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Shear bands in foliated materials: analogue modelling under coaxial deformation

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Shear bands are widely used as kinematic indicators. Despite of the large amount of studies about these structures, their development is mechanically still not well known. This work presents an experimental study of shear band localization and evolution by means of analogue modelling under coaxial deformation, paying special attention to the influence of the obliquity of anisotropy planes on the orientation of shear bands.

Series of analogue experiments were performed using the experimental apparatus BCN-Stage. The models were made by assembling layers of plasticine mixed with vaseline to increase ductility and different percentages (0% or 12%) of paper flakes preferentially oriented parallel to layering, trying to simulate the role of planar minerals. Uniaxial compression tests were first carried out to determine the mechanical properties of the analogue materials. The models were deformed at a constant strain rate of 2,5 $\cdot$ 10^{-5} s^{-1} and 26ºC up to a maximum shortening of 50%.

At the beginning of the experiments deformation was accommodated by homogeneous flattening and rotation of layers towards the extension direction. At about 15-18% of shortening the first macroscopic structures start to be visible (pinch-and-swell instabilities, tension cracks and shear fractures). Two conjugate sets of shear bands develop symmetrically for models whose layers are parallel to the extension axis, while for oblique orientations one set dominates. The shear sense of the dominant set is opposite to layer rotation sense. The models were systematically analyzed using statistical methods, focusing on the angle of nucleation of shear bands and their variation when increasing deformation.

The experimental results indicate that the initial angle of new fractures depends on the initial layer orientation and can be expressed by the following equation:

$\beta_0 = \pm$45º - ψ/2 $\pm$ α_0/2, where β_0 is the angle between the compression axis and the fracture plane, ψ is the dilation angle (ψ $\sim$20º approx. for this case) and $\alpha_0$is the initial angle between the anisotropy and the extension axis (0º$>\alpha_0$ $>$40º). For all the experiments the shortening direction bisects the obtuse angle between the faults ($\beta_0 >$ 45º), and therefore these fractures have been interpreted as *compactive shear bands* (Borja, 2004).

Progressive deformation is mainly accommodated by slipping and rotation of old fractures and nucleation of new ones. When shear fractures become less active they rotate at a similar rate than a theoretical passive marker. For coaxial deformation, both sets of shear bands would be expected to rotate towards the extension direction, but it has been observed that for α_0 $>$0º models both arrays rotate in the same sense as layers do (i.e. the obtuse bisector between faults rotates according to the layer normal). This fact means that anisotropy have a strong influence on the local stress field around shear bands that differs from the stress field applied by the experimental boundary conditions.

References:

Borja, R.I. 2004. Computational modeling of deformation bands in granular media. I. Geological and mathematical framework. *Comput. Methods Appl. Mech. Engrg.* 193, 2667–2698.