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Rock Mass Characterisation for Stability Analysis of Rock Cut Slopes in the Ophiolites of Hajar Mountains of UAE & Oman.

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The ophiolites of the Middle East region are some of the classic preservations in the world, which are the obducted (M. P. Searlea etal.) remains of the oceanic plate over the eastern margin of Arabian continent during the late Mesozoic times. Some recent opinions advocate that these are the fragments of oceanic crust formed in the mid oceanic ridge environment and later transported to the zone of convergent boundaries of the tectonic plates. Ophiolites are complex volcanic and plutonic rocks mainly composed of basic and ultrabasic suite of rocks like the Gabbro, tholeiitic basalts, herzburgite, serpentinite etc. The sole of the thrust sheets of ophiolites are marked by the metamorphic rocks showing polyphase deformation,

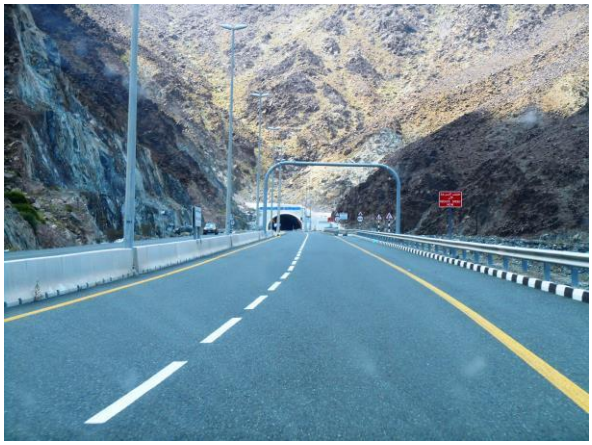

Figure 1: Typical cut slopes in the Hajar Mountains

mylonitic fabrics, and folded, imbricated, disrupted blocks. At places form tectonic inclusions in a serpentinite melange. These occur as a chain of mountains, called the Hajar Mountains, bordering the eastern margin of the United Arab Emirates (UAE) in the north to the Sultanate of Oman (Oman) in the south, extending over a length of about 210 km overlooking the Gulf of Oman to the East. The spree of infrastructure developments in the region involve deep excavations generating up to 100 m high rock cut slopes. Over 500 km of road have since been laid in the last less than a decade (including widening) cutting across the mountain hills in UAE and the Sultanate of Oman. A few tunnels have also been excavated to negotiate high peaks (fig.1).

Engineering geologically the heterogeneous and complex ophiolites suite of rocks can be characterised by their lithology, rock material and mass parameters. Based on about 10 such projects covering over 250 km of deep cuts in the Ophiolite Rock Mass (ORM) can be categorised as given in the below table:

Rock mass Description	Properties	Broad Stabilisation Category	measures

ORM-1	Dark greenish grey, medium to coarse grained, high specific weight, moderately jointed, blocky rock mass (gabbro, herzburgite) with a number of minor seams/ permeations of silica. Enclaves/ bands of quartzite noticed in the rock mass locally. Slightly weathered(II)	UCS: 34 – 55 Mpa Steeper slope angles. No Jv : 8 -12 protection, Selective RMR: 45 – 66 Shotcrete and rock bolts *GSI:* 60 – 65 locally for stabilisation.

ORM-2	These are greenish grey, banded, layered rock mass (layered gabbro) with foliations/ beddings. Shearing with slickenside's noticed along the bedding/ foliation planes.	UCS: 25 – 38 Mpa J_V : >20 RMR: 50 – 57 *GSI:* 40 – 55	Gentler slope angles. selective shotcrete and spot bolting for protection & stabilisation.
	Moderately to slightly weathered (III/II). Seam of ORM 3. ***ORM-3***		
	Pale greenish grey colour, friable/ crumbling by hand, thinly foliated, sheared at time permeated with criss-crossing quartz and calcite veins, Highly weathered (IV)	UCS: <1 – 2 Mpa RMR: 15 – 20 *GSI:* 10 – 15	Reinforced shotcrete with rock bolts/ anchors for stabilisation.

Characterisation is followed by the stability analysis for the rock cut slopes in ORM-1 using *roc science* programmes *like dips 6* for kinematic admissibility checks and identification of failure modes. *Swedge 6* and R*ocplane* are used for analytical checks for wedge and plane blocks and determine the required support measures (rock bolts and shotcrete) to achieve a factor of Safety (FoS) of 1.5 (static) and 1.2 (seismic conditions). The ORM- II and ORM- III rock mass are considered as a homogeneous mass due to the high degree of jointing and the deep weathering. The *SLOPE/ W* (Morgenstern method) is used for the stability analysis for circular failure and identify the optimum slope angle vis a vis support/ protection measures.

References:

[1] M. P. Searlea and J. Malpas (1980): Structure and metamorphism of rocks beneath the Semail ophiolite of Oman and their significance in ophiolite obduction. Transactions of the Royal Society of Edinburgh: Earth Sciences / Volume 71 / Issue 04 / January 1980, pp 247-262

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