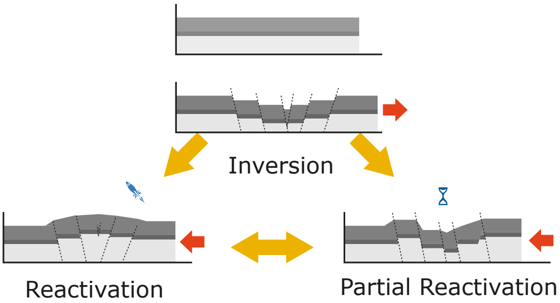
Influence of Time-dependent Healing on Reactivation of Granular Shear Zones in analogue models

A Community Benchmark

Motivation

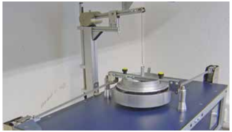
- Analogue models use frictional granular materials (sands, glass beads, etc.)
- Granular matter consolidates when under stress for an extended period of time
  - Basin inversion models
  - Quantify healing properties
  - Qualify relation to particle properties
  - Implications for analogue models
    - – Change of reactivation friction
    - → Possible change of reactivation angles
- Expand the database by [Klinkmüller et al., 2016]
  - more materials
  - healing properties

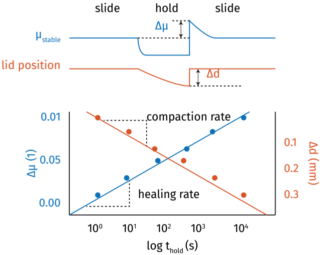


Characterisation of Granular Material Properties

Quantities and Qualities

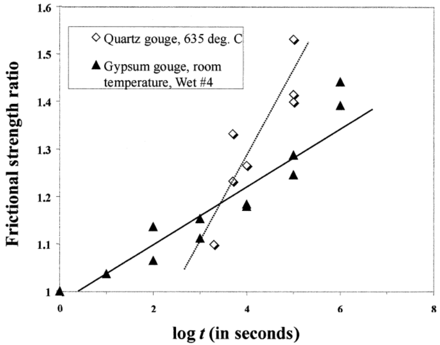
- Quantitative measures
  - Friction (cohesionless and with cohesion)
    $\mu = \frac{\tau - C}{\sigma_N}$ or $\mu_a = \frac{\tau}{\sigma_N}$
  - Healing rate $b \Rightarrow \Delta\mu \propto t_{hold}^{b}$
  - Compaction rate $c \Rightarrow \Delta d_{lid} \propto t_{hold}^{c}$
  - Stressing rate $s \Rightarrow \Delta\tau \propto t_{hold}^{s}$
- Qualitative measures (Quantification in progress)
  - Sphericity
  - Roundness
  - Surface
  - 'Quality score'
    - My personal, somewhat arbitrary measure to relate particle properties with friction



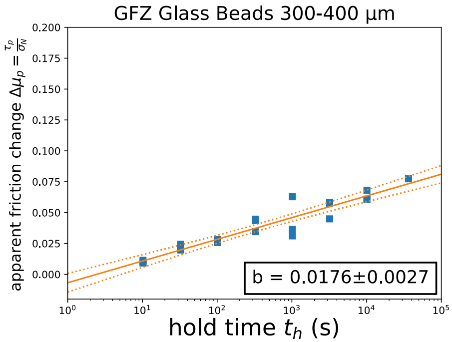


Restrengthening of Fault Zones in Analogue Models

Healing of Faults in Nature



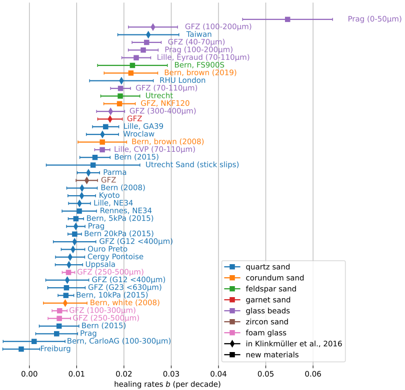
Restrengthening of fault gouge in HT-Triax-Experiments [Muhuri et al., 2003]



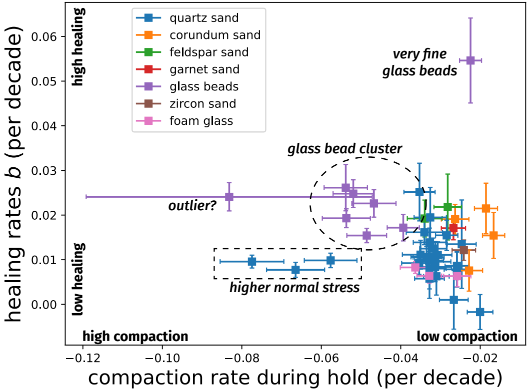
Restrengthening of fault gouge in the ringshear apparatus

Restrengthening of Fault Zones in Analogue Models

Comparison of Various Materials



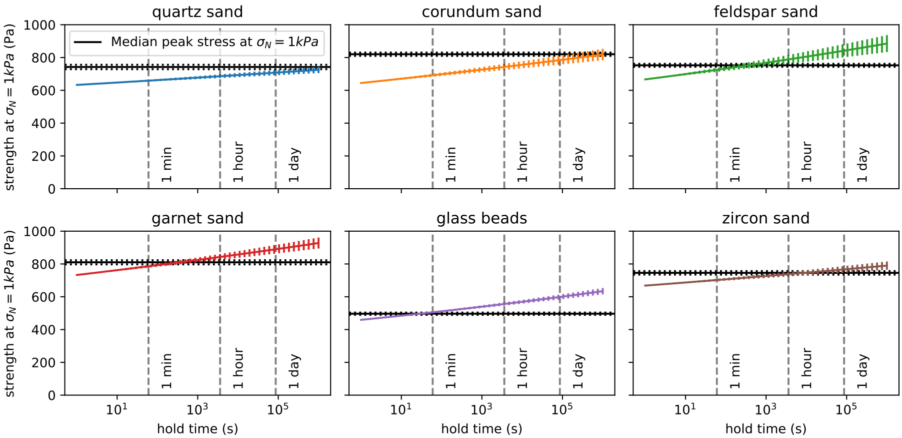
Benchmark of several Materials



Healing versus compaction during hold

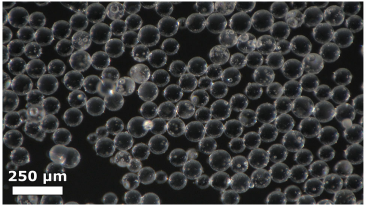
Implications for Reactivation Strength

Reactivation strength with time consolidation: $\mu_r(t) = \mu_r t^b$

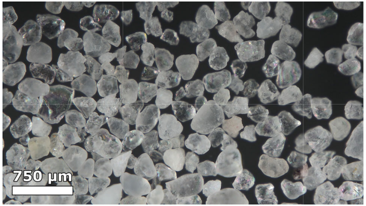


A first look at the materials

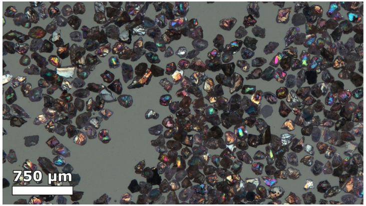
Characterizing the particle properties (surface, sphericity, etc.)



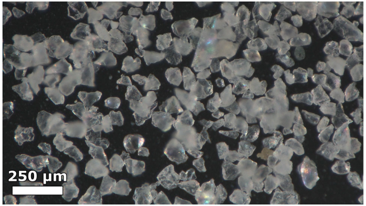
GFZ glass beads 70-110µm



GFZ G12 quartz sand



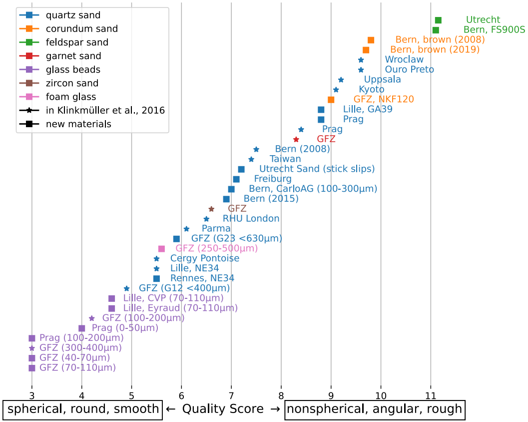
GFZ corundum brown



Wroclaw quartz sand

'Quality Score'

- A simple categorization scheme for particles
  - Sphericity (1=perfect, 2=high, 3=medium, 4=low)
  - Roundness (1=rounded, 2=subrounded, 3=subangular, 4=angular)
  - Surface roughness (1=smooth, 2=slightly rough, 3=shelly, 4=rough/jagged)
- Higher score indicates possible reasons for higher internal friction and consolidation
- Quantification with particle analysis is needed (WIP)



Conclusions and Further Work

- Healing rates are in the range of a few percent per decade
- Healing correlates with compaction
- High healing rates and low peak stresses favor creation of new faults
  - Extreme cases are glass beads and garnet sand
- Commonly used materials such as quartz and corundum sand show a significant consolidation on scales longer than a week
- A preliminary comparison with particle characteristics does not show a clear pattern

  → Further quantification of particle properties needed
  Ideas for target properties are welcome!

References I

Klinkmüller, M., Schreurs, G., Rosenau, M., and Kemnitz, H. (2016).
Properties of granular analogue model materials: A community wide survey.
Tectonophysics, 684:23–38.

Muhuri, S. K., Dewers, T. A., Scott, Jr., T. E., and Reches, Z. (2003).
Interseismic fault strengthening and earthquake-slip instability: Friction or cohesion?
Geology, 31(10):881–884.