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BLASTABILITY INDEX ON POOR QUALITY ROCK MASS

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ABSTRACT

The present paper proposes a new combined classification system connecting the quality and blastability of poor and friable rock mass, heavily broken with mixture of angular and rounded rock pieces. The proposed methodology and research that result in the Blastability Quality System (BQS) are described, and three useful diagrams of the above new system aroused from our estimations. The proposed BQS is an easily and widely used tool as it is a quickly calculator for blasting and rock mass quality. Taking into account our research calculations and the parameters of BQS, we came to some conclusions for the relation of the blast ability index magnitude with the space and orientation of discontinuities.

KEYWORDS: Blastability, Blasting, Classification System, Rock Mass

INTRODUCTION

The property, which is referred as "blastability" of a rock mass, determines how easy is to explore a rock mass under specified blast design, explosive characteristics and specified legislative constraints depending on the site specifics. Two different rock masses, when are subjected to identical blast geometry and energy input from explosives, produce quite different degrees of fragmentation (Ajoy & Akhilesh, 2012). This is because they have different resistance to fragmentation by blasting (Blanco & Kumar, 2012).Rock mass comprises of several different rock types and is affected by different stages of alteration in varying stress conditions. Blast ability appears to be a kind of intrinsic property, like the hardness of a rock and, apart from the possibility of blast fragmentation from previous blasting events, it is uncontrollable.

Many rock mass quality classification systems (RQD, Q, RMR, GSI) have been developed for drilling and excavation ability estimation. The present paper is trying to create a new system, connecting the quality and blastability of rockmass, which can be, easily, used as an in situquick method, for tunnel excavation, in order to estimate quickly the explosive results, in addition to drilling and excavation methods.

The rock mass, used in this study, is poor and friable, shared with lack of blockiness due to the close spacing of weak schistosity or sheer planes and disintegrated with poorly interlocked, heavily broken rock mass with mixture of angular and rounded rock pieces. Although the quality is very poor, a light blast may be needed as the small rock pieces are tightly connected.

ALREADY KNOWN APPROACH; BLASTABILITY INDEX CONCERNING ROCK MASS CLASSIFICATION SYSTEMS

The factors, which influence the blasting results, fall into two groups. The first group refers to the intact rock properties, which include strength, hardness, elasticity, deformability, density of rock, etc. These properties depend on rock texture, internal bonds, composition and distribution of minerals forming the rock (Zhang et al., 2011). The second group refers to the discontinuity structure that involves orientation, spacing and extent of discontinuities (Singh & Sinha, 2012). The discontinuity structure has been created by a range of long-term geological processes.

The coefficient of the Blast ability Index (BI) is a quantitative measure of the blastability of a rock mass. It is more advantageous, the coefficient BI to be determined before blasting, in order to help with the blast design of an excavation operation. Without any realistic chance, in the short term of a practical analytical solution of defining the value of a BI, for a given rock mass as a function of material properties, the development of a comprehensive assessment system for quantifying the blastability of rock masses is appear to have great potential(Latham and Lu, 1999).

Blastability index (BI) is used for the description of ease of blasting and it is also related to power factor. When the BI is lower to 8, the ease of blasting is described as "very difficult". When the BI range is between 8 and 13, the ease of blasting is described as "difficult". When the BI range is between 13 and 20, the ease of blasting is described as "moderate". When the BI range is between 20 and 40, the ease of blasting is described as "easy". When the BI is higher than 40, the ease of blasting is described as "very easy". The above parameters are closely related to excavation cost which is depended on the explosion, vibration, alteration, powder creation etc. (Kaushik & Phalguni, 2003).

In our study, BI is preferred to be calculated based on the following formula (Lilly, 1986), based on rock mass description, joint density and orientation, specific gravity and hardness:

BI = 0.5 x (RMD+JPS+JPO+SGI+H)

Where,

BI = Blastability Index

RMD (Rock mass Description)	=	10, for Powdery/Friable rockmass
	=	20, for Blocky rockmass
	=	50, for Totally Massive rockmass
JPS (Joint Plan Spacing)	=	10, for Closely Spacing (<0.1m)
	=	20, for Intermediate (0.1-1.0m)
	=	50, for Widely Spacing (>1.0m)
JPO (Joint Plane Orientation)	=	10, for Horizontal
	=	20, for Dip out of the Face
	=	30, for Strike Normal to Face
	=	40, for Dip into Face
SGI = Specific Gravity Influence	=	25 x Specific Gravity of rock (t/m^3) – 50

H = Hardness in Mho Scale (1-10)

Considering that blastability index is based on rock mass description, joint density and orientation, evokes the same parameters that the Rock Mass Rating System - RMR (Bieniawski, 1989) is also based on.

Also, the above classification can be described by the Geological Strength Index – GSI (Hoek, 1994).

NEW APPROACH CONNECTING BLASTABILITY AND QUALITY ABILITY

The lower part of the GSI diagram, which refers to i) laminated and sheared rock mass, with lack of blockiness due to the close spacing of weak schistosity or sheer planes and ii) disintegrated rock mass, with poorly interlocked, heavily broken rock with mixture of angular and rounded rock pieces, isdivided into eight parts (Figure 1); A -for GSI about 0-12, B – for GSI about 12-23, C – for GSI about 22-23, D – for GSI 7-17, E – for GSI about 18-28, F – for GSI about 16-36, G – for GSI 35-43, H - for GSI 42-50.

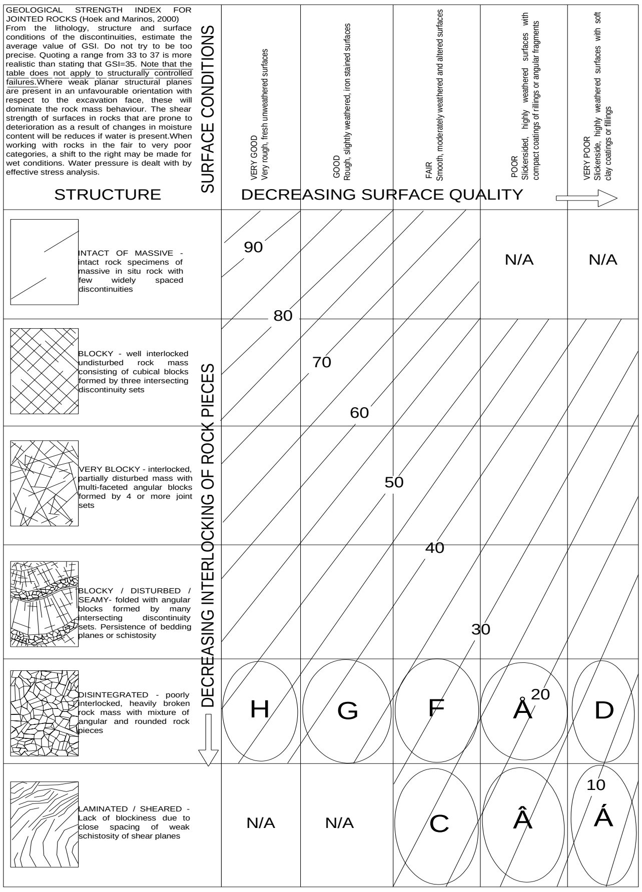

Figure 1: Eight Parts Division of GSI Diagram

Taking into account the blast ability parameters, the BI is calculated for every possible combination of the above parameters, which refers to powdery/friable rock mass. That means RMD is equal to 10 (powdery / friable rock mass). JPS is used equal to 10 for closely spacing, 20 for intermediate spacing and 50 for widely spacing. JPO is used equal to 10 for horizontal discontinuities, 20 for inclined discontinuities, where the excavation drives against dip direction, 30 for inclined discontinuities with strike parallel to face, 40 for inclined discontinuities, where the excavation drives with dip direction. SGI is calculated using specific gravity of rocks from 1 t/m^3 to 3 t/m^3.Mohs hardness scale (H) is estimated using the average price of Mohs hardness scale of the minerals which compose the rock mass. For every possible RMR combination, new combinations are calculated in addition to GSI range. Subsequently, we group the above estimations and we come to the conclusion of specified RMR range on GSI parts, taking into account rock mass hardness, discontinuity spacing and orientation. Also, the range of Blastability Index is calculated. Three useful diagrams of composite rock mass quality systems (GSI and RMR) and blastability index (BI) result from the above estimations (Figure 2-4).

BLASTABILITY QUALITY SYSTEM (BQS)

The above new BQ System (Figure 2-4) connects the rock mass classification systems RMR and GSI, structural data, hardness of rock mass, and blastability index. Initially, the discontinuities spacing is characterized; for close spaced discontinuities, with spacing lower than 0,1m, figure 2 is used. For intermediate spaced discontinuities, with spacing between 0,1m and 1m, figure 3 is used. For widely spaced discontinuities, with spacing higher than 1m, figure 4 is used.

Looking the lower part of the figures 2, 3, and 4, there is a combined Geological Strength Index diagram with RMR areas for every rock mass classification according to BI.

So, having completed the above classification, inputting the spacing and the orientation of discontinuities combined with rock mass hardness, the Blastability Index (BI) range can easily be determined. At the final stage we can input structure and surface conditions in order to estimate Geological Strength Index (GSI) and Rock Mass Rating (RMR).

This is a very useful approach as it includes the most useful characteristics of rock mass, which are easily estimated and used in situ; looking a rock mass picture can easily characterize discontinuities spacing and orientation. Also, we can estimate rock mass hardness using a Schmidt Hammer.

In addition to BQS easily and wide use, it is a quickly calculator for BI and rock mass quality, which make our choice of excavation, blast and support measures quicker.

EXAMPLES OF USING BQ SYSTEM

The excavations, during the construction of Asprovalta-Strymona’s part of Egnatia Highwayin Northern Greece, were very difficult because of rock mass quality. Rock mass was consisted of weathered and cracked gneiss with pegmatitic veins, or cracked marbles. There was no cohesion between rock mass pieces, so as they formed potential sliding wedges. When the face area of disintegrated wedges had been uncovered, the sliding was happened suddenly (Christaras et al, 2001). So, although the use of blasting was needed, the explosion had to be very careful, so as no accident may happen. Looking at the rock mass example on figure 5, rock mass has close spaced discontinuities. Using the figure 2, the orientation of discontinuities may be determined. Looking again figure 5, strike is parallel to tunnel axis. At next stage, rock mass hardness needs to be also determined. So, as the rock mass is very weathered, it is extremely soft to medium hard. Looking the figure 2, the BI is estimated14-41 and blasting is characterized as moderate to easy. That means, a small amount of explosives could be used in order to help rock mass pieces to move, helping the excavation. could be used in order to help rock mass pieces to move, helping the excavation.

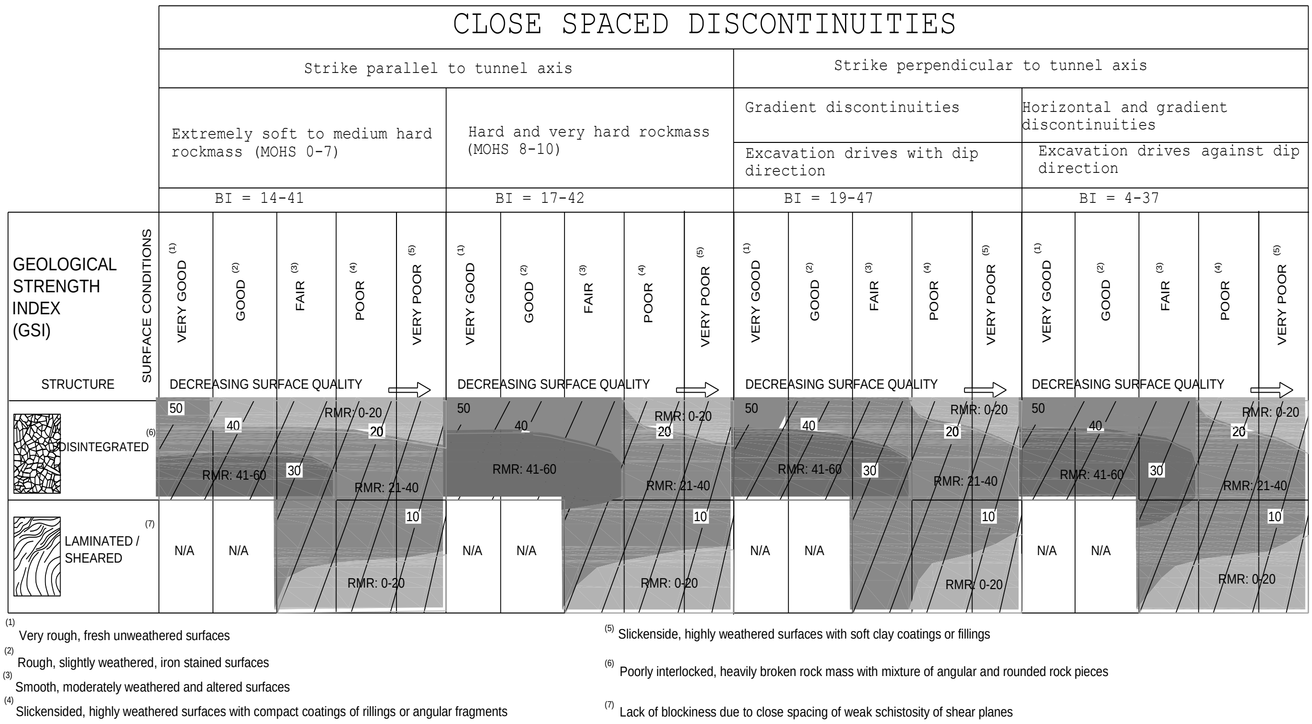

Figure 2: BQS for Close Spaced Discontinuities

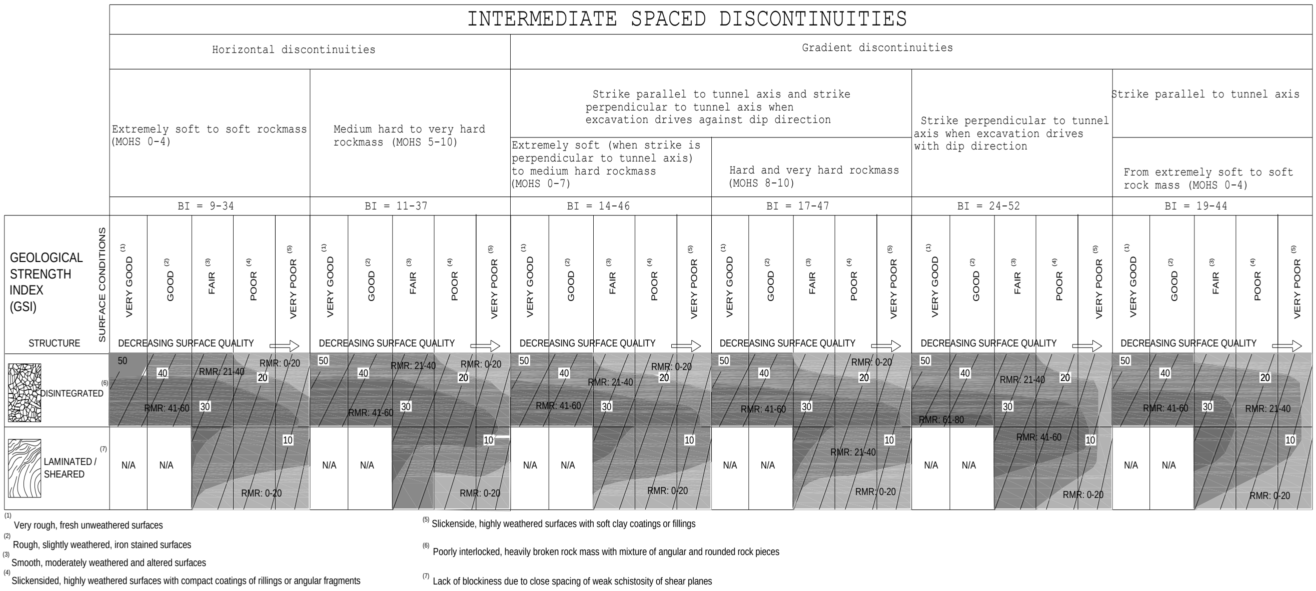

Figure 3: BQS for Intermediate Spaced Discontinuities

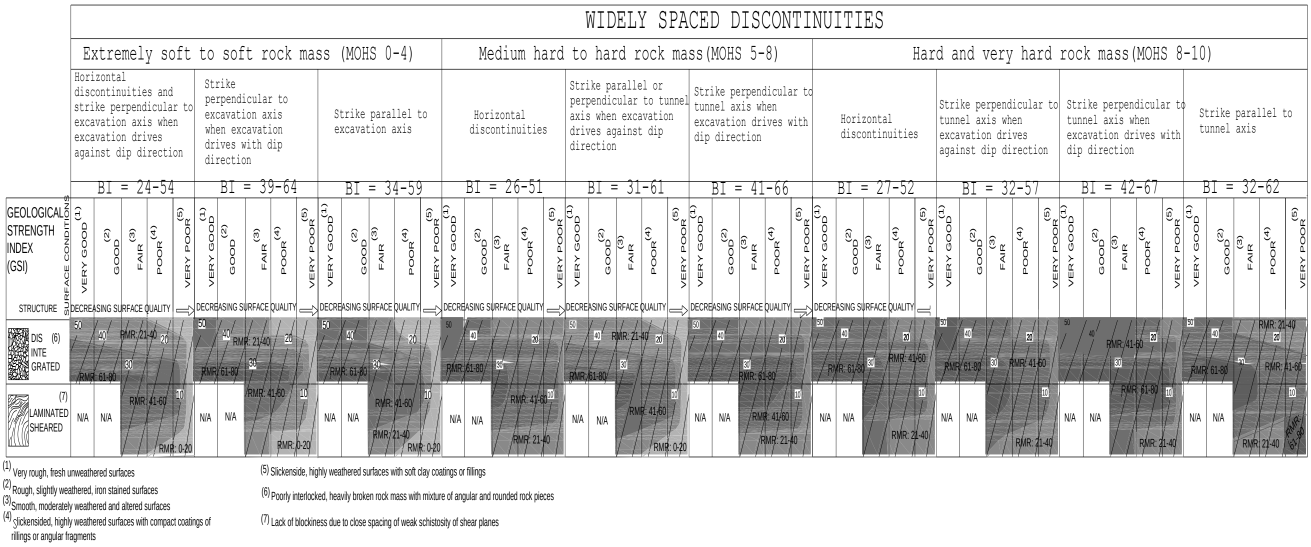

Figure 4: BQS for Widely Spaced Discontinuities

Figure 5: Weathered and Disintegrated Rock Mass Quality at Asprovalta – Strymona's Part of Egnatia Highway at Northern Greece

Furthermore, looking the lower part of the same figure, we combine the structure of rock mass, which is disintegrated, with the surface conditions, which are poor, estimating an RMR from 0 to 20 (as rock mass is disintegrated to blocky and not to laminated) and a GSI from 20 to 25. Taking into account the poor quality of rock mass, as it is described by RMR and GSI classification systems, the choose of rock mass locations, where the explosives were put, needed to be very careful. They could be placed where rock mass were strengthen and hard, so as the forces of the neighborhood locations remained on balance.

Figure 6: Chloritic Schist Rock Mass during Tunneling of Symbol Mountain at Strymonas-Kavala's Part of Egnatia Highway at Northern Greece

Although the quality of the excavated rock mass, during the tunneling of Symbol Mountain at Strymonas- Kavala's part of Egnatia Highway in Northern Greece, was characterized as medium - it was consisted by gneiss, amphibolites, marbles and plutonic rocks - the chloritic schist formation, which was created because of gneiss and plutonic rocks contact, generated unexpected failure conditions (Chatziangelou et al, 2010). Chloritic schist was a hard rock mass that excavating machines could difficulty break it. So, blasting helped excavating works. But just when chloritic schist came in touch with the air, the rock mass was very quickly weathered and loose material flowed from the walls and the face of excavation. So, explorers needed to be very careful using light explosion. According to the rock mass example on figure 6, rock mass had intermediate spaced discontinuities. Using the figure 3, the orientation of discontinuities may be determined. Looking again figure 6, there are also horizontal discontinuities. Subsequently, rock mass hardness needs to be also determined. So, as the rock mass is quickly weathered and loosed, its hardness characterizes as extremely soft to soft. Looking the figure 3, the BI is estimated 9-34 and blasting is characterized as very difficult. That means, although high explosives are effective for chloritic schist braking, the pattern of explosives need to be chosen for every location, so as collapses of the roof and sliding from walls to be avoided. Furthermore, looking the lower part of the same figure, we combine the structure of rock mass, which is laminated and sheared, with the surface conditions, which are very poor, because of slickensided discontinuities with highly weathered surfaces with soft clay (chlorite) coatings, estimating an RMR from 0 to 20 (as rock mass is sheared and no way disintegrated) and a GSI from 5 to 10. Taking into account the above characterizations, the puncture of excavation's outline was chosen, to control the pressures of blasting result.

BLASTABILITY INDEX VERSUS TO STRUCTURAL GEOLOGY

Taking into account the calculations of BI for every possible structural appearance of the rockmass, we can easily result in a diagram which connects the structural description, the hardness of rockmass and BI (Figure 7), where rock mass quality 1 refers to close spaced discontinuities, horizontal formations, and inclined formations, where the excavation drives against dip direction. Rock mass quality 2 refers to intermediate spaced discontinuities and horizontal formations. Rock mass quality 3 refers to close spaced discontinuities and gradient formations, where excavation drives with dip direction. Rock mass quality 4 refers to intermediate spaced discontinuities and gradient formations. Rock mass quality 5 refers to widely spaced discontinuities, horizontal formations, and soft gradient rock mass, where excavation drives against dip direction. Rock mass quality 6 refers to widely spaced discontinuities and gradient formations (except soft gradient rock mass where excavation drives against dip direction).

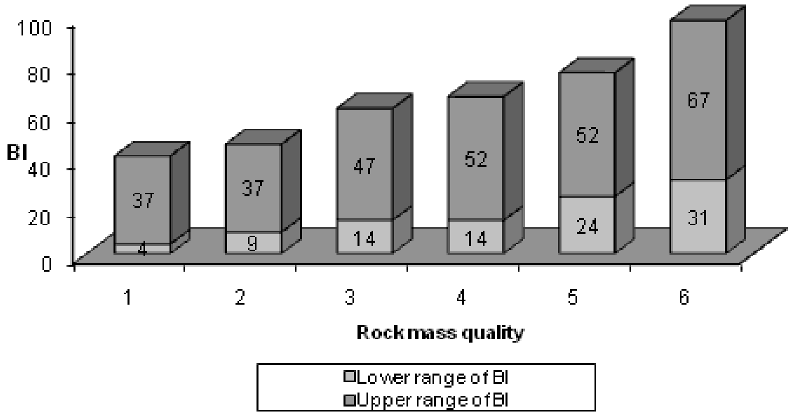

Figure 7: Rock Mass Quality versus to Blastability Index

Looking at the above diagram, we can easily conclude that

- The wider the spacing of discontinuities is, the bigger the BI is.
- BI is lower in horizontal formations than in gradient formations.
- BI is higher where the excavation drives with dip direction than where it drives against dip direction.

CONCLUSIONS

A new Blastability Quality System (BQS) is already developed connecting rock mass quality, discontinuities orientation, hardness and Blastability Index (BI). It is a wide useful system as it can be easily applied during the excavations, helping engineers on quick estimations of rock mass quality and BI, in addition to excavation way, explores and support measures.

BQS is a tool which (at the present) can be used for poor and friable rock mass, shared with lack of blockiness due to close spacing of weak schistosity or sheer planes and disintegrated with poorly interlocked, heavily broken with mixture of angular and rounded rock pieces. Taking into account the calculations of BI for every possible structural appearance of the rock mass, we conclude that the wider the spacing of discontinuities is, the bigger the blast ability index is. Also, the blastability index is lower in horizontal formations than in gradient formations. Finally, BI is higher where the excavation drives with dip direction than where it drives against it.

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