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Composite Material from By-products and Its Properties

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Abstract. The paper shows an example of utilization of specific textile admixture – fluffs of torn textiles from waste cars in production of composite with aggregate consisting entirely of unsorted recycled concrete. The admixture in the mixture of recycled concrete and cement binder fills the pores and voids in composite. The elaborated composite has working title STEREDconcrete. In the article, basic mechanical-physical properties of the composite are presented also the fire resistance of STEREDconcrete, which was determined in tests.

1. Introduction

The demand for increase of recycling creates new challenges for research institutions. Our team is engaged in investigations of utilization of crushed concrete for manufacturing of a new cement based composite.

The application of crushed concrete as aggregate for manufacturing of new concrete is quite common. Properties of concrete with recycled aggregate (RAC – recycled aggregate concrete) depend on ratio of recycled aggregate and natural aggregate used for manufacturing of the RAC. The density of RAC would not differ from normal concrete if up to 25 % of recycled aggregate is used; for higher content of recycled aggregate the RAC density used to be lower.

The compressive strength is mostly lower (4 – 45 %) [1, 2]. Other researches ascertain that RAC with recycled aggregate up to 25% reaches even higher compressive strength [3], the reason is probably in quality of the used recycled concrete aggregate crushed from high-class concrete. The tensile splitting strength is indicated lower up to 33% if more than 25% of natural aggregate is substituted [1, 4]; in contrary some studies introduced increase of by 20% [5].

We can summarize that RAC properties fluctuate, they are uncertain and thus their structural applications are economically disadvantageous. Thus an alternative approach was proposed, to design a new composite from waste for non-structural use. The intention was to consume a big amount of waste concrete fine and coarse aggregate without sorting to fractions. The composite has high void content – ca 30%. The high void content pointed to idea of filling the voids by additional admixture that could enhance the composite properties.

Properties of concrete composites are enhanced by application of steel or polymeric fibres, which affect mechanical and physical properties [6 - 8]. In a similar way fibres can be used for concrete with recycled aggregate. With respect to porous structure of RAC, synthetic the fibres are chosen.

Synthetic fibres randomly distributed in the structure of the compacted composite were the first tested admixture. Significant change of the response of the composite was detected – from brittle failure of the original composite to tough and resilient behaviour. The ability of carrying of tensile stresses after cracking is an essential feature of the composite with synthetic fibres.

Since 2012 admixture STERED has been tested. STERED is waste torn textile from car industry. The test results of mechanical properties have shown potential for practical use [9]. The desired properties of the composite for particular application can be engineered by dosage of STERED, related to amount of pores in the composite. The new composite was called STEREDconcrete and the development of the material was finalized by patent application n. 306029).

STERED is made from non-flammable upholstery textile. As a non-flammable material it should tribute to higher fire resistance of the composite. Therefore an application of the STEREDconcrete in insulating tilling boards was proposed. Thus further investigations focused on properties related to application in boards.

In the paper tests of mechanical properties are presented and tests focused in determination of fire resistance of the composite with textile shred.

2. Composition and tests of STEREDconcrete

2.1. Mixture

The composite mixture design is based on the demand of maximum waste consumption. The aggregate was recycled concrete with maximum grain size 16 mm (it was given by the specimen dimensions), binder was cement CEM I 42,5 R in dosage 400 kg/m^3 (the cement dosage was determined with respect to manufacturing of relatively thin board), water in dosage 100 kg/m^3 to reach fresh concrete consistency suitable for rolling and tamping. Dosage of the textile shred 29.5 kg/m^3 was determined to fill the volume of approximately 50% of voids in the composite.

In the first manufacturing step the recycled concrete aggregate is mixed with STERED, afterwards the cement is added and the last component added to fresh concrete (Fig. 1) is water.
The manufactured test specimens were prisms 100x100x400 mm and board with dimensions 500x1500 mm and thickness 80 mm. The prisms were compacted by tamping; the boards were compacted by combination of rolling and tamping. (Fig. 2, 3).

Figure 1. Fresh concrete composite with textile shred.

Figure 2. Compacting of the board by rolling.

Figure 3. Compacting of the board by compactor.

2.2. Results of mechanical properties tests

The prism specimens (100x100x400 mm) were examined according to ČSN EN 12390-5 standard [10] in four-point bending test (results are presented in the table 1 and Fig. 4) and then the fragments were used for determination of the compressive strength according to ČSN EN 12390-3 [11] (see table 2).

Table 1. Results of the four-point bending tests.

Specimen	Dimensions [mm]	Weight [g]	Bulk density [kg/m^3]	Flexural strength [MPa]
1.1	400x99x100.21	6350	1600	0.99
1.2	400x98.16x99.9	6585	1680	0.92
1.3	400x103.8x101.51	6495	1540	1.06
1.4	400x99.09x100.77	6510	1630	0.66
Mean value			**1615**	**0.91**

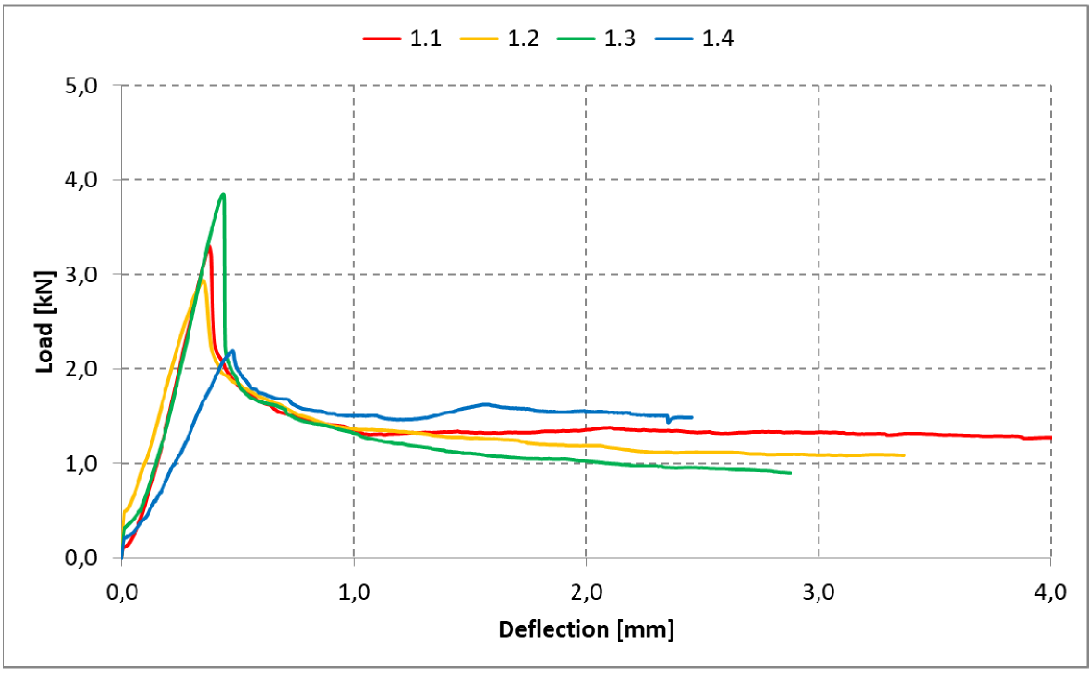

Figure 4. Load-deflection diagrams from bending test.

Table 2. Results of compressive tests on prism fragments.

Specimen	Dimensions [mm]	Force [kN]	Flexural strength [MPa]
1.1	100x99x100	57.02	5.76
1.2	100x98.16x99.9	40.96	4.18
1.3	100x103.8x100	35.93	3.46
1.4	100x99.09x100	42.8	4.32
	Mean value		**4.43**

The average value of compressive strength is 4.5 MPa, which is similar to aerated concrete. Flexural strength reaches ca 0.9 MPa; the value is relatively high compared to common concretes where the ratio of compressive and tensile strength is 1/10. The density of the composite STEREDconcrete varies from 1500 to 1700 kg/m^3 so that it can be classified light-weight concrete.

2.3. *The fire test*

Testing of the fire behaviour was performed with three boards.

Five temperature sensors were fixed on the board. The board was fixed in the test bench and loaded by fire. The flames heated the centre of the board. The sensors measured the temperature on the opposite side than flames were applied. At the same time the temperature of the flame and ambient temperature were measured. The gradients of temperature across the thickness of the board and between the centre and edges of the board were followed. Results of the test in relation temperature and time are plotted in the Fig. 5 and listed in the table 3.

Table 3. Measured values (in °C) from fire test.

Edge 1	Edge 2	Edge 3	Edge 4	Centre	Flame
21.80	16.80	21.30	27.70	21.20	22.7
19.20	18.60	21.70	28.40	22.40	63.8
28.50	20.10	23.70	30.20	24.60	158.4
24.00	20.90	25.70	29.10	24.30	237.9
26.00	21.60	29.00	30.20	25.10	409.9
20.40	20.20	26.70	29.50	23.90	523.0
32.60	26.00	36.60	37.30	31.60	632.4
30.20	22.40	33.70	39.90	31.00	700.8
27.50	26.50	41.40	39.30	31.90	785.2
34.30	45.60	57.70	48.40	49.30	849.8
33.60	55.00	65.30	53.30	56.90	710.1
34.30	57.40	70.90	58.70	57.40	622.4
36.80	58.70	67.60	62.40	59.20	576.9

Figure 5. Results of temperature measuring in the test of board 1.

3. Conclusions

The proposed composite made from recycled concrete aggregate and material STERED showed its potential for practical applications. STEREDconcrete is a low strength, light-weight composite with beneficial behaviour in fire and satisfactory thermal insulating properties.

STEREDconcrete can be used for insulation lining, in low-floor structures as a base and as layer of line structures.

The research of composite made from waste resources will tribute to profitable use of construction and industrial waste materials.

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References
[1] Mas B, Cladera A, del Olmo T, Pitarch F 2012 Influence of the amount of mixed recycled aggregates on the properties of concrete for non-structural use *Construction and Building Materials* **27** 612–622.
[2] Leiva C, Solís-Guzmán J, Marrero M, Arenas C G 2013 Recycled blocks with improved sound and fire insulation containing construction and demoliion waste *Waste Management* **33** pp. 663-671.
[3] Hansen T C 1992 Recycled aggregates and recycled aggregate concrete, recycling of demolished concrete and masonry RILEM, London (RILEM Report No. 6).
[4] Puthussery J V, Kumar R, Garg A 2016 Evaluation of recycled concrete aggregates for their suitability in construction activities: An experimental study *Waste Management* **60** pp 270-276.
[5] McNeil K, Kang T H-K 2013 Recycled concrete aggregates: a review, *International Journal of Concrete Structures and Materials* **7** (1) pp. 61-69.
[6] Bílý P, Fládr J, Kohoutková A 2017 Behavior of anchorage areas in the steel-concrete composite structure loaded by longitudinal shear forces *Procedia Engineering* **172** pp. 104-110.
[7] Tesárek P, Holub P, Havrda J, Fládr J, Prošek Z, Trejbal J, Plachý T 2017 Mechanical Properties of Cement Composites Reinforced by Carbon Microfibers: Compressive and Bending Strength *Key Engineering Materials* **722** pp. 351-356.
[8] Štemberk P, Vaitová M, Hanzlová H 2016 Prediction of Early Age Tensile Creep of Concrete Using Fuzzy Logic *Mechanika 2016 Proceedings of the 21st International Scientific Conference* pp. 253-256.
[9] Šeps K and Vodička J 2012 Fibre Reinforced Concrete with Recycled Concrete and Insulation Material STERED. Advanced Materials Research **1054** pp 262-266.
[10] ČSN EN 12930-5 Testing hardened concrete – Part 5: Flexural strength of test specimens
[11] ČSN EN 12390-3 Testing hardened concrete – Part 3: Compressive strength of test specimens