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# Influence of Partial Replacement of Fine Natural Aggregate by Fine Recycled Aggregate on Properties of Fine-Aggregate Concrete

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**Abstract:** This paper deals influence of partial replacement of natural sand by fine recycled aggregate (FRA) on properties of fine-aggregate concrete. The recycled concrete from construction and demolition (C&D) waste were crushed from fraction 32/64 mm to fraction 0/16 mm and sieved to fraction 0/4 mm. There were prepared four concrete mixtures. One mixture was reference with natural sand. In concrete mixtures FRA10, FRA20 and FRA30, natural sand was replaced 10 %, 20 % and 30 % FRA. All mixtures were designed with the same w/c ratio, the same amount of cement and the same concrete class. There were tested mechanical and deformation properties of hardened concrete. It is possible to say that the use of the FRA in concrete influences the properties of concrete. However, FRA concrete is possible to be used in the manufacturing of building structures.

**Keywords:** Recycled Aggregate Concrete; Fine Recycled Aggregate; Non Destructive Testing; Mechanical Properties; Deformation Properties; Fine-Aggregate Concrete.

## 1 Introduction

Construction and demolition (C&D) waste constitute 1/3 from a total production of waste in the Czech Republic and the European Union too. Use of recycled aggregate in concrete helps to reduce primary raw materials and the amount of C&D waste at the landfills. Government of the Czech Republic imposed targets for the reduction, reuse and recycling of C&D waste in a waste management plan of the Czech Republic [1]. This plan ordered that by 2020 70 % of the produced C&D waste must be reused and recycled. One way is to use of recycled aggregate as replacement of natural aggregate in concrete.

The use of coarse recycled aggregate as replacement of natural coarse aggregate influences the properties of concrete. This influence depends on the quality and amount of recycled aggregate in concrete [2–4]. The use of coarse recycled aggregate as replacement natural aggregate in concrete is already accepted in the Czech Republic but with specific restrictions [5]. The problem is posed use of the FRA. FRA shows a higher water absorption capacity, higher porosity and lower density [6, 7]. This paper is focused on possibility use of FRA as partial replacement of natural sand.

## 2 Experimental Research Program

### 2.1 Materials

The mixtures' constituent were cement, water, natural sand and FRA. Portland cement 42.5 MPa R was used in concrete mixtures. The RFA was obtained from recycling plant in the Czech Republic. FRA was concrete waste from demolished structures, which was crushed in the laboratory jaw crusher to maximal particle size 4 mm. Fig. 1 shows a comparison between natural sand and FRA.

(a) natural sand

(b) fine recycled aggregate

Fig. 1: Comparison between natural sand and FRA.

Tab. 1: 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 |

### 2.2 Concrete Mix Proportion

For the experiment, there were prepared four concrete mixtures. The first concrete mixture was reference with natural sand (REF). In other mixtures, natural sand was replaced by FRA of variable ratio. In concrete mixtures FRA10, FRA20 and FRA30, natural sand was replaced 10 %, 20 % and 30 % FRA (by volume). All mixtures were prepared with the same water – cement ratio 0.5, the same amount of cement CEM I 42.5R and the same concrete class C 30/37 with compressive strength 42 MPa.

### 2.3 Testing

Beams of dimensions 160 × 40 × 40 mm and 100 mm cubes were used for the testing. There were tested mechanical and deformation properties of hardened concrete. The compressive strength is the peak stress of the test specimens under uniaxial compression. The flexural strength was tested under a load in a three - point bending. Dynamic modulus of elasticity was tested non - destructive by ultrasonic method. The compressive strength, flexural strength and dynamic modulus of elasticity were tested at the age 7, 14 and 28 days.

## 3 Results and Discussion

### 3.1 The Compressive Strength

The compressive strength is the most important property of concrete. The compressive strength was tested according to ČSN EN 12390 – 3 [8]. The graph in Fig. 2 shows the compressive strength results at the age 28 days. Concrete samples with FRA show a mild improvement of the compressive strength of FRA concrete with comparison of reference concrete. Two facts are cause of this improvement. The first fact is connected with the higher water absorption capacity of the FRA. Fine fraction of recycled aggregate absorbs some amount of water, which is used for hydration, and afterwards effective water – cement ratio decreases [9]. The second fact is connected with the grading curve of FRA. The grading curve of FRA is distinct from the grading curve of natural sand.The connection grading curve of natural sand and grading curve of FRA approximates to optimal grading curve. Better packing density and lower porosity of concrete is the consequence of this fact.

Concrete samples RFA10 showed the highest compressive strength. The compressive strength of concrete samples RFA10 was 34.1 MPa, RFA20 was 32.8 MPa and RFA30 was 33.5 MPa. Differences of the compressive strength between each FRA concrete mixtures are minimal. It is necessary to verify of probably improvement of the compressive strength of FRA concrete in future research.

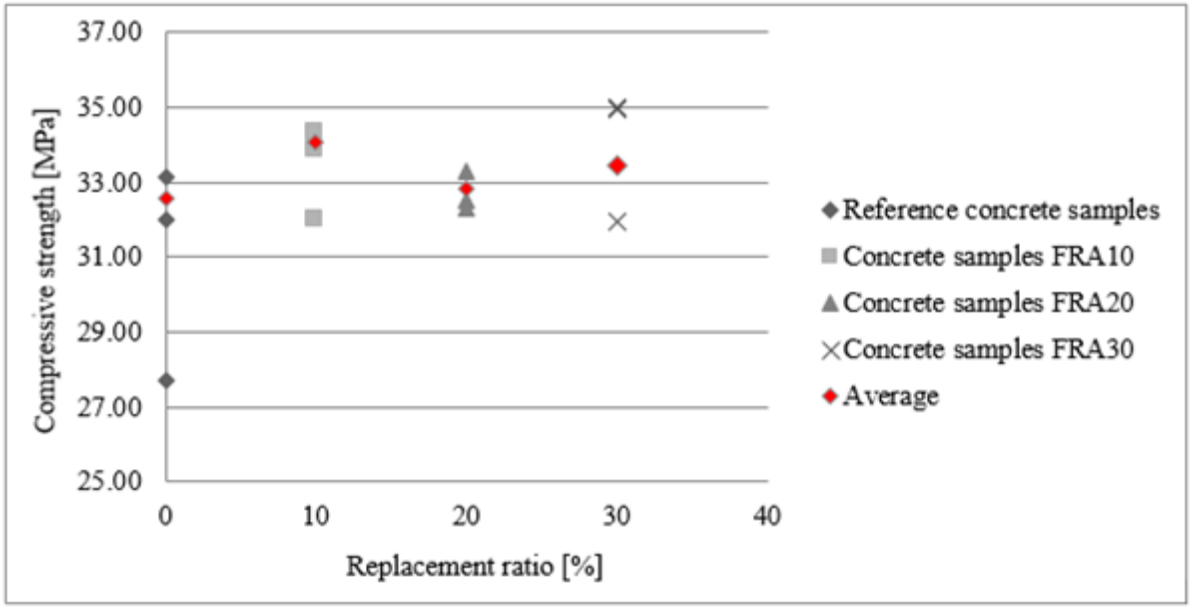


Fig. 2: Compressive strength at the age 28 days.

### 3.2 The Dynamic Modulus of Elasticity

Dynamic modulus of elasticity was tested non-destructive by ultrasonic method [10]. Testing results were evaluated according to [11]. The dynamic modulus of elasticity results are showed in Fig. 3. The dynamic modulus of elasticity of FRA concrete is similar to the dynamic modulus of elasticity of reference concrete. The dynamic modulus of elasticity of reference concrete samples was 22.5 GPa. The dynamic modulus of elasticity of concrete samples RFA10 was 22.6 GPA, RFA20 was 23.3 GPa and RFA30 was 21.9 GPa.

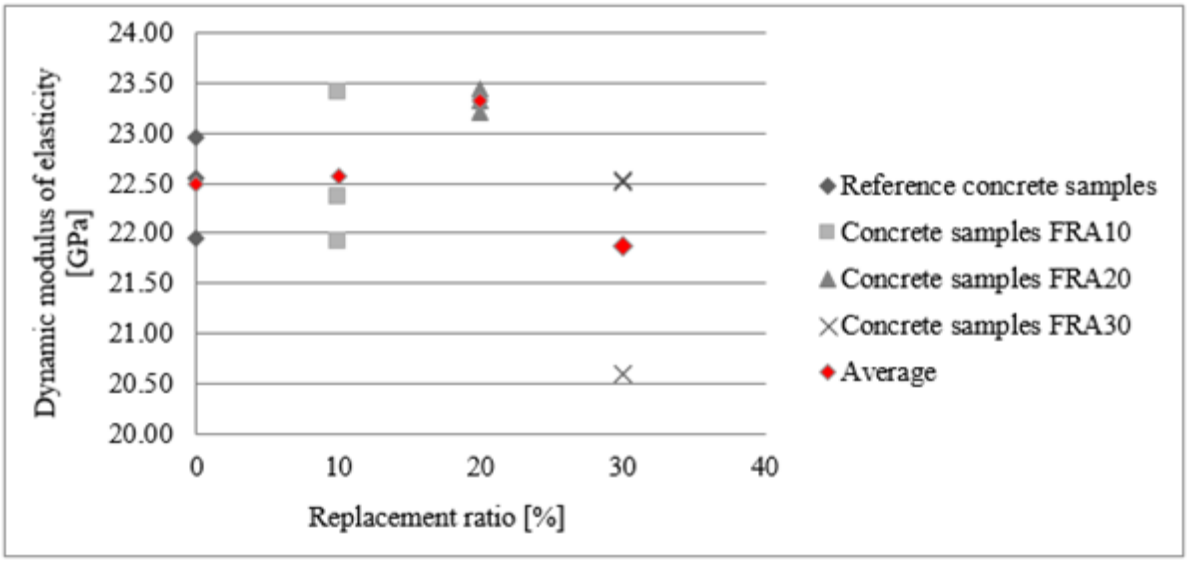


Fig. 3: Dynamic modulus of elasticity.

## 4 Conclusion

In this paper, experimental results of the influence of partial replacement of natural sand by fine recycled aggregate on properties of fine-aggregate concrete 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.
- Concrete samples with FRA show a mild improvement of compressive strength with comparison of reference concrete. Two facts are cause of this improvement. The higher water absorption of FRA is the first fact and lower effective water – cement ratio is connected with this fact. The different grading curve of FRA is the second fact. Better packing density and lower porosity of concrete is the consequence of this fact.
- The dynamic modulus of elasticity of FRA concrete is similar to the dynamic modulus of elasticity of reference concrete.

Finally, it is possible to say that it was proved, influence of the use of the FRA on the properties of concrete. It is necessary to verify of probably an improvement of compressive strength of FRA concrete in future research. However, FRA concrete is possible to be used in the manufacturing of building structures, but it is necessary to test durability and lifespan of FRA concrete.

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## References

[1] Plán odpadového hospodářství České republiky. In: nařízení vlády č. 352/20014 Sb. 2014. (in Czech).

[2] Chen H. et al., Use of building rubbles as recycled aggregates. Cement and Concrete Research (2003) 125 – 132.

[3] Martínez – Lage I. et al., Properties of plain concrete made with mixed recycled coarse aggregate. Construction and Building Materials (2012) 171 – 176.

[4] Šefflová M. et al., Thermal properties of concrete with recycled aggregate. Advanced Materials Research 1054 (2014) 227 – 233.

[5] ČSN EN 206. Specifikace, vlastnosti, výroba a shoda. Praha: Český normalizační institut, 2014. (in Czech).

[6] Evangelista, L.et al., Physical, chemical and mineralogical properties of fine recycled aggregates made from concrete waste. Construction and building materials 86 (2015) 178 – 188.

[7] Evangelista, L.et al., Mechanical behaviour of concrete made with fine recycled concrete aggregates. Cement & Concrete Composites 29 (2007) 397 – 401.

[8] ČSN EN 12390 - 3 (731302). Zkoušení ztvrdlého betonu - Část 3: Pevnost v tlaku zkušebních těles. Česká republika: Úřad pro technickou normalizaci, metrologii a státní zkušebnictví, 2009. (in Czech).

[9] Jogl M. et al., Proposal of fire resistant composites with application of lightweight aggregate Liaver. Advanced Materials Research 1054 (2014) 43 - 47.

[10] Holčapek O. et al., Destructive and nondestructive characteristics of old concrete. Advanced Materials Research 1054 (2014) 243-247.

[11] Pavlů T. et al., The static and the dynamic modulus of elasticity of recycled aggregate concrete. Advanced Materials Research 1054 (2014) 221-226.