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WASTE AL-W-B POWDER MATERIAL FOR HIGH PERFORMANCE CONCRETE

There were investigating the effect of aluminium-tungsten-boron (Al-W-B) powder as waste material, obtained from crashing and milling of Al-W-B composite material, to a high performance concrete (HPC) in order to obtain neutron absorbing material with sufficient carrying capacity but with increased porosity and decreased density concurrently. In order to evaluate the effects of Al-W-B powder to the concrete structure, HPC as a reference concrete was used. A mix design of HPC from the author's (1) previous research work was used. In this study, the influence of the Al-W-B powder in different dosages on the properties of fresh and hardened HPC was investigated. Specific minimum water/cement (W/C) ratio to each sample of HPC was applied to reach required flow ability properties of fresh concrete mixture. As source of boron composite material (CM), previously grinded powder containing boron-tungsten fibre and aluminium matrix (CM Al-W-B) is used. A method of grinding has been used for processing of CM Al-W-B powder.

1. INTRODUCTION

It was chosen to create a concrete that ensure the radiation shield properties, and with a high strength and normal low density at the same time.

High performance concrete (HPC) is designed to give optimized performance characteristics for the given set of materials, usage and exposure conditions, consistent with requirements of cost, service life and durability [1]. Architects, engineers, and constructors all over the world found that application of HPC allows them to build more durable structures at comparable costs of HPC is being used for buildings in aggressive environments, marine structures, highway bridges and pavements, nuclear structures, tunnels, precast units, etc. [2], [3].

Aluminium matrix composites are lightweight materials with fine creep and fatigue behaviour (especially at elevated temperatures), as well as with increased wear resistance if we compare it with unreinforced light metals or fibre reinforced polymers.

The initiation of this study showed that adding of Al-W-B powder to a concrete mixture significantly reduces the mechanical strength of the concrete. In order to assess fully the effects of powder to the concrete structure, it was decided to use HPC as a reference concrete. This study was supported by using an optimal recipe of HPC

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from the author's previous research work [4]. In this study, the influence of the Al-W-B powder in different dosages on the properties of HPC was investigated. In the concrete mixtures Aalborg White Portland cement CEM I 52,5 R (WPC), granite stone, sand, microsilica, SP and AL-W-B powder in different dosages were used. [5],[6]

2. MATERIALS AND METHODS

2.1 MATERIALS USED IN STUDY

WPC produced in Aalborg cement factory (Denmark) was used in the given study. Morphology of CM Al-W-B particles are in range from approximately 2μm to 100 μm.

Two groups of aggregates with particle sizes of 0–1.8 mm (sand) and 0–5.0 mm (crushed granite stone) and certain distribution of fraction were used for HPC production. Maximum aggregate size was 5 mm. The specific gravities of the fine (sand) and coarse (crushed granite stone) aggregates were 2.64 and 2.70 g/cm^3, respectively. Microsilica “Elkem-microsilica – 920 D” was used as microfiller with high pozzolanic activity. Superplasticizer (SP) ”Semflow MC”, based on polycarboxylatess, was used in HPC mixtures.

2.2 METHODS

Four groups of HPC samples were produced and compared. In the first group (marked as HPC 2.5), concrete was produced without Al-W-B (reference concrete), in the second group (marked as HPCC 2.5-1) – 0.77%, in the third group – 1.56% (marked as HPCC 2.5-2), and in the fourth group – 30% (marked as HPCC 2.5-3) by weight of cement. “2.5” in designation of samples means amount of SP (2.5% of cement weight). Due to fine particle sizes of Al-W-B, before start preparation of HPCC samples, it was decided to replace only finer fraction of used granite and sand (with particle sizes from 0.063μm to 0.150μm).

SP was added to mixing water in the above mentioned ratios by weight of cement. Laboratory type mixer was used in the production of concrete. The concrete mixtures were prepared by using the following procedure: the components of mixture were mixed as dry for 2 minutes, and then half of water was added to the mixture, mixing was continued for 1 minute, then second half of water with SP was added to the mixture and mixing was continued for another 2 minutes. After mixing of fresh concrete, W/C ratio was recorded. Flow tests were carried out on the fresh concrete batches. After completion of these tests, the fresh concrete was cast into molds, where HPC self-compacted in laboratory with the temperature of 20 ±2 °C and a relative humidity of 50–55%. For each sample of HPC and HPCC’s, five (cubes with dimensions of 100x100x100 mm) specimens were cast. The cubes of hardened concrete were used for the determination of compressive strengths**,** flexural strength and X-ray phase analysis. Additionally, to visually evaluate the increasing of fresh volume after 1 hour from moment of adding of water, three samples (cubes with dimensions of 160x40x40 mm) for each mix design of HPCC were made.

Hardened samples were taken out from the molds 24 h later and cured for 2, 7 and 28 days until the time of testing. The specimens were immersed in water at 20±2 °C until the test age.

The effects of SP on workability and consistency of fresh concrete mixes were measured using the flow cone test according to LVS EN 12350-2:2009. The compressive strength tests were performed by using "Controls-50-C4632" according to LVS EN 12390-3:2002. X-ray phase analysis was determined by using "Rigaku Ultima+".

Table 1 Mix design of HPC and HPCC's

Material	**Bulk density (kg/m^3)**	**Dosage (m^3)**			
		HPC 2,5	HPCC 2,5-1	HPCC 2,5-2	HPCC 2,5-3
Cement CEM I 52.5 R	3150	650	650	650	650
Sand	2640	494	483	478	347
Granite stone	2800	3474	3400	3364	2442
Microsilica	2400	100	100	100	100
Super plasticizer	1050	16.25	16,25	16,25	16,25
Al-W-B	143	0	5	10	200

3. RESULTS AND DISCUSSIONS

3.1 EFFECT OF SP ON PROPERTIES OF FRESH CONCRETE

Results given in **Kļūda! Nav atrasts atsauces avots.**, shows that flow ability decreases with increasing the amount of Al-W-B powder in HPC. These results correlate with another data where the Al-W-B ratio increases from 0.77% to 30% by volume of concrete while w/c ratio increases with increasing the amount of water in the concrete mix design to reach the necessary flow ability.

Cone test in all cases were symmetrical, which indicates that the quality of mixed concrete is acceptable.

Table 2. Effect of Al-W-B on properties of fresh concrete

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Test No.	Al-W-B , % (by volume)	Obtained W/C ratio	Cone flow test (mm)	Accordance to SF class
HPC-2.5	0.00	0.28	285	SF2
HPCC-2.5-1	0.77	0.29	281	SF2
HPCC-2.5-2	1.56	0.30	283	SF2
HPC-2.5-3	30.00	0.31	281	SF2
Note: SF (cone flow test) classes are set in accordance with standard LVS EN 12350-2:2009				

1 hour from moment of water adding, we visually assessed that concrete with added Al-W-B, swells (picture of swelling for sample HPCC 2.5-3 see **Kļūda! Nav atrasts atsauces avots.**). Increasing of volume was 2% (HPCC 2.5-1), 4% (HPCC 2.5-2) and 12% (HPCC 2.5-3). Increasing of volume was not the same for each point of the upper surface, because of friction between concrete surface and mould wall.

Fig. 1 Swelling of HPCC 2,5-3

3.2 EFFECT OF AL-W-B ON HARDENED CONCRETE

3.2.1. Compressive strength.

Results given in **Kļūda! Nav atrasts atsauces avots.** showed that adding of Al-W-B, decreases strength of HPC in all cases.

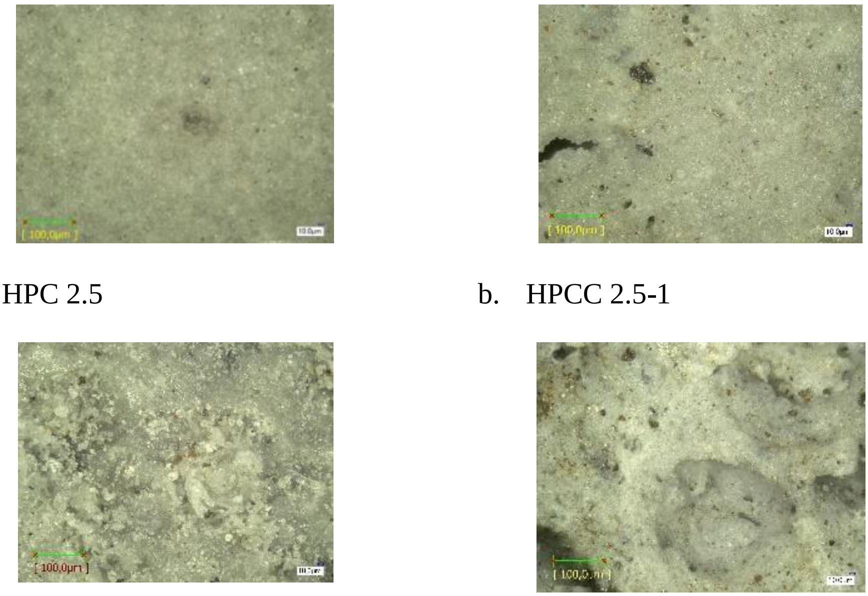
Table 3 Effect of Al-W-B on HPC compressive strength

Sample	Al-W-B , % (by concrete volume)	Compressive strength, MPa		
		2 days	7 days	28 days
HPC 2.5	0.00	**88.28**	**94.86**	**115.83**
HPCC 2.5-1	0.77	**61.36**	**58.23**	**65.43**
HPCC 2.5-2	1.56	**56.35**	**68.56**	**67.31**
HPCC 2.5-3	30.00	**4.38**	**9.39**	**12.52**

3.2.2. Investigation of surface with optical microscope.

Morphology of samples of concrete was investigated on Keyence corporation VHX-2000 optical microscope with lens VH-Z500R/W. By means of 3D digital optical capabilities, through using "large depth-of-field & super resolution imaging” function, by using constant illumination (3200 K), brightness and magnification of 500X.

As shown in **Kļūda! Nederīga grāmatzīmes pašatsauce.**, texture of concrete surface stays less smooth with increasing the concentration of Al-W-B. As observed, surface of HPC 2.5 is practically without cracks and is not contaminated with coloured particles of granite. Some cracks and remaining particles from Al-W-B powder were observed for sample of HPCC 2.5-1 (see **Kļūda! Nederīga grāmatzīmes pašatsauce.** b). Surface of HPCC 2.5-2 (**Kļūda! Nederīga grāmatzīmes pašatsauce.** c) has small particles of cement an fine aggregates that are separated from compacted cement (fingerprint of incomplete collapse of bubbles). More particles of Al-W-B have been found on surface of HPCC 2.5-2 than on surface of HPCC 2.5-1. Surface of HPCC 2.5-3 (see **Kļūda! Nederīga grāmatzīmes pašatsauce.** d) is full with large (with diameter up to 600 μm and depth up to 300 μm [excluding the connected pores]) opened pores as resulting of bubble collapsing in fresh cement. Density of particles from Al-W-B on surface is higher than visually observed on other samples.



a. HPC 2.5

b. HPCC 2.5-1

c. HPCC 2.5-2

d. HPCC 2.5-3

Fig. 2 Pictures of HPC and HPCC surfaces, obtained by optical microscope (500X)

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4. CONCLUSION

W/C ratio increased by increasing concentration of Al-W-B from 0% by volume to 30 % by volume of concrete, because of dewatering process by reaction between aluminium powder and wet cement.

Flow ability of fresh concrete decreases by increasing concentration of Al-W-B from 0% by volume to 30 % by volume of concrete.

After 1 hour from water adding, volume of fresh concrete increased by increasing concentration of Al-W-B from 0% to HPC 2.5 (0% by volume) to 12% for HPCC 2,5-3 (30% by volume). It was noticed that reaction between aluminium and wet Portland cement generates H_2 gas leading to foaming (swelling) of concrete.

Compressive strength for 28 days cured concrete reduced as following: 115.83 MPa for HPC 2.5 (0%) – 65.43 MPa for HPCC 2.5-1 (0.77%) – 67.31 MPa for HPCC 2.5-2 (1.56%) – 12.52 MPa for HPCC 2.5-3 (30% by volume of concrete).

X-ray analysis showed signal increasing for mineral svyatoslavite by increasing the concentration of Al-W-B.

Overall intensities for peaks of portlandite ($Ca(OH)_2$), hatrurite ($CaSiO_5$) and quartz (SiO_2) decreased for longer ageing concrete samples with concentration of 0.77% (HPCC 2.5-1).

Investigation with optical microscope showed that surface for samples of HPCC are less smooth and are more contaminated with coloured particles (by Al-W-B) than samples of HPC.

Only samples of HPCC 2.5-3 (30% by volume of concrete) has clearly visible of opened pores with high density on surface.

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