The mechanical properties of fine recycled aggregate concrete after freeze – thaw cycles

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Abstract: This paper is focused on mechanical properties of fine recycled aggregate (FRA) concrete after freeze – thaw cycles. The use of FRA is connected with uncertainties and doubts. The most unknown aspects of FRA concrete are related to durability. This paper presents results of mechanical properties of concrete containing FRA after freeze – thaw cycles. The FRA from concrete waste originated from recycling plant in the Czech Republic was used in experiments. Four concrete mixtures were analyzed in total. The first, concrete mixture with natural sand, cement and water was prepared as a reference concrete mixture. In other mixtures, natural sand was replaced by FRA in various replacement ratios, specifically 10%, 20% and 30%. All concrete mixtures were designed with the same parameters for clear comparison. As a consequence of the quality and amount of FRA, the test results showed the influence of FRA to the freeze – thaw resistance of concrete.

Keywords: fine recycled aggregate concrete; construction and demolition waste; mechanical properties; freeze – thaw resistance; durability.

1 Introduction

The use of recycled aggregate as a partial replacement of natural aggregate in concrete is one of the possible ways how to save natural resources. The use of coarse recycled aggregate in concrete is already accepted. However, it is possible with specific restrictions [1]. The use of FRA is connected with uncertainties and doubts. It is generally agreed that the FRA influences the properties of concrete. Concrete containing FRA shows worse physical and mechanical properties [2]. The most unknown aspects of FRA concrete are related to durability [3]. This paper presents results of mechanical properties of concrete containing FRA after freeze –thaw cycles.

2 Experimental research program

2.1 Materials

Portland cement CEM I 42.5 R, natural sand, water and FRA were used in the experimental part. The FRA was obtained from recycling plant in the Czech Republic. The FRA originated from demolished concrete structures. Afterwards FRA was crushed in the laboratory jaw crusher and separated to fraction of 0 – 4 mm. There were tested geometrical and physical properties of the FRA. The physical properties were tested by pycnometric method according to ČSN EN 1097 – 6 [4] . The test results were compared with natural sand. The physical properties of FRA and natural sand are given in Tab. 1.

Tab. 1: Physical properties of recycled and natural sand

Type of aggregate	Fraction [mm]	Density [kg/m^3]	Water absorption capacity [%]
Recycled aggregate	0 - 4	2090	8,29
Natural aggregate	0 - 4	2600	2,00

2.2 Concrete mixtures proportion

A total four concrete mixtures were designed and prepared. All concrete mixtures were designed with the same w/c ratio and the same amount of cement. The first concrete mixture was reference (FRA) which did not include FRA. Natural sand was replaced by FRA in concrete mixtures FRA10, FRA20 and FRA30 in varying ratio (10 %, 20 %, 30 %). Details of designed concrete mixtures are given in Tab. 2.

Tab. 2: Concrete mix proportion, per cubic meter

Designation	REF	FRA10	FRA20	FRA30
Cement [kg]	486	486	486	486
Water [kg]	243	243	243	243
Sand [kg]	1458	1312	1166	1021
FRA [kg]	0	146	292	437

2.3 Testing

Beams of dimensions 40x40x160 mm were used for testing. The freeze – thaw resistance was tested according to ČSN 73 1322 [5]. There were carried out a total 100 freeze – thaw cycles. 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.

The compressive strength, tensile strength and dynamic modulus of elasticity were measured after 50, 75 and 100 freeze – thaw cycles. The dynamic modulus of elasticity was tested nondestructive by the ultrasound method according to [6]. The tensile strength was examined on beams according to ČSN EN 12390-5 [7]. The compressive strength was examined on fragments of beams according to ČSN EN 12390-3 [8]. The eguipment, which was used for testing freeze – thaw resistence, is showed in Fig. 1.

Fig. 1: The equipment for testing freeze – thaw resistance

3 Results and discussion

3.1 The compressive strength

The graph in Fig. 2 shows development of compressive strength after 50, 75 and 100 freeze – thaw cycles.

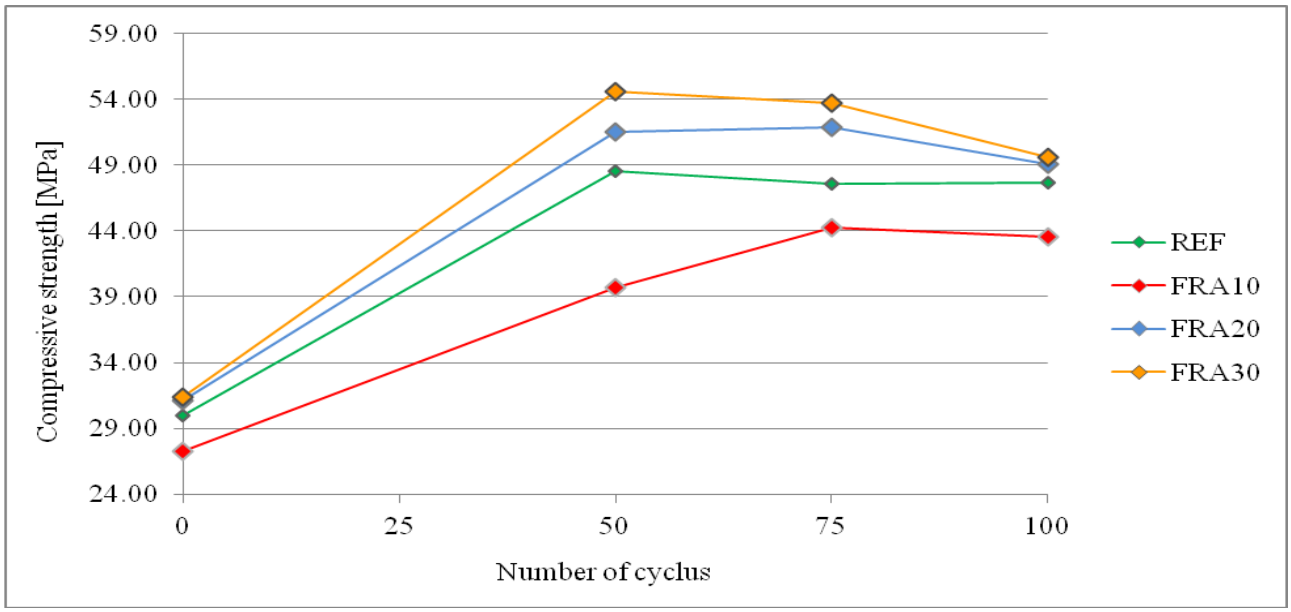

Fig. 2: Test results of compressive strength after 50, 75 and 100 freeze – thaw cycles

3.2 The tensile strength

The graph in Fig. 3 shows development of tensile strength after 50, 75 and 100 freeze – thaw cycles.

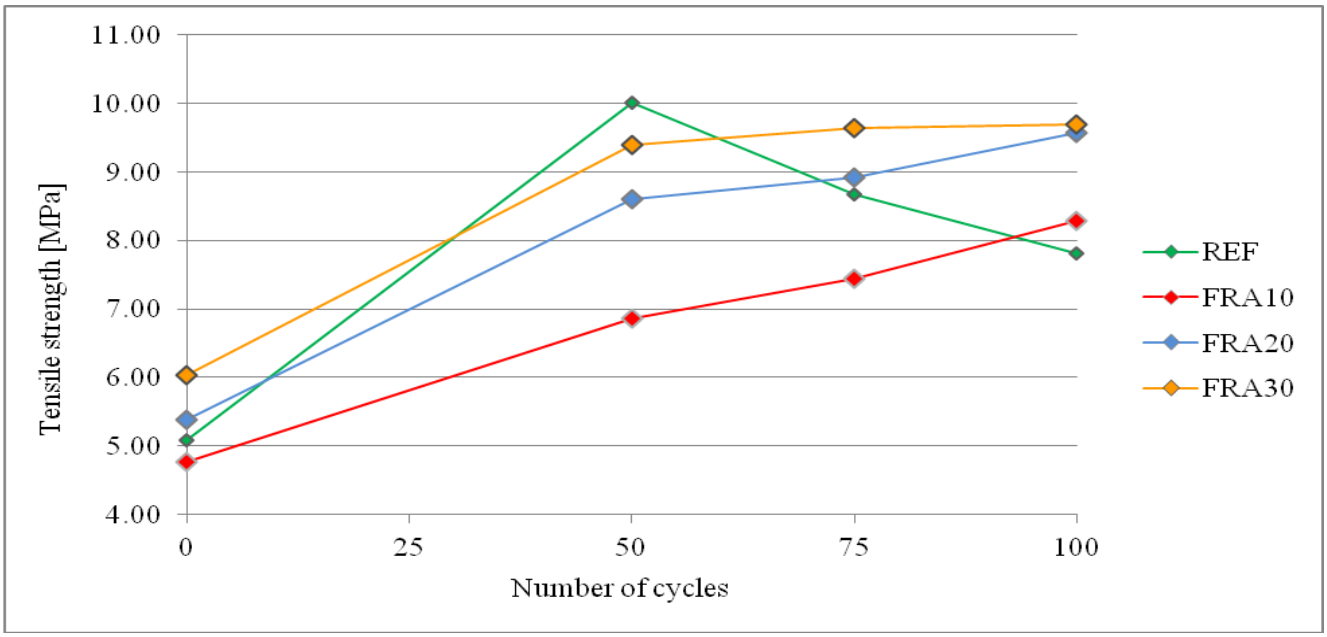

Fig. 3: Test results of tensile strength after 50, 75 and 100 freeze – thaw cycles

4 Conclusion

In this paper, experimental results of mechanical properties of FRA concrete after freeze – thaw cycles are presented and discussed. From the test results and discussions, the following conclusions are drawn:

- The use of FRA as partial replacement of natural sand influences the properties of concrete.
- The results show that the freeze-thaw resistance depends on substitution ratio of natural sand.
- The concrete samples with FRA showed good mechanical properties after 100 freeze – thaw cycles.
- It is possible tu assume good freeze – thaw resistance of FRA concrete.

Finally, it is possible to say that it was proved, good mechanical properties of concrete samples with recycled aggregate. It is possible to assume good freeze – thaw resistance of FRA concrete. Nevertheless, it is necessary to say that freeze – thaw resistance of recycled aggeragte concrete depends on many other aspects [9]. It is necessary to verify this results.

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