Geological Society of Malaysia, Bulletin 46
May 2003; pp. 75–85

Influence of discontinuity on overbreaks and underbreaks in rock excavation — case study from Beris Dam, Kedah, Malaysia

TAJUL ANUAR JAMALUDDIN AND ISMAIL YUSOFF

Geology Department
University of Malaya
50603 Kuala Lumpur

Abstract: Rock blasting excavation is largely controlled by discontinuities and the strength of the rock materials, although blasting factors are also equally important. This paper presents a case study from the Beris Dam project in Kedah, where a geologist was called upon to clarify a dispute between the contractor and engineers that excessive overbreaks at the Spillway and along the toe slab of the Main Dam were largely attributed to geological factors. To verify this issue, detailed mapping on the geological structures was carried out on the resulting exposures. Focus of the mapping was mainly on observing the nature of the rock failures (overbreaks) and collection of discontinuity data (joints, bedding, shear zones, fault). The discontinuity data were analysed kinematically by using stereographic projection to verify the mode of rock breakage. Results of the analyses indicated and conformed with the field evidences, that the overbreaks were clearly controlled by the unfavourable intersections of the bedding planes, joints, faults and shear zones with respect to the blasting lines. Overbreaks in the Spillway and the Main Dam usually occurred in wedge and planar mode of failures.

Abstrak: Kerja-kerja penggalian batuan sangat dipengaruhi oleh ketakselanjaran dan kekuatan bahan batuan, walaupun diakui bahawa dan faktor-faktor peletupan juga berperanan penting. Kertas kerja ini cuba menyajikan suatu contoh kajian kes daripada projek Empangan Sg. Beris, Kedah. Di dalam projek ini geologis profesional telah diundang untuk mengesahkan bahawa kejadian terlebih korek yang berlaku di tapak alur limpah dan kaki empangan utama disebabkan oleh faktor-faktor geologi. Untuk mengesahkan punca kepada masalah ini, pemetaan terperinci telah dijalankan di tapak-tapak berkenaan. Pemetaan geologi tersebut tertumpu kepada pencerapan keadaan kegagalan bantuan dan pengumpulan data-data ketakselanjaran (kekar, perlapisan, sesar dan zon ricih). Data-data orientasi ketakselanjaran telah dianalisis secara kinematik dengan menggunakan unjuran stereografi untuk melihat potensi ragam kegagalannya. Hasil analisis jelas menunjukkan bahawa kejadian terlebih korek memang dikawal oleh ketakselanjaran kerana orientasi garis letupan batuan yang dipilih mendedahkan potongan cerun batuan kepada kegagalan baji dan satah.

INTRODUCTION

The Beris Dam is still under construction and when completed it will be the 41st dam in Malaysia. It is located in a narrow valley of the Beris River, 1.6 km upstream of its confluence with the Muda River, in the District of Sik, Kedah Darul Aman (Fig. 1). The town of Sik, which is the administrative center of the district, lies 24 km to the south of the Dam. The dam has a catchment area of 166 km^2 of which 1,600 hectares of land will be submerged. The Beris Dam and reservoir will be used for regulating flow in the Sungai Muda Basin to augment water available for irrigation of paddy and upland crops, domestic and industrial water supply as well as other users (JPS Kedah, 2003). The main features of the Beris Dam consist of the Main Dam, which is of the "concrete face-rock fill" type, 40 m high and about 155 m long at the crest. An ogee type side channel Spillway is provided on the left abutment of the Main Dam. The Saddle Dam is located 600 m to the NW of the Main Dam right abutment. The dam is meant for water supply and it is constructed in a V-shaped, narrow valley of the Sg. Beris.

This study was originally intended as an independent study to clarify several geological issues regarding the rock excavations (Tajul Anuar Jamaluddin, 2002) which have become a disagreement between the contractor and the consulting engineers. One of which was to verify that the over excavation (overbreaks) at the Spillway and along the toe slab of the Main Dam were caused by geological factors. Overbreaks had caused some widening of the spillway dimensions and toe slab foundation. As a result the contractor had to backfill the overbreak parts with concrete resulting in a substantial additional cost.

In view of the rarity of encountering such a practical case, it was felt that this study be presented herein and thus knowledge shared amongst us in order to improve awareness on the importance of geological input in rock blasting works. The main objective of this paper is to highlight the importance of geological input, notably the influence of discontinuities, their orientation and physical characteristics, in rock blasting operations. This vital information should has been gathered during the site investigation stage and taken into serious consideration in the blasting design. So that fragmentation behaviour (mode of overbreak and/or underbreak) of the rock masses could have been predicted wisely. Consequently, the best blasting technique, likely costs and duration of works could be properly estimated. To achieve these, the geologist should have played an important role to convince both the contractor and the engineers about the relevant geological inputs. By effective communications and creativity of the geologist, the blasting contractor and engineers would be able to achieve mutual agreement on the expected results and costs incurred.

Most practical aspects of rock blasting have been described elsewhere (e.g. Langefors and Kihlstrom, 1973; Gustaffson, 1973; Matheson, 1986a) and in handbooks published by manufacturers of drilling and blasting equipments (e.g. ICI, 1975). This paper does not attempt to elaborate on the blasting practices, but only focuses on the role of discontinuities in causing blasting damage (overbreaks and underbreaks) in rock blasting excavation.

METHODS

The field study was carried out in September 2002. Geological inspection was concentrated on the rock exposures that resulted from excavation works at the foundation sites of the Main Dam and the Spillway. In order to identify the likely geological factors that caused the overbreaks along the spillway and along the toe slab of the main dam, structural (discontinuity) data were collected randomly at various spots in both left and right abutments of the main dam and both left and right walls of the spillway. The structural data were then analysed kinematically, by using computer generated stereographic projections to determine the number of joint sets and their average orientations. Strength of the rock materials was determined by conducting Point Load Index Test because of its ease and rapidity to give reliable results on the estimation of the rock Uniaxial Compressive Strength. Degree of weathering for the rock masses was described using the classification scheme of Attewell (1993). Some of the terminology used to describe the discontinuity features and field-estimation of the rock strength are given in Table 1.

SITE GEOLOGY

The Main Dam and the spillway are founded on a massive to thickly bedded sequence of conglomerate and gritstone, interbedded with some sandstone (Plate 1a, b and c). The rock sequence belongs to the Semanggol Formation of Triassic age (Ong, 1969; Burton, 1972). The conglomerate predominates at the right abutment hill and the main dam foundation. However, on the left abutment and the Spillway site, the conglomerate is interbedded with gritstone and coarse sandstone.

The matrix-supported, polymict conglomerate contains gravel to pebble-sized clasts of black to dark slate and mudstone, cert, quartz and other rock fragments (possibly volcaniclastics, sandstone and quartzite). The matrix is made up of coarse-sandy to gritty materials consisting of quartz, feldspar and rock fragments. The conglomerate, gritstone and the sandstone exposed at the foundation and left and right abutment of the Main Dam, as well as at the Spillway, vary from slightly weathered to moderately weathered (Grade II – III) rock. The rocks are generally hard, compact and well indurated. They are strong to very

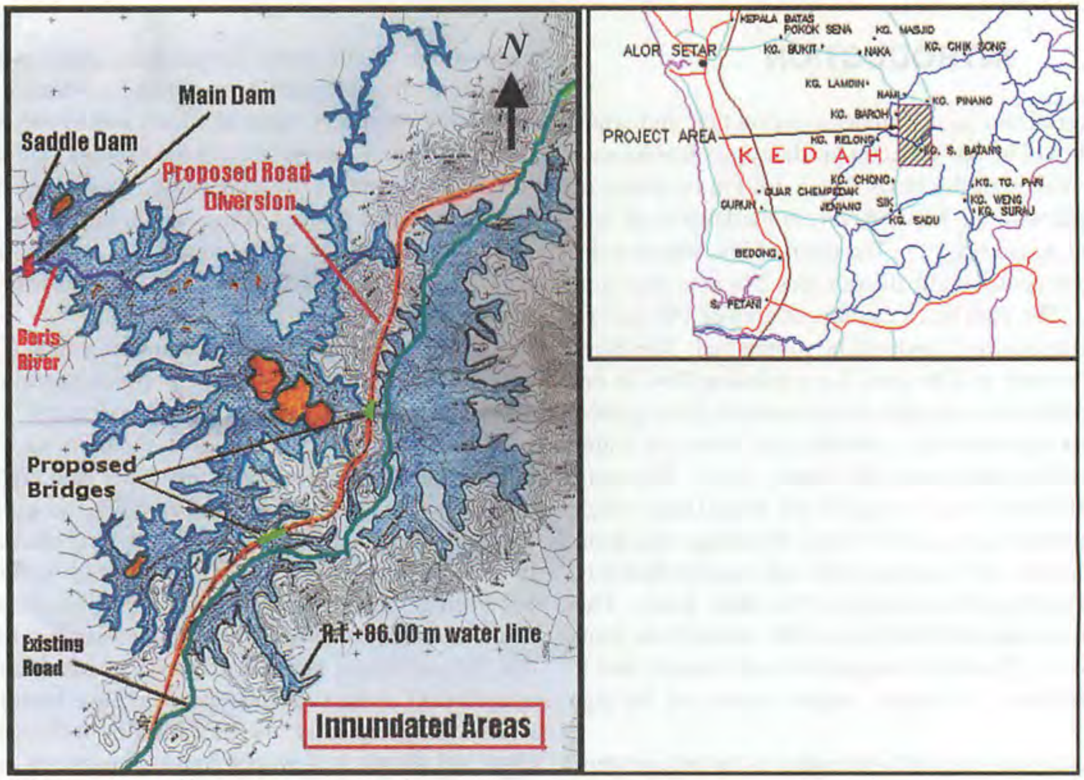

Figure 1. Map showing location of the Beris Dam (after JPS, 2003)

Table 1. Discontinuity Features and Rock Strength Estimation (after ISRM, 1981).

A. Type	B. Aperture Width (mm)	C. Nature of infill	D. Wall Strength
0. Fault Zone	0. Wide (>200)	1. Clean	1. Soft
1. Fault	1. Moderately wide (60-200)	2. Surface staining	2. Firm
2. Joint	2. Moderately narrow (20-60)	3. Non cohesive	3. Stiff
3. Shear	3. Narrow (6-20)	4. Cohesive	4. Hard
4. Fissure	4. Very narrow (2-6)	5. Cemented	5. Weak
5. Tension Crack	5. Extremely narrow (0-2)	6. Calcite	6. Medium Strong
6. Other (specify)	6. Tight (0)	7. Chlorite	7. Strong
		8. Other (specify)	8. Very Strong

E. Roughness	F. Discontinuity Spacing (mm)	G. Water
1. Steeped	1. Extremely close (<2)	1. Dry
2. Undulating	2. Very Close (2-6)	2. Seepage flow
3. Planar	3. Close (6-20)	3. <10 ml/sec
4. Rough	4. Moderate (20-60)	4. 10-100 ml/sec
5. Smooth	5. Wide (60-200)	5. 0.1-10 l/sec
6. Slickensided	6. Very Wide (200-600)	6. 10-100 l/sec
	7. Extremely Wide (>600)	7. >100 l/sec

H. Rock Strength Estimation Index Test *			
R0	Extremely weak rock	Indented by thumb nail.	0.25-1.0 MPa
R1	Very Weak Rock	Crumbles under firm blows with point of geological hammer, can be pealed with by a pocket knife.	1.0-5.0 MPa
R2	Weak Rock	Can be pealed by a pocket knife with difficulty, shallow indentation made by firm blow with point of geological hammer.	5.0-25 MPa
R3	Medium strong rock	Cannot be scraped or pealed with a pocket knife, specimen can be fractured with single firm blow of geological hammer.	25-50 MPa
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it.	50-100 MPa
R5	Very strong rock	Specimen requires many blows of geological hammer to fracture it.	100-200 MPa
R6	Extremely strong rock	Specimen can only be chipped with geological hammer.	> 250 MPa

strong rocks, which require several blows of the geological hammer to collect samples.

The gritstones are transitional between conglomerate and sandstone; and are composed of fine gravel to coarse sand grains of quartz, quartzite, sandstone, chert and mudstone as well as other rock fragments. They are grey, hard, compact and occur as interbeds in conglomerate and sandstone. The sandstone is generally light grey, fine to coarse-grained, hard, compact and well indurated rock. In places, the thick sandstone beds contain shale/mudstone partings.

The bedding planes are sometimes not clearly defined due to the transitional nature of the thick to massive beds. However, in the right abutment of the Main Dam, the bedding planes roughly strike along a W–WSW orientation and dip 15-30°N, whereas in the left abutment they strike almost E-W and dip 45-52°S. Bedding planes usually serve as the major plane of weakness for shearing and low-angle thrusting (faulting). The rocks were intensely faulted and jointed. At least 5 to 6 major sets of joints were identified. These are described in the strength of the rock materials below.

DISCONTINUITIES

Discontinuities includes all types of mechanical break or planes of weakness in rock mass (e.g. joints, bedding planes, faults, shear zones, fractures, fissures, foliation) that cause the tensile strength of the rock to be zero or much lower than the compressive strength of the rock material. The following accounts give results of the discontinuity survey carried out at the main dam and spillway foundation sites

The Main Dam

Discontinuity survey at the Main Dam site was divided into two sections; i.e. the Left Abutment and the Right Abutment. Stereographic projections of the discontinuities from the left and right Abutments of the Main Dam are shown in Figure 2a and 2b, respectively. Results indicated that the rock masses at the Main Dam site as a whole are dissected by at least 6 sets of discontinuities (e.g. Plate 2a and b).

The discontinuities are mainly found in the form of joints; although faults, bedding planes and shear zones were the most persistent (see Tables 2 and 3). Due to intense jointing and shearing, the rock mass is characterised by polygonal block shapes of variable sizes, ranging from as small as several cm^3 to up to 1.5 m^3. Intersections of the major joints give rise to highly irregular bedrock surface. This can be clearly seen in both the left and right abutments

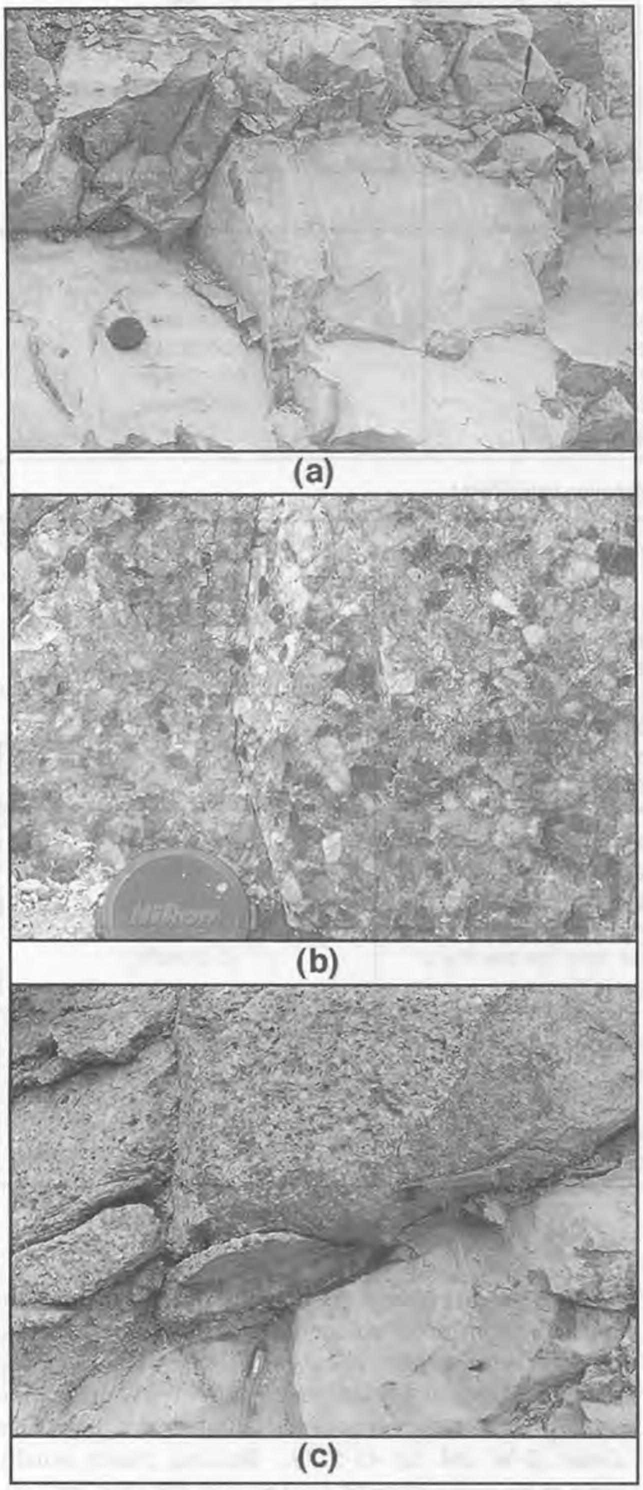

Plate 1. a) Sandstone outcrop in the right abutment of the Main Dam. b) Close-up view of the slightly weathered, matrix-supported, polymict conglomerate at the Main Dam found. c) Slightly weathered sandstone-conglomerate interbed in the right abutment of the Main Dam.

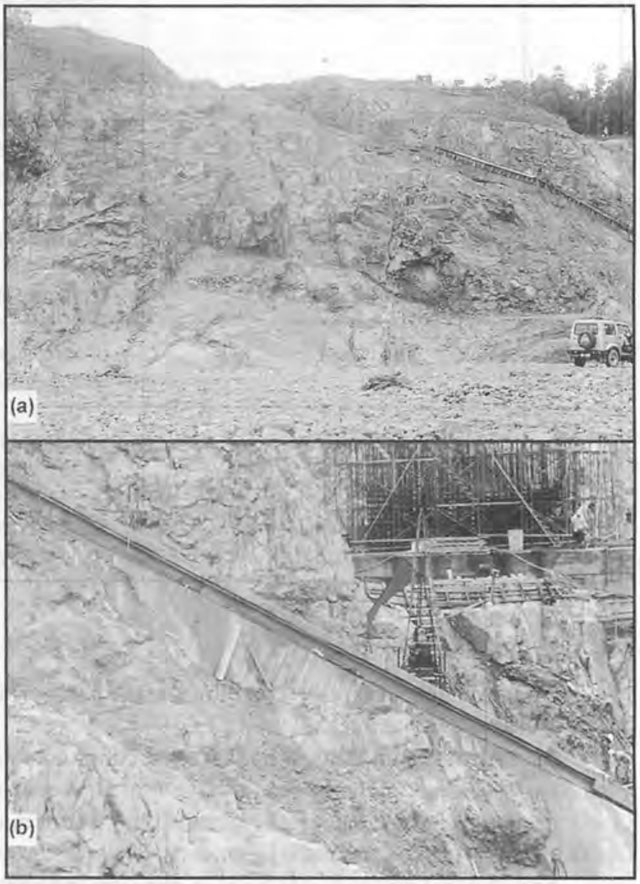

Plate 2. (a) View part of the right abutment hill of the Main Dam. Note the highly irregular bedrock surfaces due to intense jointing. (b) Part of the overbreak in the bedrock founding the toe slab on the right abutment of the Main Dam as indicated by the irregular thickness of the concrete base.

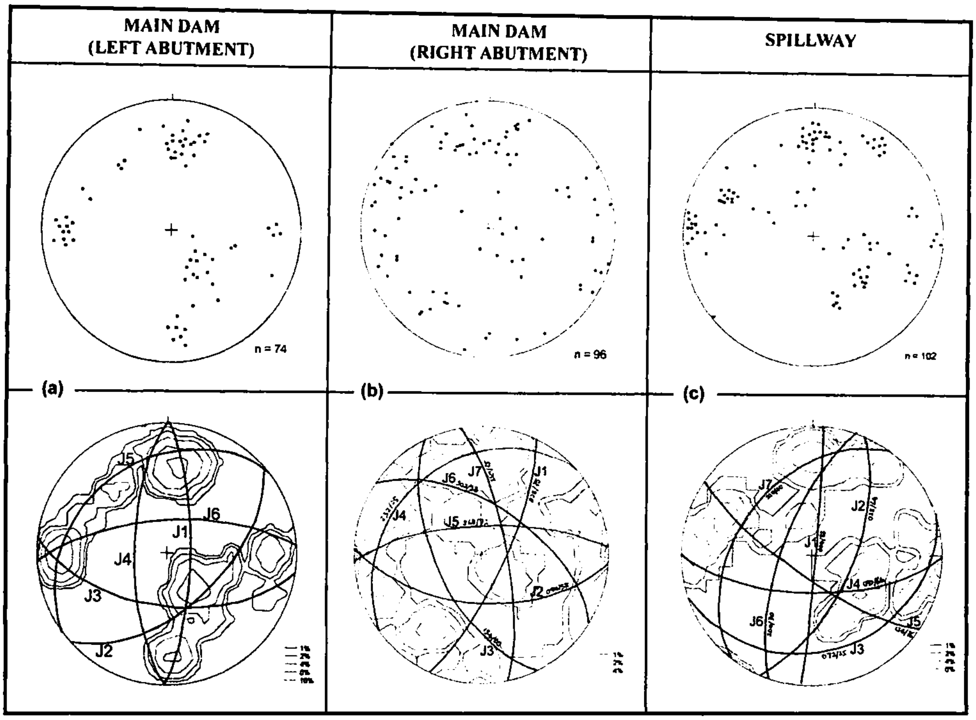

Figure 2. Stereographic plot of discontinuity data from (a) Left Abutment, Main Dam, (b) Right Abutment, Main Dam, and (c) Spillway (right and left walls).

Table 2. Summary of discontinuity data from the Left Abutment of the Main Dam

MAIN DAM — LEFT ABUTMENT		
Discontinuity Set	**Average Orientation (Strike/Dip)**	**Notes**
J1	002/75 E	Major joints + faults; highly persistent, smooth to slickensided surfaces.
J2	048/55 SE	Major joints + shear + faults; highly persistent.
J3	096/56 S	Bedding + Shear zone + some joints
J4	180/70 W	Minor, localised joints.
J5	236/28 N	Major joint; opened sheet joints, highly persistent.
J6	266/70 N	Major joints.

Table 3. Summary of discontinuity data from the Right Abutment of the Main Dam.

MAIN DAM – RIGHT ABUTMENT		
Discontinuity Set	**Average Orientation (Strike/Dip)**	**Notes**
J1	025/75E	Shear zones + faults + joints, highly persistent, narrow-wide aperture, undulating slickensided surfaces.
J2	094/58S	Joints; localised, minor and tight aperture.
J3	154/60SW	Major joints; controlling the slope face; very highly persistent, very close-closely spaced, smooth-undulating surfaces, tight, clay infilled & iron oxides stains; dry.
J4	232/25NW	Bedding + faults, very highly persistent; smooth-undulating, slickensided surfaces.
J5	268/72N	Bedding; very highly persistent; smooth , undulating surfaces; tight – wide aperture.
J6	302/58 NE	Major joint.
J7	350/75 E	Major joint.

slopes (Plate 3a) as well as along the base of the toe slab (Plate 3b). Irregularities in the bedrock surface profiles clearly suggest that the discontinuities exert profound control on the breakage behaviour of the rock masses.

The Spillway

The rock mass in Spillway is also affected by intense jointing (e.g. Plate 4a and b). The joints are very closely spaced which resulted in inequidimensional, polygonal blocks of highly variable sizes from several cm to 0.8 m across. Stereographic projection of the discontinuity data (Fig. 2c) indicates that the discontinuities can be broadly grouped into 7 sets as summarised in Table 4.

STRENGTH OF THE ROCK MATERIALS

Irregular block, rock samples, were collected from the excavation surfaces of (a) the Left Abutment of the Saddle Dam, (b) Left and Right Abutments of the Main Dam, and (c) the walls of the Spillway for the purposes of Laboratory Testing. The strength of the rock was determined with the Point Load Index Test as suggested by ISRM (1981). This test is considered as the most convenient measure of the comparative strength of irregular samples collected. The summary of the test results is given in Table 5.

The rocks in the Left and Right Abutments of the Main Dam, range between slightly and moderately weathered (Grade II – III). The test results indicate that they vary from Strong to Very Strong Rock. The rock samples which were collected randomly from the Spillway walls also range from slightly and moderately weathered (Grade II – III) rocks. The test results suggest that their strengths vary between Medium Strong Rock and Very Strong Rock.

DISCONTINUITIES IN BLASTING EXCAVATIONS

Introductory Remarks

The construction of the Main Dam and the Spillway of the Beris Dam required extensive excavation in hard rocks. Bulk blasting is used to fragment and loosen the rock mass in the excavation area, while pre-split blasting or controlled excavation is used to achieve a relatively smooth and clean rock cut surface, for example the left and right abutments of the Main Dam and the Spillway walls.

The factors influencing overbreak and underbreak (Fig.

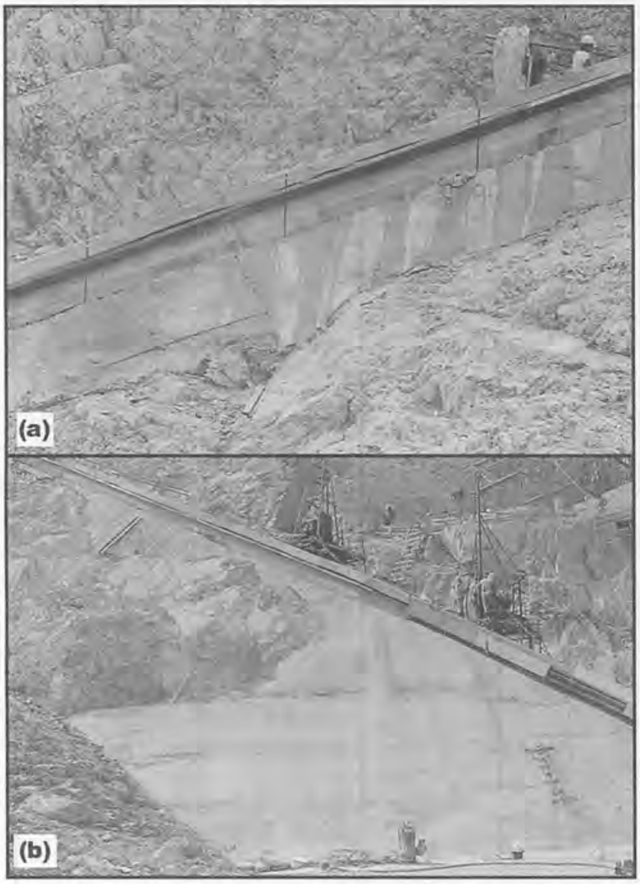

Plate 3. (a) An example of wedge-shaped overbreak below the toe slab on the left abutment of the Main Dam. (b) Part of the major overbreak (now fully backfilled with concrete) below the toe slab on the right abutment of the Main Dam.

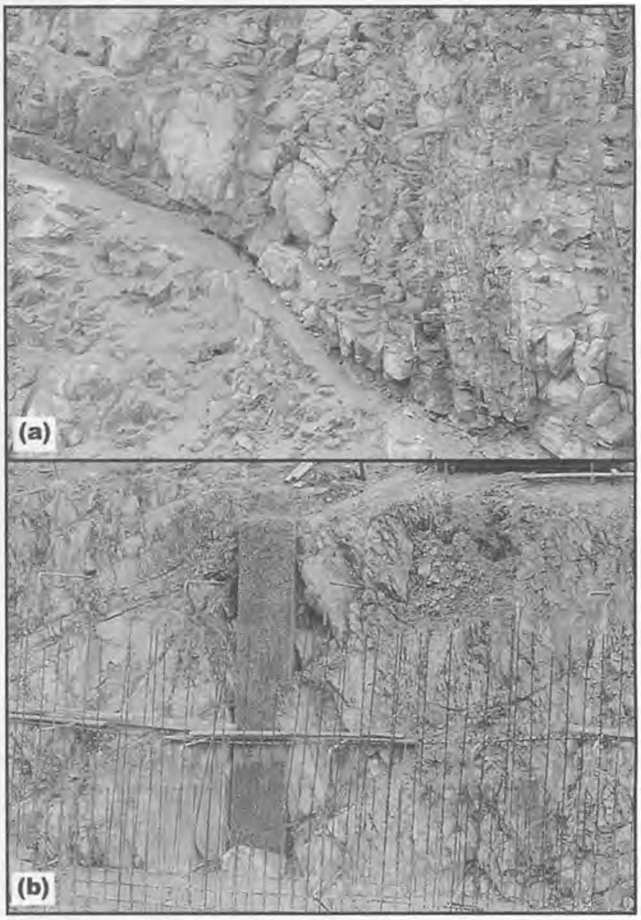

Plate 4. (a) Note the highly irregular and jagged rock surface due to intense jointing and shearing of the bedrock, which is further aggravated by blasting effects (Spillway left wall). (b) View part of the right wall of the Spillway. Note the highly persistent bedding planes and intense jointing in the rock mass.

Table 4. Summary of discontinuity data from the Spillway (left and right wall combined).

SPILLWAY		
Discontinuity Set	**Average Orientation (Strike/Dip)**	**Notes**
J1	004/88	Minor joints; localised, tight, low persistency.
J2	024/64	Major joints.
J3	072/25	Major joints.
J4	090/66	Major joints.
J5	124/76	Major joints.
J6	200/70	Joints + fault + shear zones, persistent, tight to narrow aperture, undulating to slickensided surfaces; breccia + clay infills.
J7	220/40	Sheet joints + bedding, very highly persistent, narrow-white aperture, smooth undulating surfaces.

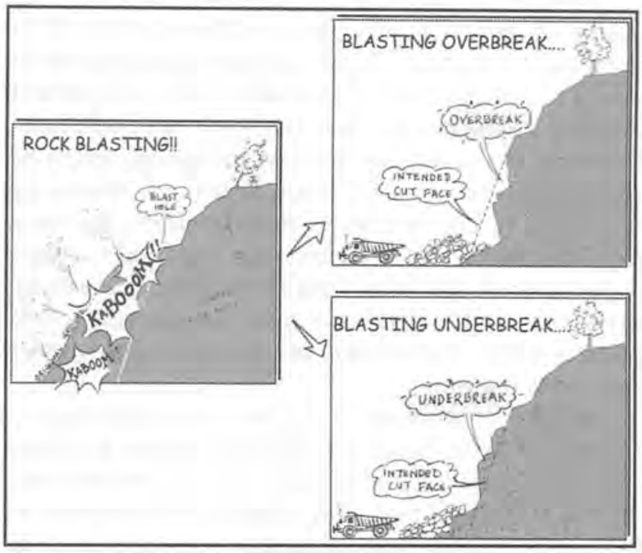

Figure 3. Cartoons illustrating definition of blasting overbreak and underbreak in jointed rock mass.

Table 5. Summary of Point Load Index Test Results.

		Corrected Point Load Index Strength, Is_{50} (MPa)	Calculated Uniaxial Compressive Strength, UCS (MPa)	Rock Strength
(A) MAIN DAM (Left & Right Abutments, undifferentiated)	Minimum	2.32	51.06	Strong Rock
	Maximum	6.43	141.55	Very Strong Rock
	Average	3.63	79.95	Strong Rock
(B) SPILLWAY (Left & Right Walls, undifferentiated)	Minimum	1.57	34.58	Strong Rock
	Maximum	8.71	191.59	Very Strong Rock
	Average	4.28	94.20	Strong Rock

3) can be grouped into two categories (Ibarra *et al.*, 1996); i.e. 1) the geological factors or the make up character of the ground and 2) the nature of the excavation (blasting) operation. The relationship between blasting, geological conditions and overbreak and underbreak has been long discussed (e.g. Hoek and Bray, 1981; Ibarra *et al.*, 1996 and many others), but there has been no systematic and quantitative investigation of them. The geological factors influencing overbreak and underbreak are mainly structural discontinuity planes. The orientation, spacing (block size), filling materials (or alteration), persistency of discontinuity all contribute towards influencing the blasting damage. Other geological factors include the strength of the intact rock and in-situ ground stress.

Overbreak and underbreak can also be the result of poor blast design and/or execution. Even a well-designed blast can give poor results if poorly implemented. The blasting factors which influence overbreak and underbreak include: a) explosive type and powder factor, b) charge concentration, c) delay time, d) perimeter blasthole pattern, e) drilling deviation, f) blasthole length and diameter, and g) large hole cut. (Ibarra *et al.*, 1996). Discussions on blasting design and nature are beyond the scope of this paper.

A study by Ibarra *et al.* (1996) shows that as the rock quality (measured by Q-system of Barton et al., 1974) improves, the amount of overbreak tends to decrease while that of underbreak tends to increase. They also showed evidence that rock quality may be slightly more influential in causing overbreak, and that explosive energy might be slightly more influential in causing underbreak. Increasing the explosive energy reduces underbreak but increases overbreak. As rock quality deteriorates, overbreak increases and underbreak decreases. "Wall rock damage" caused by overbreaks and underbreaks may consequently cause problems to cut slope stability and thus increase the overall cost of the project.

Rock excavation in the Spillway was conducted by adopting pre-split blasting technique – where a closely spaced with small diameter blastholes were drilled along the line of the final face. The trimming of underbreak to the final wall surface was executed by machine excavation (pneumatic rock breaker, e.g. Plate 5). The blast holes were drilled at approximately 70°, along the line of the toe of the proposed bench. The intention was to result in the formation of a clean fracture running from one hole to the next. However; this was not always the case because the resulted faces can also be irregularly rough and jagged due to overbreak and underbreak which inevitably modify the Spillway dimensions off the original design.

Blasting Overbreak in the Spillway

In order to assess the influence of the geological structures upon the formation of blasting overbreak, kinematics stability analyses (Hoek and Bray, 1981) was adopted on the discontinuities data collected from the right and left wall of the Spillway (Fig. 4a and 4b). From these analyses it was found that the left wall (cut slope) is subjected to numerous wedge failure due to intersection of J1xJ6, J3xJ6, J3xJ7, J3xJ5, J2XJ5, J4xJ5, J4xJ6 and J4xJ7. The cut slope is also prone to planar (slab) failure (rock slides) due to the daylighting J4 and J5 joint sets. Combinations of these rock wedges and rock-slabs (e.g. Plates 6, 7, 8), explain the excessive development of overbreak in the left wall of the Spillway.

An almost similar case is found in the right wall (Plate 4b). Elements of rock instability naturally exist in the rock mass due to intersections of J2xJ7, J1xJ7 and J1xJ6, which are responsible for overbreak in the form of rock wedges. While set J4 and J5 can easily produce block toppling or rock falls during and/or after blasting operation. A clear example of wedge overbreak in the Spillway is shown in Plate 6-7.

Even if the blasted rock faces are relatively smooth, the impact of blasting operation might have resulted in numerous loose wedges and rock blocks hanging in the cut slopes due to the existing intense jointing. During the trimming works for the final cut faces, the loosened wedges and blocks can be easily dislodged from their in-situ position, and thus cause overbreaks.

Blasting Overbreak along the toe slab of the Main Dam

Excessive overbreak was also evident in the Main Dam, notably below the toe slabs in both left and right abutments of the Main Dam (e.g. Plate 4b). To assess the influence of geological structures on the formation of these overbreaks, kinematics stability analyses were carried out on the discontinuity data. Results of analyses for the left abutment and right abutment are shown in Figure 4c and Figure 4d, respectively.

Along the left toe slab, unstable wedges were naturally well developed due to the intersections of J6xJ4 and J6xJ3 joint sets. Joint set J4 would have served for the sliding of rock slabs (planar failure), while joint set J1 is responsible for toppling or rock falls in the rock cuts intended by the blasting line. Along the right toe slab; wedge failures were taken place along the intersection of J1xJ3, J1xJ2, and J2xJ3. As an example, the rock slide, which caused a major overbreak shown in Plate 4a, is attributed to the presence of daylighting J2 joint set. Some examples of joint-controlled overbreaks indicated by these analyses are clearly evident in the field as captured in Plate 4.

In summary, overbreaks along the base and side walls of the toe slabs can be attributed somehow, to the presence of unfavourably oriented joint systems in the rock mass.

DISCUSSIONS

The precise nature of the mechanism of rock fragmentation as a result of detonating an explosive charge is not fully understood. However, excessive overbreaks, as seen along the toe slab of the Main Dam and the Spillway walls, are clearly influenced by structural discontinuities (e.g. bedding, joints, shear zones and faults).

Pre-split blasting is a method of blasting which is normally successful in a relatively homogenous, massive and less fractured rock mass, such as granite and other plutonic rocks. However, in bedded and heavily jointed and layered rock mass, the resulting face is not always satisfying. There has been a common misconception that the only step required to control blasting damage is to introduce pre-split or smooth blasting techniques. The successful of pre-split blasting in heavily jointed and bedded hard rocks excavation such as those encountered at the Beris Dam site, can not be guaranteed. Particularly where the joints are open, highly persistent, and are inclined towards the pre-split line.

The open and highly persistent joints allow the explosion gases to vent and fracturing follows the joints rather than the intended pre-split line. There is very little that can be done to remedy this problem other than to change the direction of the cut slope face on the first place. Obviously, the wall rock damage done, whatever their cause, will have a major disruptive effect upon the integrity of the rock mass and this, in turn, will cause a reduction in

Plate 5. Trimming of the blasted surface in the plunge pool section of the Spillway.

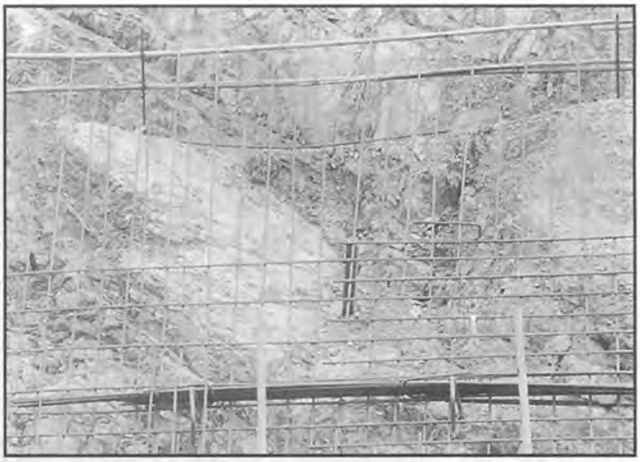

Plate 6. Intersection of bedding plane and subvertical joint give rise to wedge overbreak in the Spillway wall.-

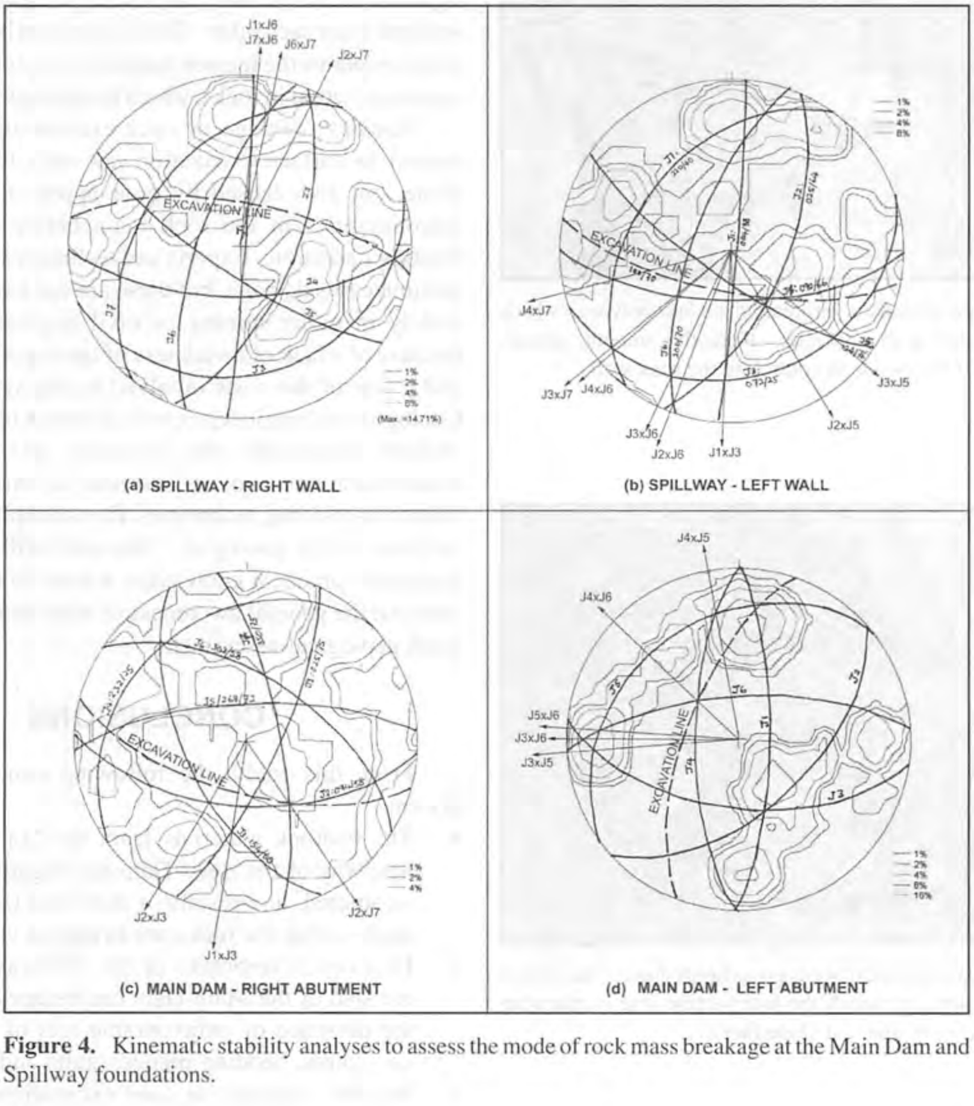

Figure 4. Kinematic stability analyses to assess the mode of rock mass breakage at the Main Dam and Spillway foundations.

Plate 7. Example of planar overbreak in the Spillway wall which has been backfilled with concrete. Note the smooth, planar, subvertical joint surfaces which controlled the rock wall.

Plate 8. A typical example of wedge overbreak due to intersection of two sets of joints, in which the intersection line is plunging towards the excavation line (cut slope face).

stability of the individual benches which make up the slope.

The orientation of joints relative to the perimeter of the excavation is very critical in controlling rock fragmentation and breakage in blasting operation (Fig. 5). Overbreak and underbreak are typically less where joints and faults strike nearly perpendicular to the strike of the slope cuts and greater when joints are parallel to the tunnel axis. When joints run closely parallel to the proposed orientation line of the slope, the rock tends to break along the joints rather than along the lines intended by the designer. Overbreak can be expected to increase with the combination of 2 joint sets and increase dramatically with the intersection of 3 or more near orthogonal joint sets (Martna, 1986).

An additional cause of blasting inducted damage is that of fracturing induced by release of load (Hagan, 1983). This mechanism can be explained by the analogy of dropping a heavy steel plate onto a pile of rubber mats. These rubber mats are compressed until the momentum of the falling steel plates has been exhausted. The highly compresses rubber mats then accelerate the plate in the opposite direction and, in ejecting it vertically upwards, separate from each other. Such separation between adjacent layers explains the tension fractures frequently observed in open excavation in rocks, which encourage slope instability.

Needless damage or over excavation is often being caused to surface excavation not only by poor blasting alone, but also caused by poor appraisal on the role of discontinuities in the rock mass before conducting the blasting operation. Experts and techniques are available to minimize this damage, but these are not being applied very widely in either mining or civil engineering industries because of a lack of awareness of the benefits to be gained, and a fear of the costs involved by engaging a geologist. Geologists and engineers involved in rock blasting operation should recognize the current lack of effective communications and, in addition to engineers work in improving blasting techniques; they should be more willing to listen to the geologist. Not only will engineers gain invaluable practical knowledge, a great deal can be done to improve the general awareness of what can be achieved by good geological assessment.

CONCLUSIONS

From this study, the following conclusions can be drawn:

- The bedrock materials from the Main Dam and the Spillway of the Beris Dam are slightly to moderately weathered, and results of the Point Load Index Tests suggest that the rocks are ***strong to very strong rock.***
- Excessive overbreaks in the Spillway and along the toe slab of the Main Dam can be attributed largely to the presence of unfavourable sets of discontinuities; i.e. joints, bedding planes, faults and shear zones.
- Needless damage or over excavation is often being caused to surface excavation not only by poor blasting

alone, but also caused by poor appraisal on the role of discontinuities in the rock mass before conducting the blasting operation. This case study gives another example where geological inputs are very important in engineering practice, i.e. rock blasting excavations.

ACKNOWLEDGEMENT

TAJ would like to thank all the site staffs and Earthwork Contractor/Engineers of the Beris Dam for their kind cooperation and trust given to me to carry out this study. En. Zamrut Daunar of Geology Department UM helps in preparing the digital photographs is very much appreciated. Prof. Dr. J.K. Raj is thanked for his review and comments to improve the manuscript of this paper.

REFERENCES

ANON, 1977. The description of rock masses for engineering purposes: Working Party Report. *Q. Jour. Engng. Geol., 10*, 355-388.

ATTEWELL, P.B., 1993. The role of Engineering Geology in the design of surface and underground structures. *In:* Hudson, J. A. (Ed.), *Comprehensive rock engineering*. Pergamon Press, Oxford, vol. I, 111-154.

BURTON, C.K., 1972. The geology and mineral resources of the Baling area, Kedah and Perak. *Mem. Geol. Survey Malaysia 12*, 150p.

GUSTAFFSON, R., 1973. *Swedish blasting technique*. SPI, Gotherburg, Sweden. 378p.

HAGAN, T.N., 1983. The influence of controllable blast parameters on fragmentation and mining costs. *In: Proc. 1st Int. Symp. On Rock Fragmentation by Blasting*. Lulea, Sweden, 31-51.

IBARRA, J.A. MAERZ, N.H. AND FRANKLIN, J.A., 1996. Overbreak and underbreak in underground openings Part 2: causes and implications. *Geotechnical & Geological Engineering, 14*, 325-340.

ICI, 1975. *Blasting practice*. Imperial Chemical Industries Ltd., Glasgow.

ISRM (INTERNATIONAL SOCIETY OF ROCK MECHANICS), 1981. *In:* Brown, E.T. (Ed.), *Suggested method for rock characterization, testing and monitoring*. Pergamon, Oxford.

JPS (Jabatan Pengairan & Saliran Malaysia) Kedah, 2003. Beris Dam. http://agrolink.moa.my/did/irrigation/beris-dam.htm.

LANGEFORS, V. AND KILSTROM, B., 1973. The modern technique of rock blasting, 2nd ed. Wiley, New York, 403p.

MARTNA, J., 1986. The influence of rock structure on the shape and support of a large headrace tunnel. *Proceedings of the International Congress on Large Underground Caverns, Frienze, Italy. Vol. 2*, 260-269.

MATHESON, G.D., 1986a. Design and excavation of stable slopes in hard rocks with particular reference to presplit blasting. *In: Rock Engineering and excavation in an urban environment*. The Institution of Mining & Metallurgy. London, 271-284.

MATHESON, G.D., 1986b. Session 10. Drilling and blasting – Discussion. Authors' replies. *In: Rock Engineering and excavation in an urban environment*. The Institution of Mining & Metallurgy. London. 521-524.

ONG, S.S., 1969. *Geology of the Muda Dam area, Kedah, West Malaysia*. BSc (Hons.) Thesis, Department of Geology, University Malaya (unpubl.).

TAJUL ANUAR JAMALUDDIN, 2002. Geological assessment of the rock excavations at the foundation site of the Beris Dam, Kedah. 19p (Unpubl. Report).

Manuscript received 5 March 2003