

Supplementary Materials

The Effect of Water, Nanoparticulate Silica and Dry Water on the Flow Properties of Cohesionless Sand

Leigh Duncan Hamilton ^{1,*}, Harald Zetzener ¹ and Arno Kwade ¹

¹ Institute for Particle Technology, Technische Universität Braunschweig, Volkmaroder Straße 5, 38104 Braunschweig, Germany

* Correspondence: Leigh-Duncan.Hamilton@tu-braunschweig.de

Equipment Used for Preparation and Characterisation



Figure S1. MX 1250, Rommelsbacher: A high shear blender equipped with a rotor and six blades used to produce dry water. The Maximum speed is $22,000 \text{ min}^{-1}$ and the blade diameter is approximately 0.07 m.

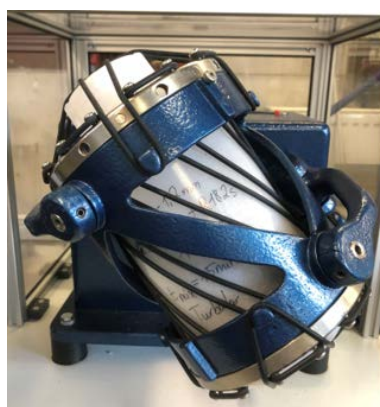


Figure S2. Turbula mixer, Willy A. Bachofen AG: A 3D shaker mixer applied to create mixtures of coarse sand and dry water. The frequency during mixing was 49 min^{-1} and the container filling degree was 70 %.



Figure S3. GranuDrum by GranuTools: A device to measure the dynamic angle of repose based on the rotating drum method. The black cylinder was filled to 50 % by volume and speeds were varied between 2 min^{-1} and 50 min^{-1} . Note, the glass screens were replaced with Perspex discs to avoid problems during measurements (water spreading on the screen). Image source: <https://www.granutools.com/en/granudrum>

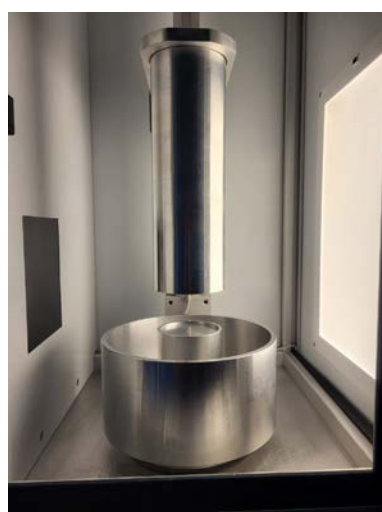


Figure S4. Device constructed at the Institute for Particle Technology, TU Braunschweig: A device to measure the static angle of repose based on the hollow cylinder method. The cylinder was filled with 150 ml sample before it was elevated at 150 mm/min . Cylinder length and diameter were 60 mm and 120 mm, respectively.

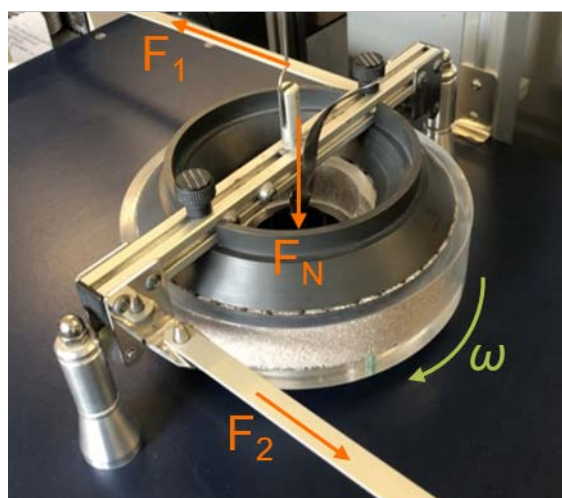


Figure S5. Ring shear tester, RST-01, by Dietmar Schulze GmbH: A device used to measure bulk behaviour in a quasi-static environment under normal stress. The normal stress ranged from 125 Pa to 16 kPa. The shear cell has a volume of approximately 950 ml and the shear velocity was 1.0 mm/s . F_N is the normal force, F_1 and F_2 are forces resulting from the pull rods, and ω is the angular velocity.

Nomenclature

Table S 1. List of Symbols

Symbol	Description [Unit]
AM	Additive manufacturing
AoR	Angle of Repose
CI	Cohesive index [-]
DW	Dry water
DW _{H₂O:R812S}	Dry water with ratio of water (H ₂ O) to Aerosil R812S
EDX	Energy-dispersive X-ray spectroscopy
H ₂ O	Water
m _i	Mass of substance i [kg]
μCT	Micro-computed tomography
n	Frequency / Rotational speed [min ⁻¹]
n _{DRUM}	Drum rotational speed [min ⁻¹]
R812S	Aerosil R812S
SAC	Surface are coverage
SEM	Scanning electron microscope
SiO ₂	Silicon dioxide, quartz
SPI	Selective Paste Intrusion
t _{mix}	Mixing time [min]
V _i	Volume of substance i [m ³]
WAAM	Wire Arc Additive Manufacturing
w _i	Weight percentage of substance i [%]
W _{s,m}	Measured solids content
α _{d,r}	Dynamic angle of repose [°]
α _{s,r}	Static angle of repose [°]
Q _B	Bulk density [kg/m ³]
σ	Normal stress [Pa]
σ _{pre}	Pre-consolidation stress [Pa]
τ _{sf}	Shear stress at steady-state flow [Pa]
φ	Filling degree [%]
φ _{sf}	Angle of internal friction at steady-state flow [°]

Supplementary Information to Energy-Dispersive X-Ray Spectroscopy (EDX)

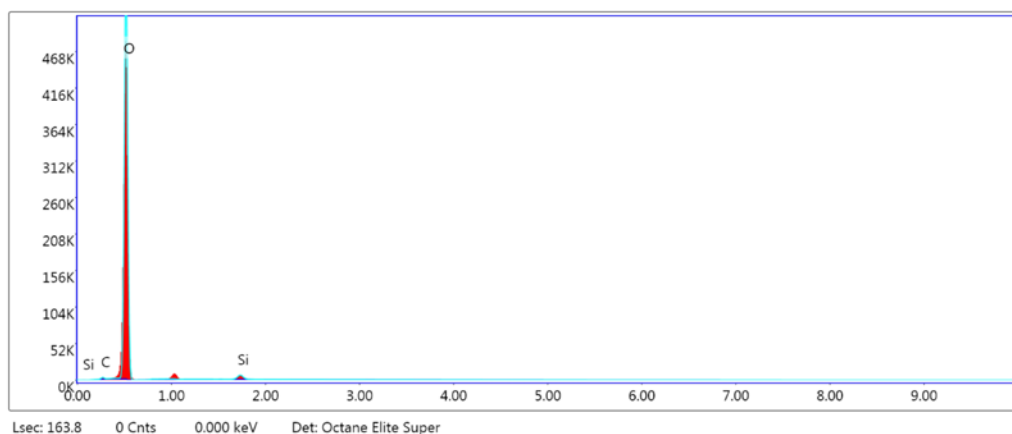


Figure S6. Sum Spectrum EDX: Analysis of dry water.

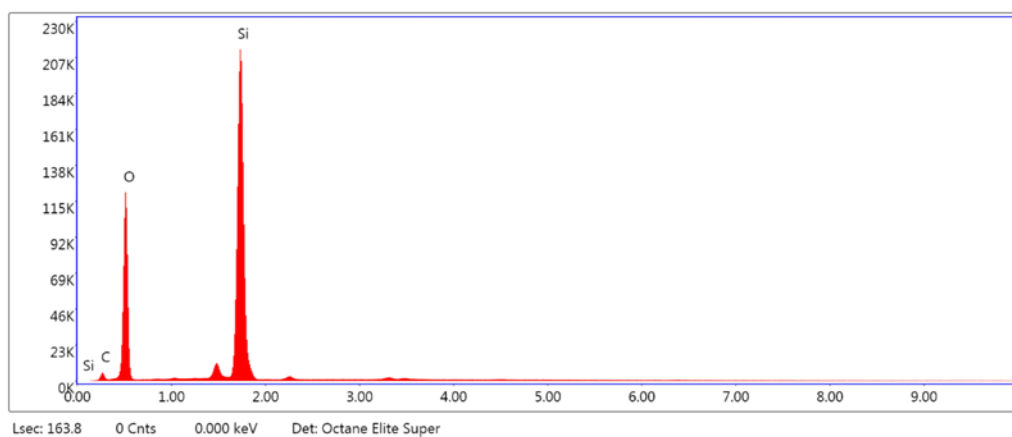


Figure S7. Sum Spectrum EDX: Analysis of coarse sand particle surface after mixing with dry water.