Geotechnical and geomechanical characterization of the “fault gouge” of the “Alhama de Murcia” active fault, SE Spain.

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Here we present the results of the mechanical and mineralogical study of the fault rock of the Alhama de Murcia fault. This fault is one of the most active faults in the Iberian Peninsula. It shows segments partially formed by exhumed fine grained fault rocks (fault gouge FG) with a thickness of more than 50 m developed mainly in a brittle regime. Several strength and strain tests have been carried out, both in-situ and in laboratory, considering different stress orientations in relation to the tectonic fabric. Undisturbed samples encountered from two fault observatory boreholes drilled near Lorca, (FAM-1 and FAMSIS-IGN, of 174 and 40 m depth, respectively) has been used for the laboratory tests. The FG shows a hard soil and soft rock like mechanical behavior with uniaxial compressive strength < 2 MPa and elastic moduli (E) < 12 GPa. The tenso-deformational behaviour at low confining stresses is mainly plastic, acquiring a strain-hardening behaviour at high shear strain. The FAM-FG shows a very notable tectonic fabric controlled by a frictionally weak preferential orientation of the plate like minerals arranged in an anastomosing texture that controls the mechanical strength. The results of the strength tests show the variability of the friction coefficient (µ) depending on the stress orientation in relation to this tectonic fabric. The FG exhibit mineral assemblage similar to the shicsts, suggesting that it has been developed mainly as a result of comminution mechanisms of the hanging wall protolite. The mineralogical composition of the FG contains mica minerals (muscovite and paragonite), quartz (mainly powdered) and traces of feldspar and carbonates. The predominant clay minerals are illite, paragonite, and, occasionally and some kaolinite. In some samples, it has been observed the presence of very sparse graphite and smectite. The plate like minerals are arranged in a preferred orientation (turbostatic microfabric), that surround the quartz porphyroclasts. The friction coefficient (µ) varies between very low values (0.29-0.49) for planes oriented favourably to the tectonic fabric (following the fault failure kinematic), to very high values (>1.19) for planes unfavourably oriented.
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Geological and Geographic Setting
Located in the SE of Spain, the Alhama de Murcia Fault (FAM) is one of the most active faults in the Iberian Peninsula. It shows segments composed partially by exhumed fine grained fault rocks (fault gouge, FG), occasionally over 50m thick, and developed mainly in a brittle regime (Martinez-Diaz et al., 2012).

Mineralogy and Microfabric
X-ray diffraction test, optical microscopy and Scanning Electron Microscopy

Shear tests
Undisturbed samples
For direct shear tests, face surface is unfavorably oriented to the tectonic fabrics in undisturbed samples. (VS)

Reconstructed samples
Slipped (0.35mm) and reconstructed FG samples (LS) and pulverized FG quartz samples (GQ) analysed by direct shear tests.

Uniaxial and Triaxial compression tests
Uniaxial tests performed in vertical samples (VST). Consolidated Undrained Triaxial tests performed in vertical samples (VST) and is oriented in the current tectonic stress direction samples (OS).

Strength tests

FG mineralogy is represented mainly by potassic and sodic mica, quartz in an amorphous and carbonates (dolomite and calcite) in a lower amount. Chlorite was also found in some samples. Clay minerals are mainly represented by illite and paragonite with a very low amount of kaolinite.

FG presents an anastomosing microfabirc (turbostatic microstructure) with a very fine matrix. This matrix, with a cataclastic appearance, is composed by a mineral aggregates moture with a preferred orientation such as coating aplitic quartz.

FG shows very low resistance to simple compression. Uniaxial tests show values of n=0.7 to 1.5 Mpa. It was also obtained indirectly by triaxial tests. By this method it fluctuates depending on the tectonic fabric orientation regarding to the axial stress (n=0.1 - 0.3 Mpa).

Conclusions
FAM Fault gouge has geomechanical and geotechnical properties between hard soil and soft rock (n=0.2-0.25).

Episodes exhibit dramatic differences in strength properties. Friction varies from μ=0.3 to 1.2 depending on the applied stress orientation in relation to tectonic fabric.

Strain hardening behavior was seen with large deformations which increases material rigidity by compaction. It has been observed in all samples that friction angles stabilize around 22°.

Material velocity classification
In situ velocity measurements

Elastic Properties of FG from in situ tests

In situ Geophysical velocity test

Conclusions
FAM Fault gouge has geomechanical and geotechnical properties between hard soil and soft rock (n=0.2-0.25).

Samples exhibit dramatic differences in strength properties. Friction varies from μ=0.3 to 1.2 depending on the applied stress orientation in relation to tectonic fabric.

Strain hardening behavior was seen with large deformations which increases material rigidity by compaction. It has been observed in all samples that friction angles stabilize around 22°. This might be related to orientation of the phyllosilicates.

In situ, compressional and shear wave velocity and elastic modulus results, show an homogeneous material. However, there is a big difference between indirect and direct tests.