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Simple Observations on the Stability of Slopes in Complex Bimrocks

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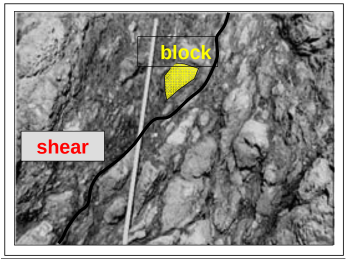
Introduction

This Poster introduces concepts that must be considered during slope stability analyses of *bimrocks*, (block-in-matrix rocks), complex geological mixtures of geotechnically significant rock blocks within a bonded rock matrix of finer texture (Medley, 1994).

Bimrocks frustrate geotechnical engineers designing and constructing roads, tunnels and dams because of their extreme spatial and mechanical heterogeneity.

Bimrocks are ubiquitous but are little understood by geotechnical engineers because they occupy the vast technical desert between the realms of soils engineering and rock engineering.



Tectonic melange of the Franciscan Complex, California. Pervasive shears negotiate around blocks. Scale is 1.5 m long. After Medley (1994)

Bimrocks include melanges (French: *mélange*, or "mixture") sheared serpentinites, breccias, decomposed granites, lahars, weathered rocks with corestones; and tectonically fragmented rocks such as fault rocks.

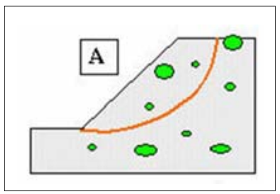
Melanges are composed of mixtures of pervasively and intensely sheared serpentinite or shale matrix, enveloping strong blocks of greywacke sandstone, limestone, chert, greenstone and exotic metamorphic rocks in which shears tortuously negotiate around blocks.

Blocks in melanges and fault rocks range in size between sand and mountains, and are present at all scales of engineering interest. The threshold size blocks and matrix is 5% of the characteristic dimension which scales the problem at hand: tunnel diameter, footing length, triaxial specimen diameter; landslide height, etc.

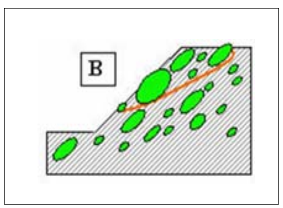
Some Common Bimrock Situations in Slopes

Landslides are common in block-poor melanges. It is also common to see large blocks buttress slopes. (Indeed, large blocks encountered during earthwork construction should be left intact as much as possible.) Hence, from a slope stability viewpoint, it is vital to characterize the fabric of bimrocks, Some basic geological situations which the geotechnical will encounter are illustrated here.

"Geotechnical significance" in the definition of bimrocks means there are enough strong blocks in the mixture to effect geomechanical advantages to the rock/soil mixture by forcing failure surfaces to negotiate around the blocks. As block volumetric proportions increases beyond about 25%, overall frictional strength also increases but cohesion strength tends to decrease because of the greater number of weak block/matrix contacts.

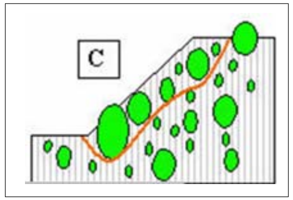


Situation A shows a hillslope in a low-block proportion bimrock that can be analyzed as a conventional soil.



Situation B shows a hillslope where there is a higher proportion of blocks, which cannot readily be conventionally analyzed as soil nor rock.

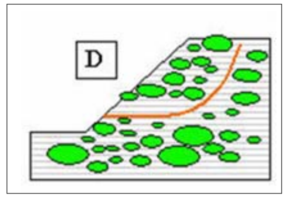
Furthermore, typical of melanges and fault rocks, there is a fabric of sub-parallel blocks and shears, oriented out-of-slope, which decreases slope stability



In Situation C, blocks are oriented at high angles to the slope, which increases stability due to the increased tortuosity of the failure surfaces forced around the blocks. Furthermore, the large blocks or block-rich regions at the toe of slopes tend to buttress slopes and add to slope stability.

The effect of buttressing blocks is shown in the photograph where landslides (yellow arrows) in a Franciscan Complex melange (Northern California) are buttressed by blocks (red rings).

Situation D illustrates the common condition of variations in the block proportion within the rock mass. Failures can be expected through those regions where there is continuity within a low-proportion, weaker domain.



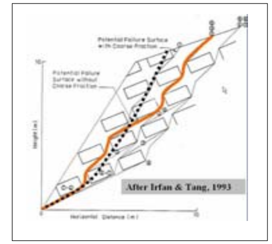
These simple geological situations clearly indicate that one cannot predict the location or geometry of potential failure surfaces within melanges and other bimrocks. Accordingly, rather than performing deterministic slope stability analyses with trial failure surfaces, it is better to perform stochastic analyses with trail failure zones, or bands, with widths between 5% to 15% of the height of the landslide (Medley & Sanz, 2004).

Slope Stability and Volumetric Block Proportions

Using a simple model, Medley & Sanz (2004) explored the extent to which blocks increase the slope stability of bimrocks, relative to the stability of the slope in pure matrix. For a 10 m high, 35 degree slope (as illustrated) analyses were performed using random arrays of rectangular blocks with size distributions typical of Franciscan Complex melanges, and various areal block proportions.

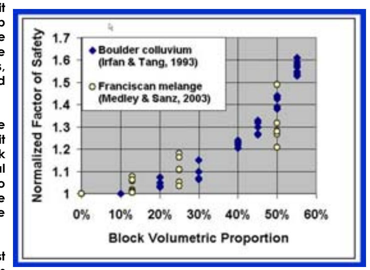
The strength parameters of the matrix was c = 10 kPa (200 pounds per square foot) and φ = 25 degrees. The critical failure surface for a matrix-only slope had a Factor of Safety of 1.26.

Graphical tracings of some possible failure surfaces were exported into SlopeW™, (Geo-Slope International, Inc.) and slope stability analyses performed to identify the Factors of Safety. To generalize the findings, the Factors of Safety were normalized by dividing them by the Factor of Safety for the matrix-only case (FS=1.26).



Medley & Sanz (2004) incorporated findings from Irfan & Tang (1993), who performed stability analyses of 10m high, 60 degree slopes in boulder colluvium. The model colluvium slopes contained uniformly sized and uniformly separated blocks, layered out-of-slope. Block proportions were varied between 10% and 55%. The strength properties of the matrix were generally c'= 5 kPa and φ' = 35 degrees.

Combining the results of stability analyses performed for melanges and boulder colluvium, it is apparent that there is a good relationship between the normalized Factors of Safety and the volumetric block proportions, despite the significant differences in the model geometries, orientation of blocks, geology of the modelled materials, and slope stability methods used.



Although considerably more analyses should be performed to define the statistical variations, it appears that up to about 25% to 30% block proportion blocks provide little geomechanical advantage. However, from this lower limit to greater than 55%, there is marked increase in slope stability, due to increases in the tortuosity of failure surfaces negotiating blocks.

This finding is remarkably similar to that of Lindquist & Goodman (1994) who determined that there was considerable increase in frictional strength for physical model melanges with volumetric block proportions between about 25% and 70%.

Conclusions

Blocks in melanges, fault rocks and other bimrocks, have geomechanical effects. The Factor of Safety for slope stability of model bimrocks increases with the tortuosity of failure surfaces. The increases are largely related to increases in volumetric block proportions, and to a smaller extent, to block orientations. Block orientations (relative to directions of governing stresses) are in turn controlled by anisotropies of block and shear fabrics.

That Factors of Safety are clearly related to volumetric block proportion indicates that conventional geotechnical analysis techniques may be useful to the practitioner investigating the slope stability of geologically complex mixtures such as melanges, fault rocks and other bimrocks. Nevertheless, more work must be performed (perhaps by performing Monte-Carlo type simulations using 3-Dimensional models) to understand the statistical viability of using simple analytical approaches for complex geological conditions.

References

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