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Study of the Strength Development of the Fine-Aggregate Concrete with Recycled Cement Powder

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Abstract: The paper deals with possibility of use cement powder of recycled concrete aggregate as partial replacement of cement in concrete mixture. The main topic of this article is the study of evaluation of the mechanical properties of the fine-aggregate concrete with partial cement replacement by recycled concrete powder in time. The compressive strength, tensile strength in bending and dynamic modulus of elasticity were tested at the age 7, 14 and 28 days. The fine recycled concrete which was used as partial replacement of cement had the same grain size as cement. The replacement rate was 5 %, 10 % and 15 %. Mechanical properties were investigated by using cubic and prismatic specimens.

Keywords: Recycled Aggregate; Recycled Concrete; Construction and Demolition Waste.

1 Introduction

Concrete is one of the most widely used construction materials, because of its excellent mechanical and durability properties if it is properly designed and produced. More than 10 billion tons are produced each year [1]. Recycled C&D waste is possible to use as partial replacement of natural aggregate. Lower quality of recycled aggregates compared to natural aggregates negatively influences the mechanical properties of recycled concrete but it is possible to use it for structural concrete elements without high requirements on mechanical and durability properties. On one hand, this method is important for natural aggregate saving with increasing production of concrete structures but on the other hand aggregate represents only 13 % to 20 % of total CO_2 emissions of concrete. In terms of reductions in CO_2 emissions, it is more important find way how to reduce cement in concrete mixture, because cement represents 74 % to 81 % of total CO_2 emissions of concrete [2]. It was verified that recycled cement powder is possible to use instead of 10 % of cement in concrete mixture [3]. The strength development of hydraulic binders based on Portland cement does not stop after 28 days [4] but for the study of strength development of cement composites is the most important first 28 days [5].

2 Materials and Experiments

Fine-aggregate concrete with natural sand were prepared for mechanical and deformation properties testing and strength development of concrete with partial cement replacement. The compressive strength, tensile strength in bending and dynamic modulus of elasticity were tested at the age 7, 14 and 28 days.

2.1 Materials and Mixtures

The recycled concrete from C&D waste were crushed from fraction 32/64 mm to fraction 0/16 mm and sieved to fraction 0/0.125 mm. This recycled cement powder from recycled concrete was used as partial replacement of cement in concrete mixture. There were used Portland cement 42.5 R in mixtures and the replacement rate of cement was 5 %, 10 % and 15 %. The reference concrete include only Portland cement and there were no replacement by recycled cement powder in conrete mixture. Concrete mixtures were designed as

Tab. 1: Concrete mixtures with different replacement of cement.

Mixture	REF	CEM 95	CEM 90	CEM 85
Natural sand	1458	1458	1458	1458
Cement CEM I 42,5	486	462	437	413
Recycled cement powder	0	24	49	73
Water	243	243	243	243
w/c ratio	0.5	0.5	0.5	0.5

concrete class C 30/37 with compressive strength 42 MPa. All mixtures had the same amount of natural sand and water and had the same water-cement ratio. The amount of cement and water- cement ratio was designed according to the Czech standard CSN EN 206 [6].

(a) recycled concrete of fraction 32-64 mm

(b) recycled cement powder of fraction 0-0,125 mm

Fig. 1: Recycled concrete, which was crushed and used as partial cement replacement.

2.2 Experiments

The mechanical and deformation properties were studied on two type samples. The tensile strength in bending, dynamic modulus of elasticity and compressive strength were tested on beams 160 × 40 × 40 mm and the compressive strength was tested on cubes 100 × 100 × 100 mm. The mechanical and deformation properties were studied at the age 7, 14 and 28 days.

The dynamic modulus of elasticity was determined by ultrasonic velocity test instrument according to the Czech standards CSN EN 12504-4 [7] and CSN 73 1371 [8]. There were measured transit time between the transducer and the receiver, which were placed in the opposite side of measured specimen (beams 160 × 40 × 40 mm) [9].

2.3 Results and Discussion

2.3.1 The Compressive Strength

The compressive strength is the fundamental mechanical property of concrete [10]. The development of compressive strength depends on the hydration of binders. If the part of Portland cement is replaced by different binder such as cement powder from recycled concrete is assumed to different development of compressive strength of concrete. The results of compressive strength development, which were measured at the age 7, 14 and 28 days, is shown in Fig. 2.

There is the compressive strength development of concrete with partial replacement of cement by cement powder from recycled concrete in Fig. 2. The best values were measured for CEM 95, which means replacement of cement by 5 % of cement powder. The reason for this result is probably higher water absorption of recycled cement powder, which absorbs hydration water and reduces effective water-cement ratio. Due to higher amount of recycled cement powder and thus lower amount of Portland cement in mixture have CEM 90 and CEM 85 poorer compressive strength than reference concrete.

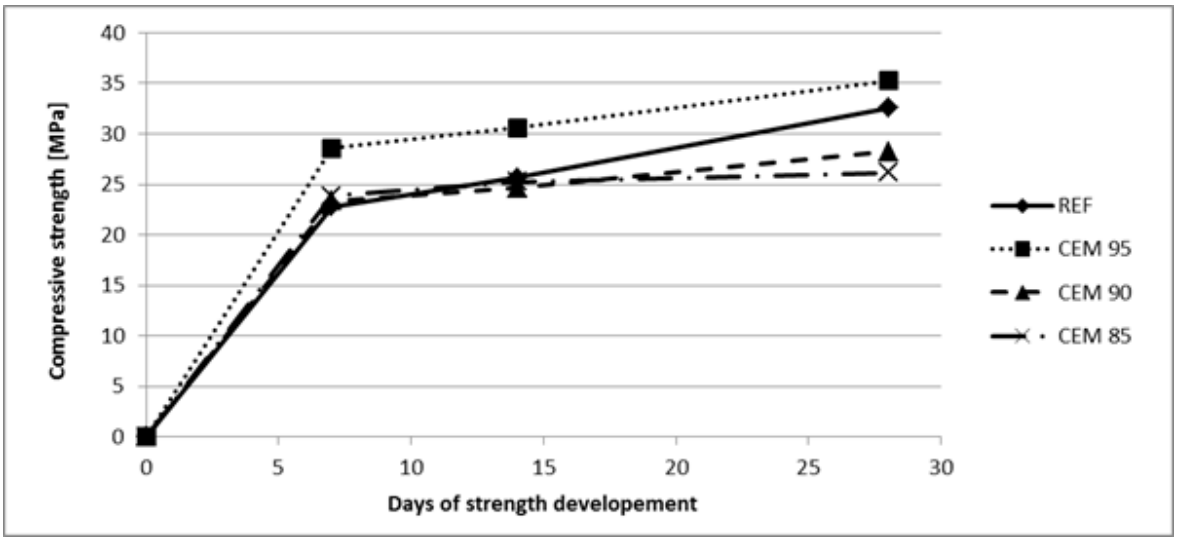

Fig. 2: Compressive strength development.

2.3.2 The Dynamic Modulus of Elasticity

The dynamic modulus of elasticity is tested by non-destructive testing. Measuring of the dynamic modulus is mostly provided by ultrasonic method. The ultrasonic pulse velocity method is one of the most widely used non-destructive testing method for evaluating properties of concrete structures [11]. Modulus of elasticity of concrete depends on the type of aggregate, compressive strength, water-cement ratio and method of concrete curing [12]. The dynamic modulus of elasticity was measured at the age 7, 14 and 28 days (see Fig. 3.)

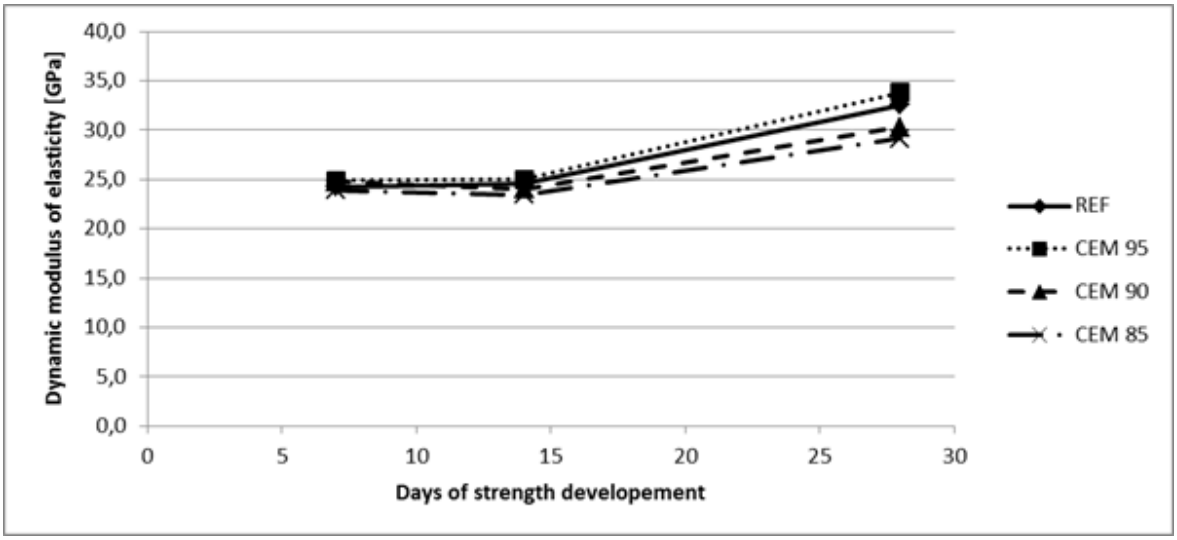

Fig. 3: Dynamic modulus of elasticity development.

There is the dynamic modulus of elasticity development of concrete with partial replacement of cement by cement powder from recycled concrete in Fig. 3. The measured values have similar results for each mixture as compressive strength. The best values were measured for CEM 95, then for reference concrete REF and further the dynamic modulus of elasticity decreases with higher replacement of recycled cement powder.

3 Conclusion

In conclusion, it was proved that partial replacement of cement by cement powder from recycled concrete negatively influences properties of concrete. However, it is possible to use recycled cement powder for non-structural concrete elements without high requirements on mechanical and durability properties.

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