Study of the Freeze-Thaw Resistance of the Fine-Aggregate Concrete

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Abstract: This paper deals with possibility of use the fine fraction of recycled concrete aggregate as partial replacement of sand in concrete mixture. The main topic of this article is the study of evaluation of the durability of the fine-aggregate concrete with partial replacement of sand by fine recycled concrete. The freeze-thaw resistance was tested. The weight loss was measured after 25, 50, 75 and 100 cycles of freeze-thaw. The dependence of weight loss after freeze-thaw cycles on water absorption capacity of fine aggregate concrete were expressed. The fine recycled concrete which was used as partial replacement of sand originated from highway demolition. The replacement rate was 10 %, 20 % and 30 %. Durability properties were investigates by using cubic and prismatic specimens.

Keywords: recycled aggregate; recycled concrete; construction and demolition waste;

1 Introduction

Production and utilization of concrete is regarded as a large consumer of natural resources such as natural aggregates and non-renewable fossil fuels. Buildings consume around 40 % of the global annual stone, sand and gravel [1]. High and constantly and rapidly increasing concrete consumption causes still growing environmental impact in terms of natural resources depletion. More than 10 billion tons of concrete are produced each year [2]. Recycled C&D waste is according to standards possible to use as partial replacement of coarse natural aggregate [3]. The use of fine recycled aggregate (FRA) as partial replacement of sand has not been allowed yet. Although, the sand extraction from seaside has high environmental impact such as increasing seaside erosion, changing wave behavior, local fauna and flora ecosystems and other environmental aspects. The local ecosystems are also negatively influence during sand extraction from riverbed [4].

Cement composites are very often exposed to the effect of thermal changes. On one hand, it is the effect of cyclic temperature loading [5]. On the other hand, it is freezing and thawing during winter. The durability properties of concrete, especially freeze-thaw resistance, could be negatively influenced by water absorption of recycled aggregate concrete. The water absorption of fine aggregate concrete with partial replacement of sand is higher. The increase is between 6% and 10% in dependence on replacement rate [6]. Higher water absorption of recycled aggregates compared to natural aggregates causes higher water absorption of concrete. The dependence of water absorption of concrete on water absorption of aggregate was estimated according to results of experimental investigation [7]. Although, the durability properties of recycled aggregate concrete could be worse in comparison with conventional concrete, it is possible to use it for structural concrete elements without high requirements on durability properties.

2 Materials and Experimental program

Fine-aggregate concrete mixtures with natural sand and various replacement by fine recycled aggregate was prepared for testing freeze-thaw resistance of concrete. Freeze-thaw resistance were tested according to Czech standard CSN EN 73 1322 [8]. The same concrete mixtures were tested on water absorption by immersion and water absorption of capillarity.

2.1 Materials and mixtures

The waste concrete blocks from recycled C&D waste were crushed from fraction 32/64 mm to fraction 0/16 mm and sieved to fraction 0/4 mm. This FRA from recycled waste concrete was used as partial replacement of sand in concrete mixture. There were used Portland cement 42.5 R in mixtures and the replacement rate of sand was 10 %, 20 % and 30 %. Concrete mixtures were designed as concrete class C 30/37. All mixtures had same amount of cement and had same water-cement ratio. The mixtures are listed in Tab. 1.

Tab. 1: Concrete mixtures with different replacement of sand

Mixture	FNAC	FRAC	FRAC	FRAC
Replacement rate		10%	20%	30%
NA 0/4 mm [kg]	1458	1312	1166	1020
FRA 0/4 mm [kg]	0	146	292	438
Cement CEM I 42,5 [kg]	486	486	486	486
Water [kg]	243	243	243	243
Total w/c ratio [-]	0.5	0.5	0.5	0.5

The specimens of FNAC and FRAC are shown in Fig. 1.

Fine natural aggregate concrete (FNAC) Fine recycled aggregate concrete (FRAC)

Fig. 1: Specimens of fine natural aggregate concrete and fine recycled aggregate concrete

2.2 Experimental program

The freeze-thaw resistance was examined on beams 160 × 40 × 40 mm. The weight, dynamic modulus of elasticity, flexural strength and compressive strength on fragments were measured after 25, 50, 75 and 100 cycles of freeze-thaw. The freezing cycle takes 4 hours of freezing by air of minus 20°C and the thawing cycle takes 2 hours of thawing by water of 20°C.

Water absorption capacity of hardened concrete with different replacement rate of natural sand by FRA was tested by immersion test. Cubes 100×100×100 mm and beams 40×40×160 mm at age 28-days were after 14-days wet curing removed from water and dried in oven for 14 days. Beams 40×40×160 mm at age 28-days of hardened concrete with different replacement rate of natural sand by FRA were 3 days tested by capillarity test

3 Results and discussion

The results of freeze-thaw resistance of fine-aggregate concrete with partial replacement of sand by fine recycled aggregate were expressed by weight loss after 25, 50, 75 and 100 cycles. The freeze-thaw resistance depends on water absorption capacity of concrete. From this reason, the dependency of freeze-thaw resistance on water absorption capacity is shown in this investigation.

3.1 The freeze- thaw resistance

The results show that the freeze-thaw resistance depends on substitution ratio of natural sand. The lowest weight loss after 100 cycles of freezing and thawing, which means the higher freeze-thaw resistance, was measured for reference concrete without FRA and the highest weight loss, the lower freeze-thaw resistance, was measured for the fine aggregate concrete mixture with the highest replacement rate of sand (see Fig.2).

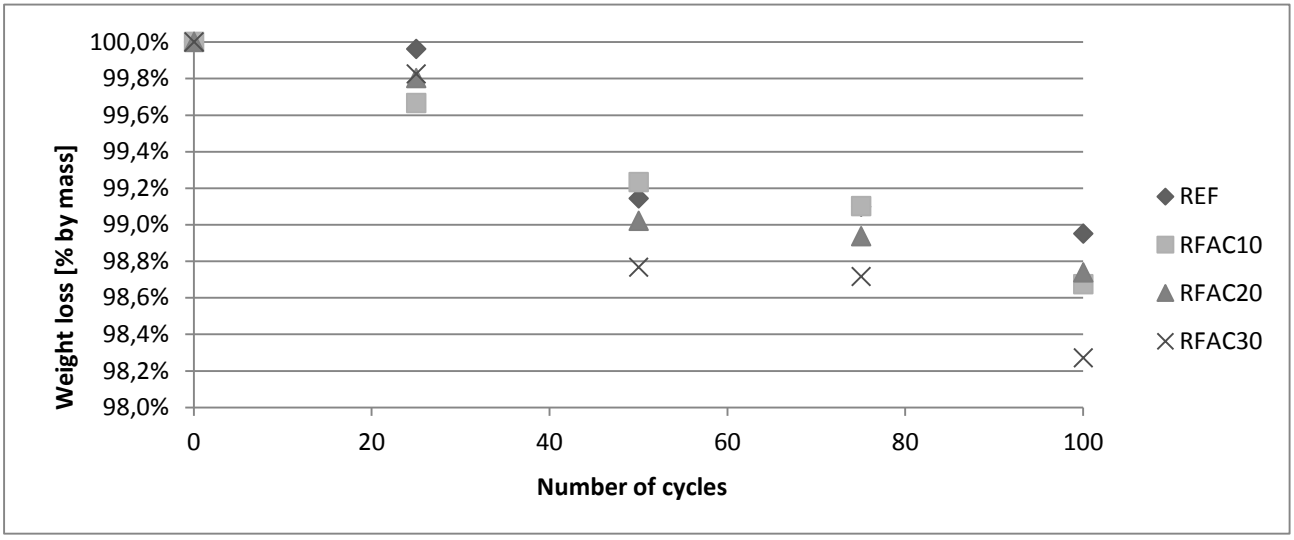
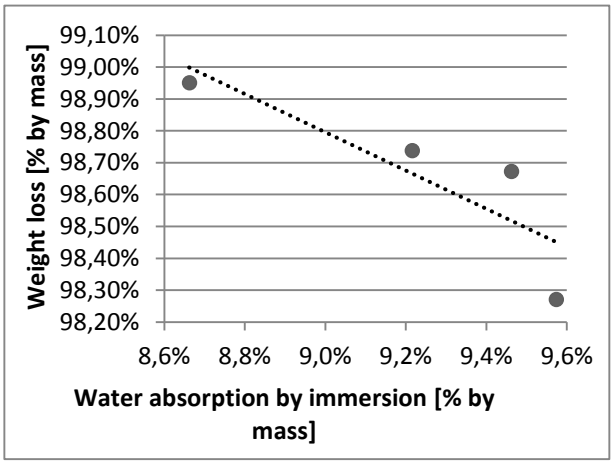


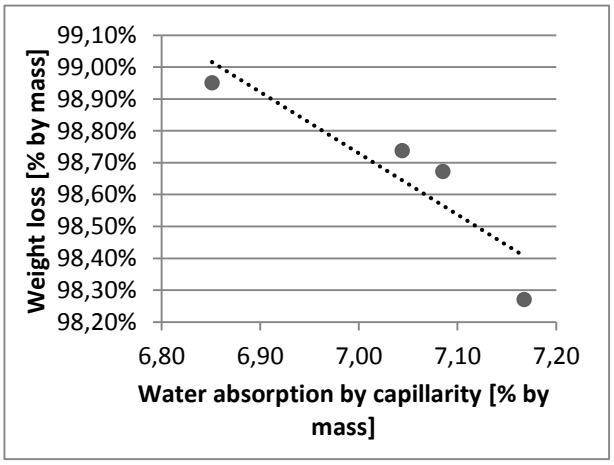
Fig. 2: Weight loss after freeze-thaw cycles of samples with different replacement rate of sand

3.2 The freeze- thaw resistance

The results show that the freeze-thaw resistance also depends on water absorption of concrete, which is naturally connected with amount of recycled aggregate in mixture and its higher water absorption. The graphs show the almost linear dependence of freeze-thaw resistance of fine aggregate concrete on water absorption by immersion and water absorption by capillarity (see Fig. 3).



Weight loss after 100 cycles of freeze-thaw on water absorption by immersion



Weight loss after 100 cycles of freeze-thaw on water absorption by capillarity

Fig. 3: Dependence of weight loss after 100 cycles of freeze-thaw on water absorption capacity

4 Conclusion

In conclusion, it was proved that partial replacement of sand by FRA negatively influences durability of concrete, especially its freeze-thaw resistance. However, the weight loss of samples with FRA was less than 2 %. From this reason, it is possible to say that the weight loss of fine aggregate concrete with partial replacement of sand by fine recycled aggregate after freeze-thaw cycles is not essential. Consequently after verification this conclusion, the use of FRA is possible for concrete structures, which are influenced by freeze-thaw. Finally, is was verified that the freeze-thaw resistance is influenced by water absorption capacity of fine aggregate concrete and amount of fine recycled aggregate has impact on this characteristic. Due to the almost linear dependence of freeze-thaw resistance on water absorption capacity, the predictive model of freeze-thaw resistance of concrete could be established.

Acknowledgement

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