Suitability of desert or recycling sands as raw material for concrete production

Characterization of
particles · powders · pores

Introduction

Sand is an essential raw material for the production of concrete for the construction industry. One might think that due to the large area deserts such as Sahara, Gobi, Australian Desert etc. sand would be available in unlimited quantities as a raw material. This is not the case, however, as these sands are not suitable for the production of high-quality concrete with appropriate mechanical properties.

The Federal Institute for Geosciences in Hannover has recently addressed this issue and concluded that the reason for the unsuitability of desert sand grains is not primarily the increased roundness, but the lack of certain size fractions such as coarse and medium sand [1]. Desert sand is therefore too fine to be used as concrete sand.

In order to classify a sand as suitable concrete sand in terms of quality, a measuring device must be able to determine the particle size distribution over the relevant particle size range and to statistically display the roundness of the grain - the Bettersizer S3 Plus provides both.

Measurement technology

The Bettersizer S3 Plus is a combined particle size analyzer of the latest generation, consisting of the two measuring methods „static light scattering" and „dynamic image analysis". Due to the advantages of this combination, this system offers a comprehensive and exact characterization of powders and dispersions regarding particle size and shape from the nano- to the millimeter range (measuring range 0.01 – 3,500 µm).

Figure 1 shows the DLOIOS technology (Dual Lens & Oblique Incidence Optical System) on which the Bettersizer S3 Plus is based:

The particles to be measured are pumped through the double measuring cuvette system in a solvent of choice. In the first cuvette, short-wave parallel laser light (532 nm) hits the particles and is scattered characteristically depending on the particle size distribution. This scattered light is reliably detected by the fixed detector system over an angular range of 0.02 – 165°. This extremely large measuring range is realized using the DLOIOS system, a patented single-laser technique with double lens system and oblique light incidence.

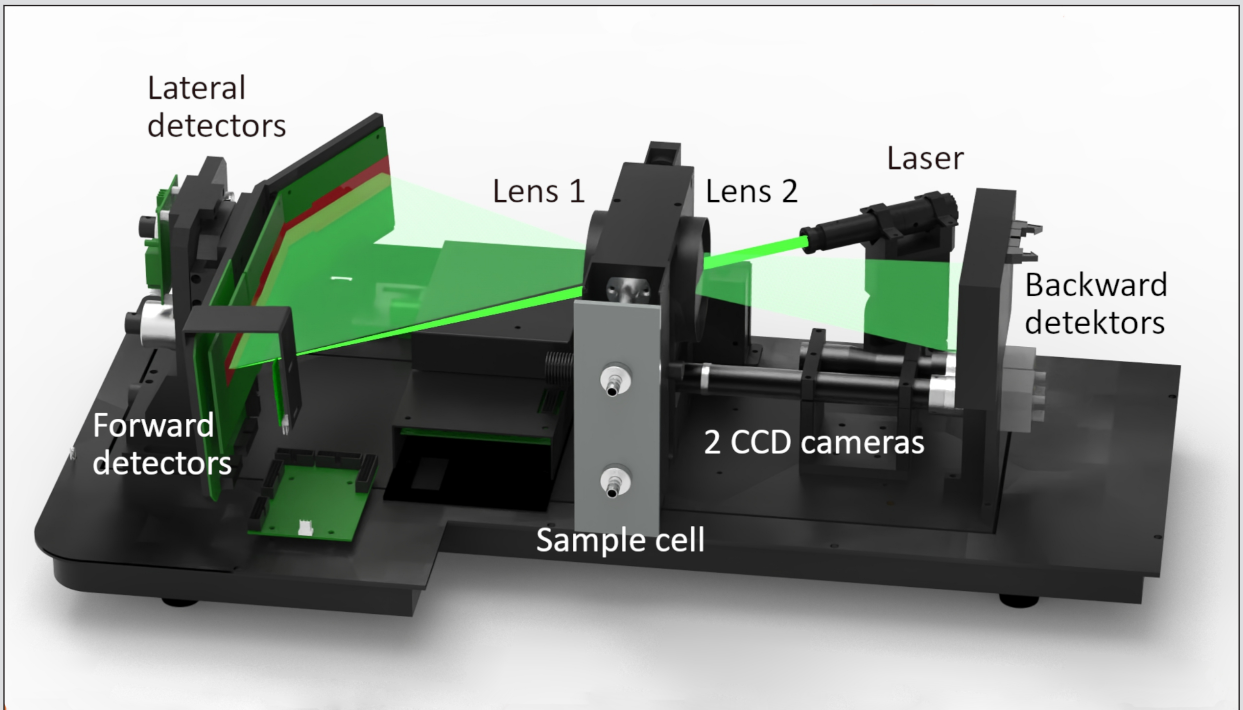


Figure 1: *Schematic representation of the DLOIOS technology of the Bettersizer S3 Plus*

Suitability of desert or recycling sands as raw material for concrete production

3P INSTRUMENTS

Characterization of particles · powders · pores

In the second cuvette, the particles are continuously photographed, evaluated and statistically classified by the image analysis system, consisting of two high-speed CCD cameras and high-precision telecentric lenses, at a rate of up to 10,000 particles/minute in real time. The cameras are equipped with a 0.5X lens (15-fold magnification) and a 10X lens (300-fold magnification), can be used individually or combined and cover a particle size range from 2 – 3,500 µm.

In summary, the Bettersizer S3 Plus with its unique design allows

- the exact particle size measurement of very small particles from 10 nm (DLOIOS technique)
- real number and volume distributions with suitable equivalent size diameters (CCD camera technology)
- higher accuracy in the coarse range than conventional static light scattering devices (combination method DLOIOS and CCD camera technology)
- Detection of individual oversized grains, agglomerates, air bubbles (CCD camera technology)
- Shape analysis with more than 20 specific shape parameters

Experimental procedure and results

A commercially available standard sand used in the construction industry (CEN standard sand DIN EN 196-1) and an untreated desert sand were used for the tests. Both sands were then riffled down over several stages to the required representative test quantity (approx. 2 g). These samples were analyzed in water using the Bettersizer S3 Plus in three ways:

1. **Static light scattering** (DLOIOS technique [2])
2. **Combined method using static light scattering and dynamic image analysis** (CCD camera, 0.5X lens)
3. **Dynamic image analysis** (combination of 2 CCD cameras with 0.5X and 10X lens [3])

In addition, several (separated) sample fractions of both sands were measured to test the quality of the sample preparation. The area equivalent diameter [4] was used as diameter for the dynamic image analysis.

The combined method (light scattering, image analysis) and dynamic image analysis proved to be the most suitable method for the entire size range of the sands. **Figure 2** and **Table 1** show, using the standard sand as an example, that both methods produce a very similar distribution curve for the sands presented here.

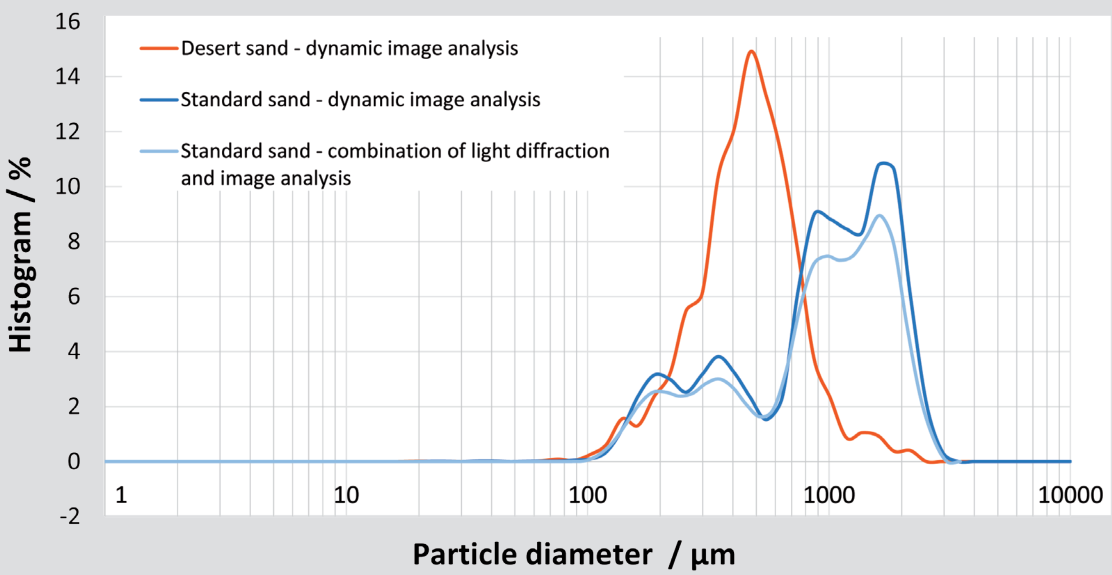


Figure 2: *Particle size distribution curves of desert sand (dynamic image analysis) and standard sand (dynamic image analysis and combined methods in comparison)*

Suitability of desert or recycling sands as raw material for concrete production

Characterization of particles · powders · pores

Table 1: *Characteristic percentage values for the particle size distribution curves in Figure 2*

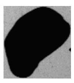
Sample	D3	D6	D10	D16	D25	D50	D75	D84	D90	D99
Desert sand - dynamic image analysis	145.9	185.5	223.1	263.1	316.8	433.6	575.9	656.9	740.8	1544
Standard sand - dynamic image analysis	150.9	177.7	216.8	298.6	461.4	958.9	1476	1678	1828	2422
Standard construction sand - combination of light diffraction and image analysis	150.3	177.8	217.4	295	457.5	943.9	1434	1631	1781	2341

A comparison of the distributions of the two sands (desert sand and standard sand) shows significant differences from about 300 – 400 µm: The standard sand has the (volumetric) main fraction of its particles approximately between 500 and 2000 µm. The desert sand, on the other hand, shows mainly particle sizes between about 200 and 800 µm. In addition, the standard sand has a polymodal distribution with four distinct peaks, while the desert sand shows an almost monomodal distribution.

Besides the area equivalent diameter, the so-called FERET diameters play an important role in image analysis [4]. The ratio of maximum FERET to minimum is a measure for the expansion of a particle: The larger this value is, the more elongated the particle will be. Consequently, a sphere has the smallest possible L/D value of 1.

In order to compare the two sands with each other, the L/D values of their particles were considered from a size value of 300 µm, which in both systems represents approximately a volume fraction of 80 – 85 %. **Table 2** shows an example from the individual particle list of both sands, the equivalent diameter and the L/D value (range about 1000 µm – 2500 µm). It is noticeable that the L/D value of the desert sand particles is on average considerably higher than that of the standard sand.

Table 2: *Extract from the individual particle list of desert sand and standard sand (between about 1,000 and 2,500 µm) with camera image, equivalent area diameter and L/D value*

	Desert sand		Standard sand	
				
Diameter / µm	1986	1872	2576	2320
L/D-value	2.554	1.662	1.537	1.255
				
Diameter / µm	1464	1312	1555	1543
L/D-value	2.13	1.518	1.197	1.47
				
Diameter / µm	994.3	988.2	1032	1028
L/D-value	1.463	1.849	1.014	1.034

3P INSTRUMENTS

Characterization of particles • powders • pores

Suitability of desert or recycling sands as raw material for concrete production

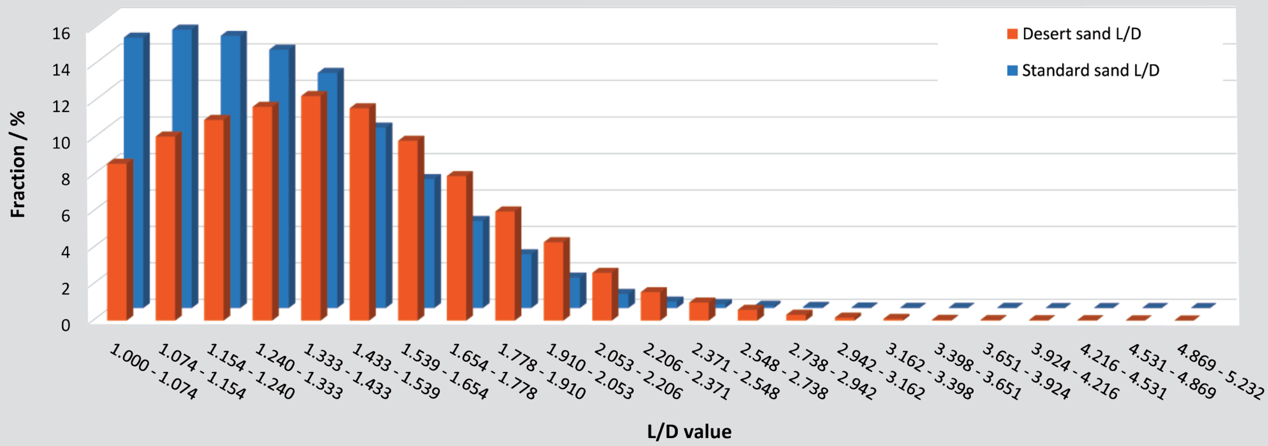


Figure 3: *L/D value distribution of desert sand and standard sand (dynamic image analysis)*

Table 3: *Characteristic percentages of the L/D value distribution curves in Figure 3*

	L/D3	L/D10	L/D25	L/D50	L/D75	L/D90	L/D99	Max L/D	Average L/D	Number of particles
Desert sand > 300 µm	1.025	1.085	1.202	1.401	1.65	1.933	2.62	30	1.47	81791
CEN standard sand > 300 µm	1.014	1.049	1.126	1.27	1.464	1.671	2.164	4.29	1.323	26629

Figure 3 shows the distribution function of L/D values of both sands in comparison, **Table 3** shows characteristic percentages for each of the two curves. The shift of the length to width diameter values of the desert sand to larger values is clearly shown, the grains of the desert sand are therefore longer than those of the standard sand.

Summary

The particle size measurements, which were carried out on a desert sand and a standard sand within the framework of the experiments presented here, confirm the statement made in [1] that the desert sand lacks certain size fractions in the medium and coarse range. Furthermore, its distribution is almost monomodal, whereas the standard sand has four distinct modes.

Another observed difference is the shape of the sands: The L/D-value distribution of the desert sand is shifted in comparison to larger values, the grains are much longer. To which extent this might be a general difference of these sand types has to be investigated in further studies.

In summary, the Bettersizer S3 Plus, due to its unique design (static light scattering combined with a double CCD camera image analysis system), is ideally suited to comprehensively characterize a sand with respect to its suitability as concrete sand.

Literature

[1] Press release BGR; https://www.bgr.bund.de/ DE / Gemeinsames / Nachrichten / Aktuelles / 2019 / 2019-08-06_wuestensand.html

[2] ISO 13320 Particle size analysis - Laser diffraction methods

[3] ISO 13322-2 Particle size analysis - Image analysis methods - Part 2: Dynamic image analysis method

[4] ISO 9276-6 Representation of results of particle size analysis - Part 6: Descriptive and quantitative representation of particle shape and morphology

3P Instruments
Rudolf-Diesel-Str. 12
85235 Odelzhausen
Germany
Tel. +49 8134 9324 0
info@3P-instruments.com