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Strain weakening and localisation: material properties or boundary effects?

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Strain weakening is commonly seen as one of the major causes of localisation of deformation into shear zones in brittle media. Several studies, both numerical and physical experiments, investigate its influence. Typically, these studies choose a certain model configuration and test various material properties and their influence on localisation in that particular configuration. This approach, however, does not take into account the fundamental importance of boundary conditions on the processes of localisation, weakening and overall shear zone evolution.

To address this issue, we perform physical experiments in granular materials. We create shear fractures within a sample of granular material (sand) using different experimental apparatuses that apply different boundary conditions. Among them are standard machines such as a Ring-Shear Tester and the classical Riedel set up, as well as a newly designed set up. Boundary conditions can be varied from purely kinematic to more dynamically controlled and from laterally confined to unconfined. Nevertheless, the final result of deformation is an approximately straight strike-slip shear zone in all cases. We monitor boundary force (i. e. material strength) and, where experimentally accessible, strain, at high temporal resolution during deformation.

With our different set ups we are able to produce very different patterns of deformation and weakening in the same material under the same constant rate of shearing and with the same final result. Observed patterns span from nearly instantaneous formation of one single through-going shear zone to slow, step-wise growth of a complex network of interacting cracks. Weakening in all cases matches well the structural evolution. Variations of weakening for a given material in different set ups are larger than for different materials in a given set up.

Our results show that for a given material the style and rate of localisation can change drastically, depending on only slight changes of lateral confinement or the way shearing is induced. This needs to be taken into account when designing future models as well as interpreting field data. Furthermore, our data indicates weakening to be experiment-specific rather than a material property. We therefore argue for localisation being the cause, rather than the result, of strain weakening.