Geophysical Research Abstracts
Vol. 16, EGU2014-5169, 2014
EGU General Assembly 2014

Towards quantification of the interplay between strain weakening and strain localisation in granular material

Malte C. Ritter, Matthias Rosenau, Karen Leever, and Onno Oncken
GFZ Potsdam, Geodynamics, Potsdam, Germany (malte.ritter@gfz-potsdam.de)

Strain weakening is the major agent of localisation of deformation into shear zones and faults at various scales in brittle media. Physical analogue models using granular material are especially apt to investigate both phenomena, because they are able to reproduce them without the need of any assumptions concerning the physics behind. Several attempts have been made to quantify either strain weakening (e. g. Lohrmann et al., 2003, using Ring-Shear tests) or strain localisation (e. g. Schrank et al., 2008, using a variation of the classical Riedel-experiment). While Ring-Shear tests yield excellent data on strain weakening through measuring shear stress during localisation, they do not allow monitoring the process of strain localisation in-situ because of experimental inaccessibility of the small scale kinematics. In Riedel-type strike-slip experiments, on the other hand, no direct measurements of shear stresses have been available so far. Furthermore, they contain a strong boundary condition in form of a pre-defined linear discontinuity at the base. This forces the formation of Riedel-Shears, i. e. a complex fault system, that makes it difficult to define strain localisation on single faults.

We developed a new experimental set-up, in which the formation of a strike-slip shear zone in granular material is induced using an ndenter with stress and strain monitored at high accuracy and resolution. In a first set of experiments we used a horizontal sand layer indented by a vertical wall. The sand layer is laterally unconfined and rests on low-viscosity silicone oil in order to minimize basal shear strength. Compared to the Riedel experiments, this avoids the boundary condition of a pre-existing basal discontinuity allowing one single, hrough-going shear crack to form and propagate. The indenter moves at a constant rate and is equipped with a force sensor that measures the applied push, which integrates over shear stresses along the fault and the base of the sand pack. Therefore simultaneous monitoring and analysis of strain weakening and strain localisation becomes feasible.

Here we present results from first tests of this setup demonstrating its capability and limits. Various granular analogue materials with differing mechanical properties are tested and compared to results in ring shear and axial tests. Preliminary results show a principal pattern of correlated strain weakening and localisation that is characterized by a phase shift between stress and strain evolution during shear zone formation: Strain localisation has its maximum when the weakening rate is highest. Strain then delocalises, however, and reaches a steady state when the material strength reaches a stable value.

References:

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