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EFFECT OF DISPERSANT ON GROUND GRANULATED BLASTFURNACE SLAG PARTICLE SIZE DISTRIBUTION DETERMINED BY LASER DIFFRACTION METHOD

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ABSTRACT
Particle size distribution measurements were performed on ground granulated blastfurnace slag by laser diffraction with the powder dispersed in distilled water with sodium hexametaphosphate used as dispersing agent, as well as in pure distilled water and propan-2-ol. Two samples of slag with Blaine fineness 4700 cm^2/g and5500 cm^2/g were tested.The results showed significant differences between results obtained by using different dispersants. Percentiles dv10 and dv50 are significantly lower when propan-2-ol or pure water were used instead of water with SHMP as dispersing agent.

1. INTRODUCTION
Supplementary cementitious materials (SCMs), such as ground granulated blastfurnace slag (GGBS), fly ash, microsilica, etc. are generally used to produce a sustainable concrete. Alongside their chemical properties, fineness and particle size distribution (PSD) of SCMs are the most important factors for their performance in concrete [1]. The size distribution of cement and SCMs is typically very broad and spanning over two or three decades, from the submicrometer range to 100 μm. In the dried state particles are usually highly agglomeratedand for that reason they must bedispersed in order to differentiate between weakly bound agglomerates and primary units [2].Wet and dry sieving, various sedimentation techniques, Blaine and BET methods are traditionally used for fineness evaluation.Majority of these techniques are slow, subjected to operator influences and give low reproducibility.Recently, laser diffraction emerged as one of the most common techniques for particle size analysis. It is based on the general principle that the angle of laser light

diffracted by a particle corresponds to the size of the particle. Large particles scatter light at small angles relative to the laser beam and small particles scatter light at large angles. Samples usually contain particles of different sizes, so light diffraction results in a specific diffraction pattern.By analyzing such a pattern according to Mie's diffusion theory of light,the exact particle size distribution of the sample can be deduced.There are two dispersion techniques for laser diffraction, wet and dry dispersion. In the case of wet dispersion, the particles are dispersed in a suitable liquid, with the processes of wetting and shear during stirring causing deagglomeration. Also, energy is imparted to the system using ultrasonication which disperses agglomerates to the primary particle size of the material. The measurements results are influenced by variations in surface chemistry of thepowders, solids concentration, the nature of the medium, and theamount of mechanical energy expended to break up agglomerates [2,3,4].ISO 13320-1 is a reference for the theory and general operation of a laser particle-size analyzer [5]. Required optical parameters(the refractive index and the absorption index) for supplementary cementitious materials analysis are presented by Yewel et al. [6].The objective of this paper is to provide comparative results of GGBS particle size distribution (PSD) tests obtained by laser diffraction in different liquids.

2. MATERIALS AND METHODS

This study includes analyses of GGBS produced in ArcelorMittal Zenica. Two GGBS samples of different fineness were prepared by grinding in laboratory ball mill. Specific surface area (SSA) of the samples was 4700 and 5500 cm^2/g, respectively, and it was determined by automatic Blaine permeabilimeter according to EN 196-6. The chemical analysis of the GGBS obtained by X-ray fluorescence (XRF) is shown in Table 1.

Table 1. Chemical composition of GGBS

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI
% weight	43,33	8,08	0,43	41,59	4,18	1,44	0,10	0,96	0,8

The PSD of the samples was analyzed according to ISO 13320. The Malvern Mastersizer 2000 with Hydro 2000G dispersion unit was used for wet analysis. Distilled water and dispersing agent sodium hexametaphsophate (SHMP) are proposed for GGBS dispersion in the reference manual [7]. In addition, GGBS samples were dispersed in distilled water without dispersing agent, as well as inpropan-2-ol. Samples were premixed in liquids and ultrasonicated for 3 minutes to deagglomerate particle clusters.

The GGBS optical parameters are:

- refractive index n=1,62 and
- absorption coefficient k=1,00 [4].

The optical parameters of dispersants are:

- refractive index of water 1,330 and
- refractive index of propan-2-ol 1,390 [4].

The optical system uses two laser light sources: a He-Ne laser (633 nm) and a solid state diode laser with an unspecified wavelength in the blue spectrum.

3. RESULTS AND ANALYSIS

The results of laser diffraction analysis with different dispersants are presented in Table 2, as well as in Figure 1 and Figure 2. The volume weighted percentiles are:

- d_v10 – the particle diameter below which 10 % of the sample volume exist,
- d_v50 – the particle diameter below which 50 % of the sample volume exist and
- d_v90 – the particle diameter below which 90 % of the sample volume exist.

Table 2. Blaine fineness and volume weighted percentiles for GGBS samples

Blaine fineness	Dispersant	d_v10 (µm)	d_v50 (µm)	d_v90 (µm)
4700 cm^2/g	Water	0,95	8,36	40,49
	Water + NHMP	1,36	10,28	34,35
	Propan-2-ol	1,37	8,24	31,84
5500 cm^2/g	Water	0,79	6,38	29,27
	Water + NHMP	1,07	9,21	40,05
	Propan-2-ol	0,97	6,74	37,31

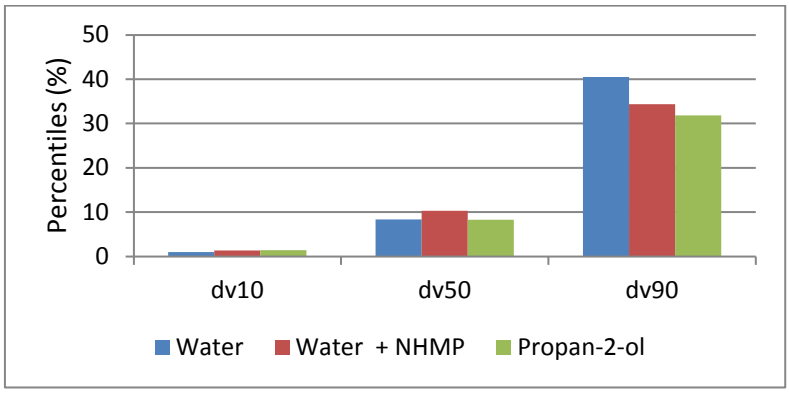

Figure 1. Volume weighted percentiles of GGBS (SSA = 4700 cm^2/g)

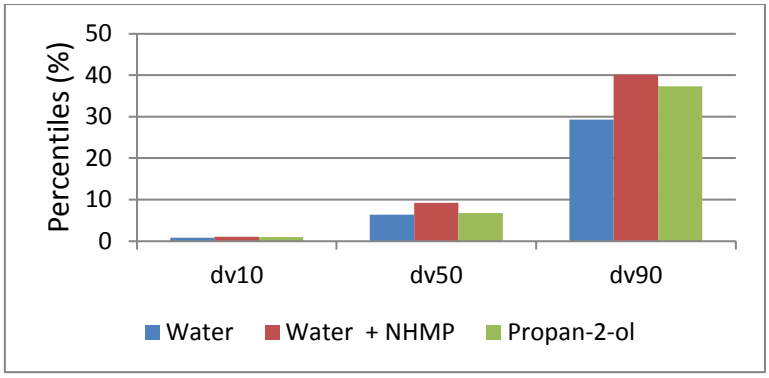

Figure 2. Volume weighted percentiles of GGBS (SSA = 5500 cm^2/g)

Percentiles d_v10 and d_v50 are significantly higher when water with SHMP was used as a dispersant, while percentiles d_v90 show certain inconsistency. Figure 3 shows PSD frequency curves of GGBS with SSA= 4700 cm^2/g and Figure 4 shows PSD frequency curves of GGBS with SSA= 5500 cm^2/g.

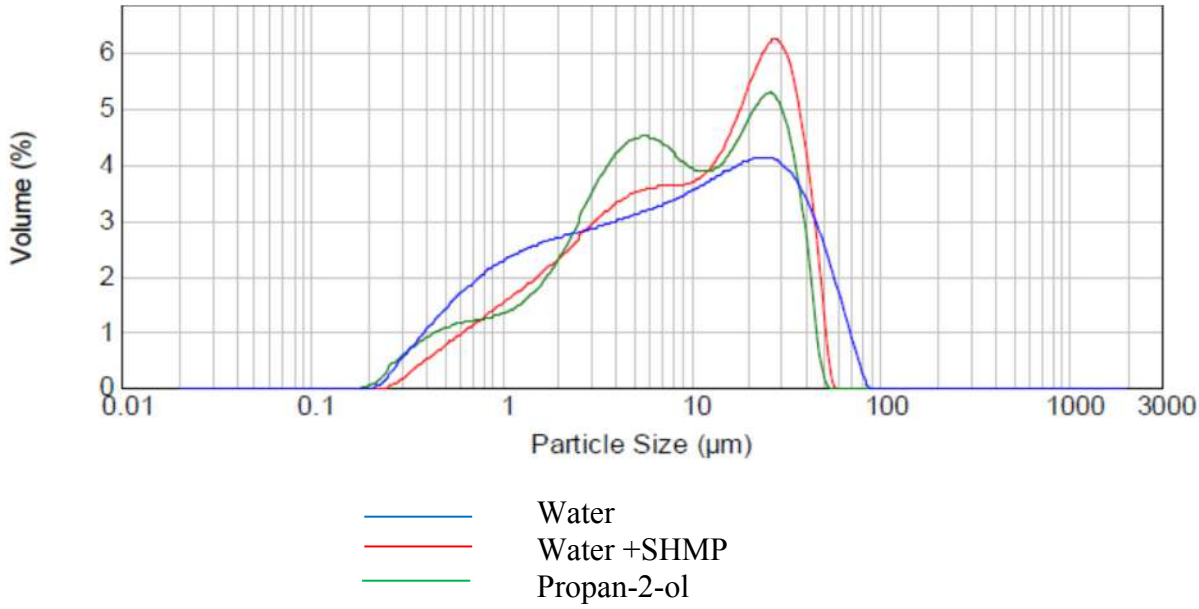

Figure 3. PSDfrequency curves of GGBS (SSA=4700 cm^2/g)

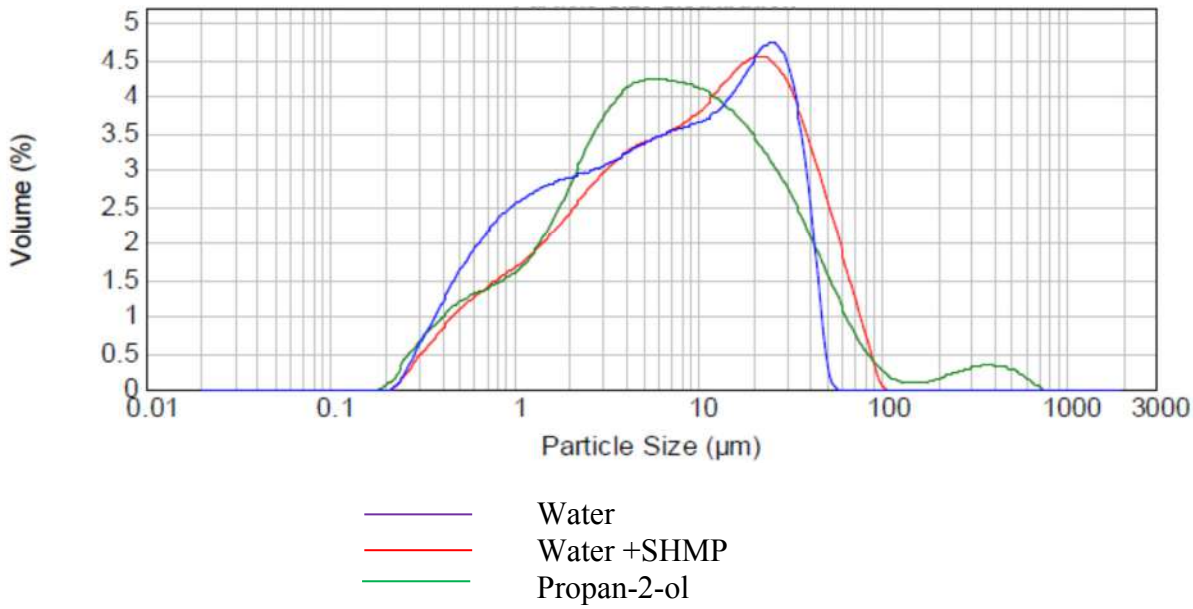

Figure 4. PSD frequency curves of GGBS (SSA=5500 cm^2/g)

Frequency curves shown in Figure 3 and Figure 4 enable a more preciseidentification ofthe differences between the results of measurements influenced by dispersant used. All curves shown in Figure 3 presents a major peak at 20-40 µm, while the green curve (propan-2-ol) have a second peak at 3-6 µm. The green curve (propan-2-ol) shown in Figure 4 has a peak shifted to the lower particle sizes compared to the blue (water) and red curve (water + SHMP). The blue curves shown in Figure 3 and Figure 4 indicate that more particles below 2 µm are present in both GGBS samples dispersed in water. The green curve shown in Figure 4 has semi-disconnected peak at 200-600 µm, which can only be explained by reagglomeration of particles during ultrasonication.

4. CONCLUSION

The analysis presented indicated that PSD results obtained by laser diffraction method are strongly influenced by the choice of dispersant. It is of major importance that powders should be adequately dispersed prior to testing since misleading results are obtained if agglomeration of particles takes place. By percentile analyzing it can be concluded that the values of d_v10 and d_v50 are significantly lower when propan-2-ol or water without dispersant were used instead of water with SHMP as dispersing agent. Also, GGBS with SSA= 5500 cm^2/g has tendency to reagglomerate in propan-2-ol.

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