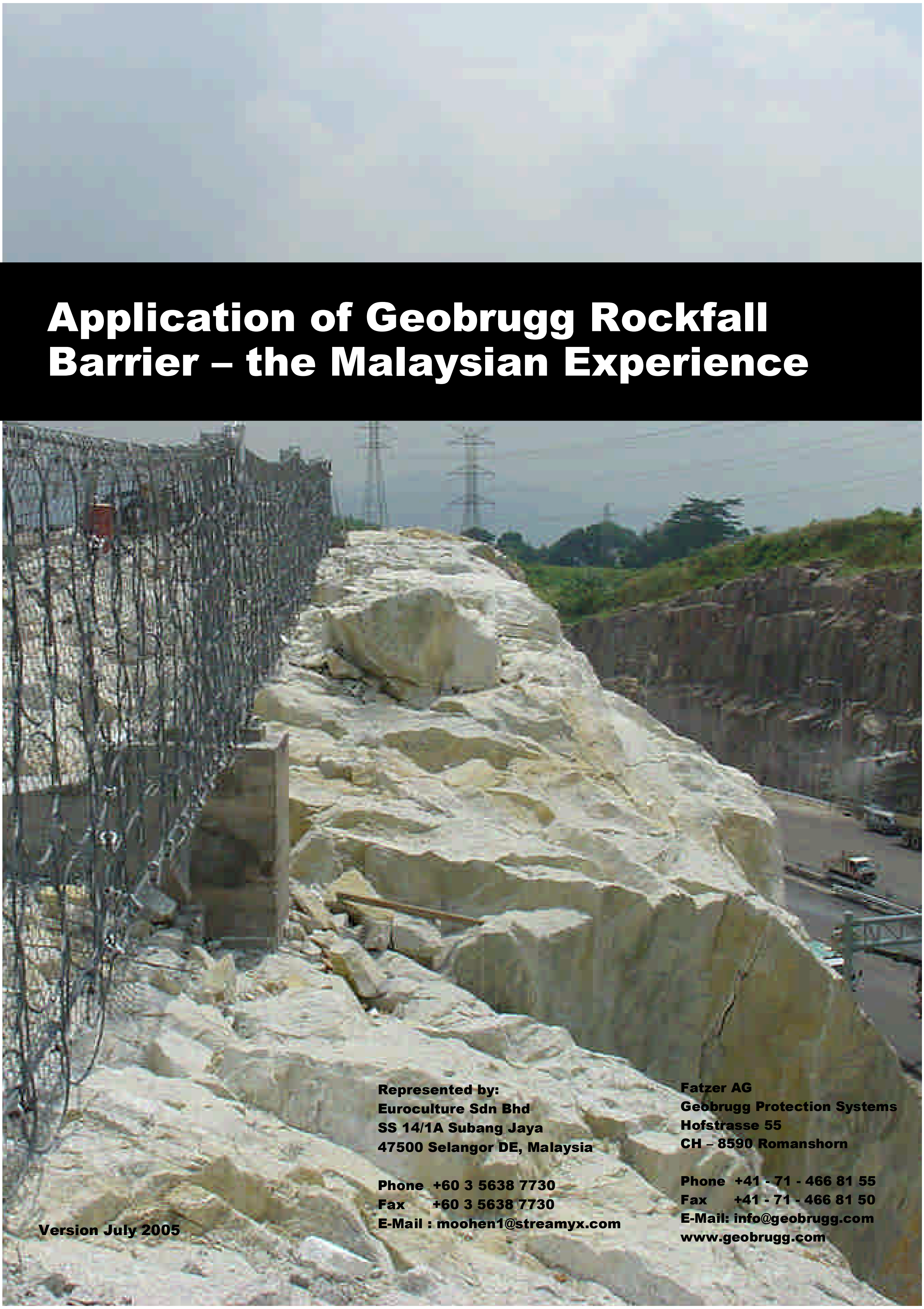
Application of Geobrugg Rockfall Barrier – the Malaysian Experience



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On 26th November 2003, a massive rock slope failure occurred at Bukit Lanjan Interchange as part of the New Klang Valley Expressway (see Figure 1).

Figure 1: Location Map of Bukit Lanjan Interchange

The failure occurred immediately after a period of heavy rainfall. The substantial large volume of rock debris (approx. 35,000m^3) that came to rest on the expressway had blocked the expressway completely and forced the entire stretch of the expressway to be closed for 6 months for rehabilitation works (see Photo 1)

Immediately after the failure, the Engineer had commissioned site investigations that include topography survey, geological mapping, deep boreholes and laboratory tests to assess the likely cause of failure and also to provide geotechnical information required to design for rehabilitation of the failed slope. From the site investigation results, it was inferred that the rock slope failure was a complex wedge type failure. The wedge was formed by two discontinuities that daylighted out of the slope and the third discontinuity acted as release plane. It was also demonstrated that for failure to occur there was a requirement for water pressure to be acting on the potentially unstable wedge.

Photo 1: Aerial View of Rock Slope Failure at Bukit Lanjan Interchange

A series of rehabilitation options were considered by the Engineer, taking the results of the site investigation results and cause of failure into account. The options include slope re-profiling, reinforcement of the rock slope, construction of tunnel ("place and cover") and expressway re-alignment. Slope re-profiling was adopted to take account of the site conditions i.e. slope and failure geometry, soil materials above the failure, changed rock condition adjacent to the failure, and the unfavorable orientation of natural discontinuities with respect to the failure within the rock mass, etc.

Detailed design had been undertaken by the Engineer taking into account of accepted practices and local considerations. The bench height in rock was 9 meters; with an inclination of 9V:1H. This inclination was adopted to account for accuracy of drilling works for rock blasting and to reduce the rock fall trajectory on the final battered slope. A 5 meter berm width in the rock cut had been adopted to reduce the potential localized rock fall from encroaching to the expressway at the toe of the slope and also to take account of construction practices. A 20 meter wide berm had been allowed for at the third bench and 10m wide berms are incorporated at the sixth and ninth benches in order to achieve the overall slope angle of 48° as suggested was appropriate by the kinematic analysis. These berms will provide the required access to inspect the slope face during maintenance and will also act as safety berms to contain inadvertent minor rock falls.

For the weathered rock layer above the fresh competent rock, a slope height of 1V:1H had been adopted with a bench height of 5 meters. The thickness of the weathered rock was expected to be variable and will be determined by the Engineer on site.

For slopes within the residual soil, a slope profile of 1V:2H was adopted with an intermediate berm width of 2.5 m. The stability analysis showed that the factor of safety against instability was satisfactory (greater than 1.50). This satisfied both Public Work Department and Malaysia Highway Authority's geotechnical design requirements. The soil slope surfaces exposed in the cut were protected from surface erosion using geocells, a 3-dimensional lightweight and flexible mat made from high density polyethylene strips and in-filled with fertilized top soil to encourage the establishment of vegetation (grass).

At the base of the rock cut, a 14 meter buffer zone was proposed to contain the run-out from inadvertent rockfalls. A rock trap ditch measuring 7 meter wide and 1.5 meter deep will be constructed at the toe of the slope. Rock fall fencing type AXI-150 manufactured by GEOBRUGG with impact energy resistance of 1500 kJ was incorporated as a mitigation measure to prevent small loose rock (less than $1m^3$) from landing on the expressway.

The rock fall fencing was designed to be installed at the 20m wide berm. It was aimed to contain any unwanted loose rocks above the 20 wide berm from encroaching to the expressway. The analysis showed that falling rock from the benches below 20m wide berm should be contained in the designed rock trap ditch (see Photo 2).

Photo 2 : Completed Geobrugg Rock Fall Fence at 20m Wide Berm

It has been assumed that unstable rock blocks of greater than 1.0m were stabilized by means of rock bolts, dowels, shotcrete etc. As such, the rockfall analyses took into account debris size less than 1.0m i.e. varied from 0.1m to 1.0m diameter.

The rock trap ditch had been modeled with 0.5m thick gravel bedding. The gravel bedding was intended to absorb the impact energy of boulders and to minimize its travel distance. The size of the rock trap ditch was limited to 6.0m from the toe of the rock slope to take other factors such as alignment into account.

The design parameters, such as density of the rock, rock surface roughness, tangential coefficient of frictional resistance, damping factors, initial velocity required in the rockfall analysis were based on the past experience in similar conditions at a site in Singapore.

Photos 3 to 5 showing the process of installation of Geobrugg rock fall fence at the site.

Photo 3 : Installation of Rock Anchor

Photo 4 : Installation of Steel Post of Fence

Photo 5 : Almost Completed Geobrugg Rock Fall Fence at 20m Wide Berm

As the slope was re-profiled to an overall slope angle of 48°, which was inferred to be safe from global/major instability based on the kinematic analysis. However, the following measures were adopted singly or combined to stabilized localized instability:-

- Removal/scaling,
- Rock fall containment using netting, ditches, shotcrete etc.;
- Support and protection i.e. buttress and dentition;
- Rock dowels/bolts/anchors; and
- Sealing of joints/discontinuities using shotcrete.

The application of these stabilization and protection measures was very much dependent on the rock slope conditions after blasting works and the insitu rock conditions. Geological and geomorphological mapping were undertaken by experienced engineering geologists immediately after slope clean-up works to identify potential localized failures.