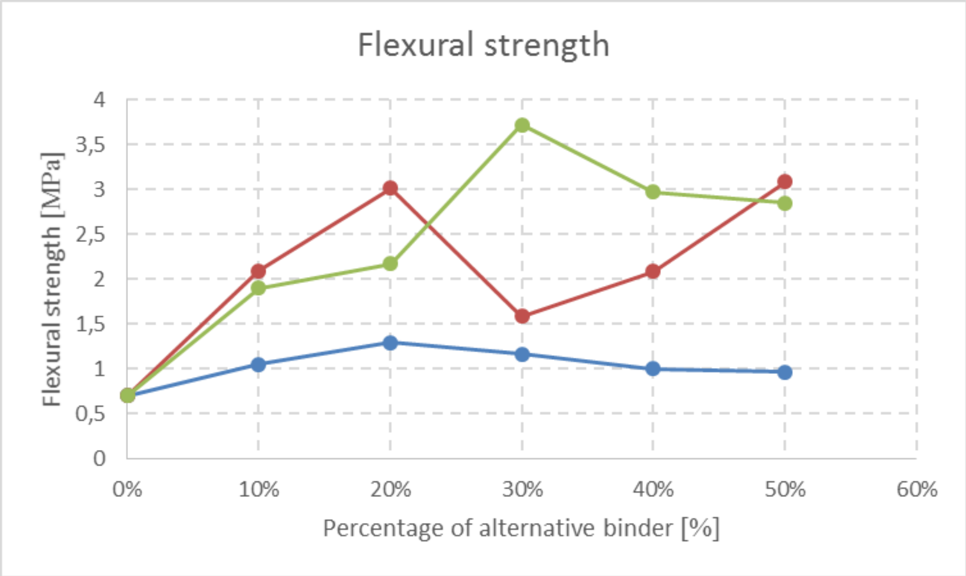

Figure 4: Relation of flexural strength on alternative binders content

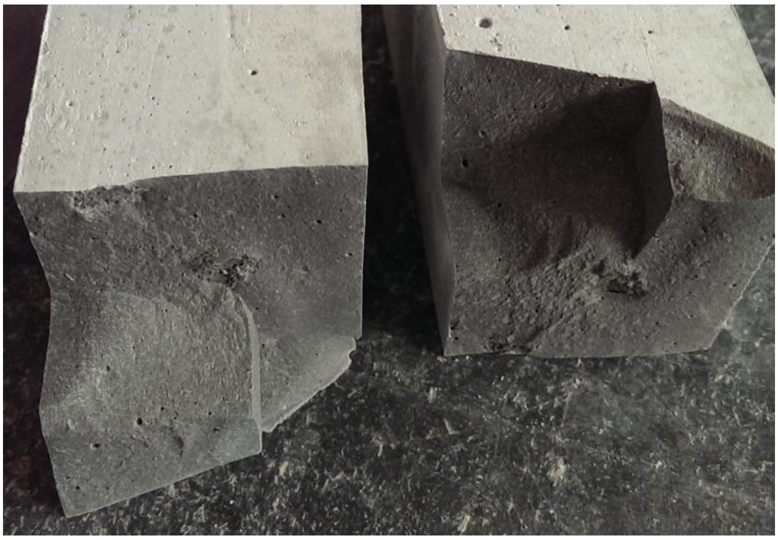

Figure 5: Non-standard fracture plane after three-point bending test

III. CONCLUSION

Use of micro-grounded recycled concrete and fly-ash adversely affects compressive strength of the composite but positively influences flexural strength. Fly-ash significantly decreases compressive strength whereas it increases flexural strength. Micro-grounded recycled concrete effect is opposite. Their appropriate combination could optimally affect both strength and it may become the best variant for application in construction industry.

By partial substitution of Portland cement by alternative binders the composite cost can be lowered and at the same time tribute to sustainable building by saving of primary sources.

IV. ACKNOWLEDGEMENT

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