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Optimization of efficiency of rock breaker using Geological data:Reference to Mumbai, Maharashtra, India.

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Abstract

The rock breaking is required for various purposes such as mining, tunneling, foundation and other infrastructure projects. There are various methods for the rock breaking. But breaking of rock in the urban area is most challenging due to limited working space, local administration approvals, adjoining structures and low noise & vibration. The Mechanical hydraulic breaking of the rock is most common methods used in urban areas. The efficiency of hydraulic breaking machine is depends on rock type, rock strength, type of machineries and Chisel to be used for breaking. There are various Chisel, used for different purpose with different operating machines. The impact of Chisel varies in different rocks class and different machines. In this paper we discussed the types of non-explosive rock breaking available in markets and focused on challenges faced during used of hydraulic rock breaker in Mumbai; and concluded that planning for deploying breaking machine should be based of geological data with worst rock condition, suitable machine, chisel and other rock breaking options if encountered hard rock and project progress is going down. It is also suggested that geologist can better suggest the breaking methods in hard rock as per rock mass and jointed plan.

Keywords:Rock breaking, Hydraulic breaking, Chisel, geological factors, Joint plan,CercharAbrasion Index

1. INTRODUCTION

The development of infrastructure project or any civil structure in rockyterrain requiresrock breaking. There are various methods of rock breaking depending upon combination of Geological, social and type of project. The developing Infrastructure projects in urban area are full of challenges such as space limitation, low noise, less vibration and other local government issues. Various infrastructure projects are under progress in urban areas as well as in Mumbai also.

Mumbai is economical capital of India as well as worlds 5th most populated city where average population density is about 32303 per square kilometer (Wikipedia). Mumbai is situated on Deccan trap and make up of Basalt and volcanic breccia rock. The Mumbai have varying topographical features, most of area is flat and Mumbai is surrounded by north-south trending hill range, coastal area and having creeks. Basalt, Volcanic breccia, Rhyolite, Trachytes, shales are the main rocks exposed at various location in Mumbai (Sethna S F, 1999). As per geotechnical & geological parameters insitu rock strength varies from very hard to poor (grade 1 to IV) in nature.For betterment of public, various infrastructure projects are going on and as whole Mumbai have rocky foundation, rock breaking is always required.

In this paper, we will try to discuss types of rock breaking with their affecting factors, challenges in rock breaking by hydraulic breaker and problem faced during rock breaking as per rock class in Mumbai and finally suggested the points to be considered for smooth rock breaking in hard rocks.

2. DISCUSSION

2.1 Types of non-explosive rock breaking methods

The rock breaking in urban area is much difficult than rural area. The urban area such as Mumbai, having various limitations and single or multiple rock breaking methods would be recommended based on rock and project. Blasting is general method of rock breaking due to high efficiency, low cost but high vibration, fly rock, dust, toxic gases, noise are negative factor of blasting. Accordingly alternate non explosive methods were developed, which are discussed below Table 1:

Every method has its own limitations such as for the highly weathered or weak rock, the manual method would be better, hydraulic splitting used in precious stone mines, hydraulic breaking used for the engineering construction for highly to moderately weather rock, drilling boring used in mines and tunnel, static expansion & Carbon dioxide crackers use in different types of mines, concrete and other. The metal burner have used for more efficient precious stone mines, plasma

Non explosive Rock breaking methods								
Manual		Mechanical			Chemical			Electrical	
Hammering	Fire				Static Expansion	Carbon dioxide cracker	Metal Burner		
		Hydraulic Splitting	Hydraulic Breaking	Drill boring Machine				Plasma Blasting	Heat Splitting

Table 1: *Non explosive rock breaking methods (after Zhou et.al, 2018)*

blasting is also used for develop the cracks in the hard rock and heat splitting is only used for break the Auxiliary rock or hard rock.

The mechanical breaking is most convenient for the rock breaking in urban area. For starting of deep excavation such as high rise building, underground metro stations, shaft for launching of Tunnel Boring Machines etc, first piling to be done for providing support from the surrounding rocks. The depth of piling would be decided on the basis of intact rock or depth of excavation. For pilling, hydraulic breaking & drilling boring machine haveused. But before starting of rock breaking, geotechnical studies of that area have to be completed, it would be helpful for finalization in type of machine to be used for rock breaking. Sometimes insitu rock properties become differ compared to the data received during geotechnical investigation and hydraulic breaker chisel or machines got damaged frequently and progress would be very slow; sometimes as slow as 7-8 hours or more time required for breaking in 0.50 meter depth in rock. Apart from changing the breaking machine, it would be better to get the underground geological profile for the better understand the thickness of hard strata by geophysical testing.

The rock breaking are depends on the type of breaking machines, chisel impact rate, energy applied on rock and the rock class encountered. All these points are mentioned below.

There are four main types of Chisel available in market, given in table no 2 with the best uses.

The Hydraulic breakers can be divided into 3 types on the basis of its operational pressure, impacted rate and rated energy impact, given in table 3.

S No	Type of Chisel	Application
1	Wedge type	Excellent split power. Good penetration. Used for trenching and slope finishing
2	Moil Type	Provide high penetration through point. Used for hard rock bed and concrete breaking which required high penetration.
3	Cone Type	Used for nonabrasive and soft rock, concrete and other general used in trenching or demolition.
4	Blunt Type	Best crushing effect. Used for breaking of blasted rock, boulder, secondary rock breaking, scaling in mines & tunnels and reduction of oversize rock in crusher operations.

Table 2:*Types of Chisel and there uses.*

Figure 1:*Type of Chisel (DN Hydraulic breaker Chisel).*

Hydraulic breaker	Operational pressure (in Mega Pascal MPa)	Impact rate (blows per minutes bpm)	Rated Impact Energy (Joules)
Small breaker	<14	< 400	< 1000
Medium breaker	14-18	350-700	1000-9000
High capacity breaker	16-22	450-900	>9000

Table 3:*Types of hydraulic Breaker with operational pressure (MPa)*

The impact of operational pressure of machine depends on the type of breaking machine and the chisel. The correct selection of Chisel and hydraulic breaker can increase the rate of rock breaking and machineries life also. As for the soft rock medium or small breaker would be suitable but for hard rock, high capacity breaker would be used for effective breaking. Below table no 4 has mentioned type of civil works and breaker to be used. Small capacity breaker would be suitable for highly weathered rock and for medium to hard rock, medium capacity and high capacity breaker will be suitable and for the insitu rock breaking (Igneous and siliceous rocks), the high capacity breaker would be suitable. But it would be better to get the subsurface rock class for depute the suitable breaking machine.

S. No.	Working	Hydraulic breaker
1	Highly weathered rock	Small & medium capacity breaker
2	Boulder breaking	Medium and High capacity breaker
3	Trenching	
4	Pit building, Deep excavation	
5	Tunnel	
6	Dock excavation	
7	Insitu rock breaking	High capacity breaker
8	Foundation Pile driving (hard Rock)	

Table 4:*Civil works and preferred hydraulic breaker.*

For know the subsurface data, the geotechnical investigation would be recommended and by laboratory test on the core samples, we get the approximate idea about the subsurface rock. But the rock strength observed in geotechnical investigation is only strength of that core pieces butthe insitu rock strength may be varies depending on the Rock Mass Rating (RMR) which depends on six rock factors as proposed by Bieniawski (1976, 1989) and revised accordingly in year 1989.

The RMR parameters are given below:

1. Uniaxial compressive strength of rock material.
2. Rock Quality Designation (RQD).
3. Spacing of discontinuities.
4. Condition of discontinuities.
5. Groundwater conditions.
6. Orientation of discontinuities

On the basis of RMR classification system, the rock mass is divided into a number of structural regions and each region is further classified. The boundaries of the structural regions usually coincide with a major structural feature such as a fault or with a change in the rock type. In some cases, significant changes in discontinuity spacing or characteristics, within the same rock type, may necessitate the division of the rock mass into a number of small structural regions. The rock class based on RMR is given below:

RMR Value	Rock Class	Insitu strength in Mega Pascal (MPa)
81-100	I	>250 MPa
61-80	II	100-250 MPa
41-60	III	50-100 MPa
21-40	IV	25-50 MPa
< 20	V	<25 MPa

Table 5:*Rock Class as per RMR and Insitu strength (MPa)*

Another rock mass classification, the Geological Strength Index (GSI) system, widely used for the design and practice of tunnel, deep excavation and mining process, is a unique rock mass classification system related to the rock mass strength and the deformation parameters based on the generalized Hoek-Brown and Mohr-Coulomb failure criteria and proposed by Evert Hoek, in year 1994. The GSI can be estimated using standard chart and field observations of the rock mass blockiness and discontinuity surface conditions. The GSI value gives a numerical representation of the overall geotechnical quality of the rock mass. The GSI system concentrates on the description of two factors, rock structure and block surface conditions. The guidelines given by the GSI system are for the estimation of the peak strength parameters of jointed rock masses.

Tsiambaos G et al, 2010, had done the various case studies and observed that rocks having insitu strength is less than 70MPathen hydraulic breaker is required for loosening the rock mass with GSI value between 55-65, while ripping is successful in the rock mass with GSI value below 55. If insitu rock strength is greater than 70 MPa, blasting is required from GSI value 60 for rock structure blocky to

very block itself and sometimes blasting is required at transitional zone with GSI value is 45-60 (Fig 2&3).

Abrasiveness of rock is main factor that affect the breaking of rock. When we applied pressure for breaking the rock, it resists the applied pressure and depends on internal composition and structure of mineralsand the varies in each and every material. Many researchers worked on rock Abrasivity properties and proposed different index. But CercharAbrasion Index (CAI), proposed by Alber et al., 2014 had most widely accepted and standardized by ASTM (2010) and International Society for Rock Mechanics (ISRM), used for measure of the relative abrasivity of different rock materials on metal. Based on the measured CAILianyang Zhang (2017) has proposed the abrasivity of rock and typical value of CAI for various type of rock according to Table 6 and figure 4. One the basis of table 6 its suggested that CAI value between 3-3.9 is classified as high, CAI 4-4.9 shows Very high and CAI value higher than 4.9 is classified as extremely high. Those rock content high Siliceous materials (Sandstone, Quartzite, Gneiss and Granite) having higher CAI value and difficult to break.

Plinninger and Restner, 2008 had proposed the relationship between life of the breaking tool and abrasivity, given in table 7. The extremely high abrasive materials consume the tools life and specific pick consumption is also very high.

3. CHALLENGES DURING ROCK BREAKING IN MUMBAI

Mumbai is made up of hard to moderately weak Basalt, volcanic breccia, Shale and hard to very hard Rhyolite, Trachyte rock. Before the finalizing the type of breaking machine and chisel, project authority has review the rock class encountered during the geotechnical investigation. The volcanicbreccia rock is weak and breaks easily with medium capacity breaker also but when basalt or Rhyolite or Trachyte rock encountered, requires the high capacity breaker. As volcanic breccia, basalt, Rhyolite and Trachyte are interbedded with each other with the different thickness; site progress would be affected badly and frequently mechanical breakdown happens (breaking of Chisel). The Abrasive Index of rock plays an important role in

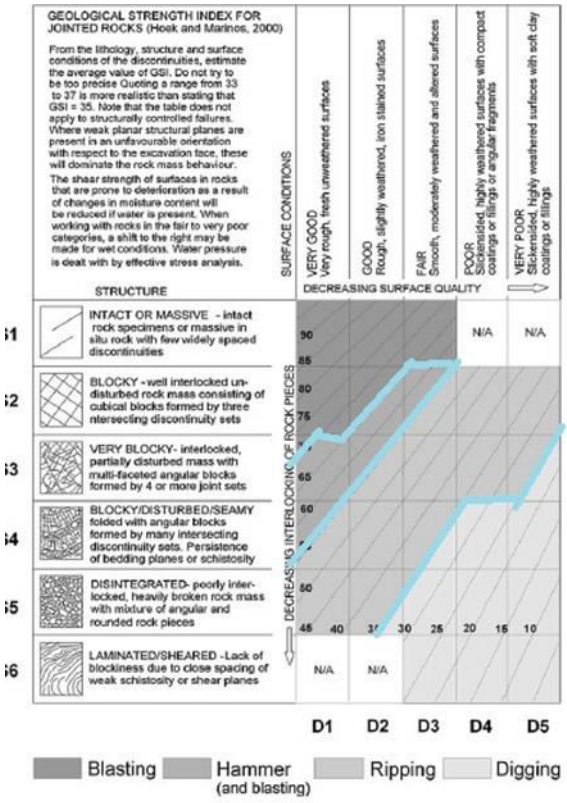

Fig 2:*Rock Class and suitable rock breaking methods (insitu strength less than 70MPa) (Tsiambaos G et al, 2010).*

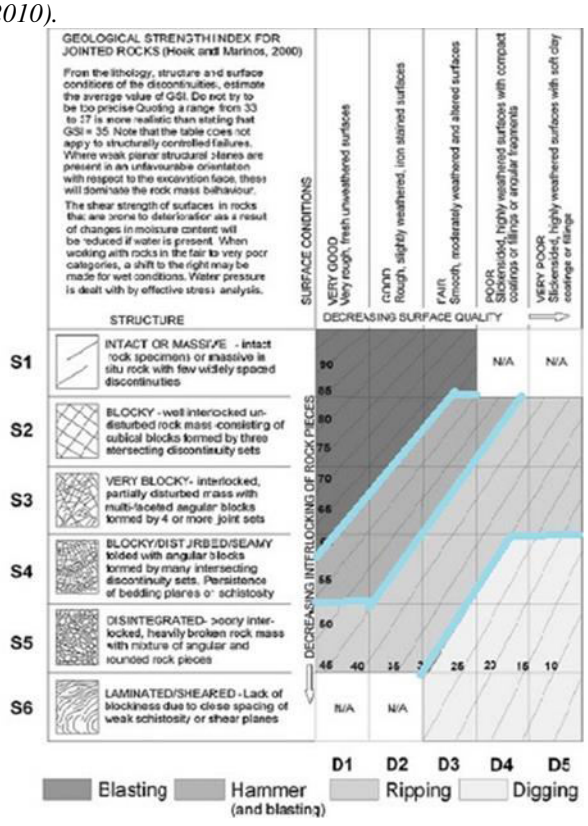

Fig 3: *Rock Class and suitable rock breaking methods (insitu strength more than 70 MPa) (Tsiambaos G et al, 2010).*

Mean CAI	Abrasively Classification
0.1–0.4	Extremely low
0.5–0.9	Very low
1.0–1.9	Low
2.0–2.9	Medium
3.0–3.9	High
4.0–4.9	Very high
≥5	Extremely high

Table 6:*Abrasivity Classification based on CAI (Lianyang Zhang , 2017; Alber et. al., 2014)*

Abrasivity	Drill bits (Ref 45 mm)	Point attack picks
	Drill bit lifetime (drilled m/bit)	Specific pick consumption (Picks/m3)
Very Low	>2000	<0.01
Low	1500-2000	0.01-0.05
Moderate	1000-1500	0.05-0.15
High	500-1000	0.15-0.30
Very High	200-500	0.30-0.50
Extremely High	<200	>0.50

Table 7:*Abrasiveness and breaking tool life (Plinninger and Restner, 2008)*

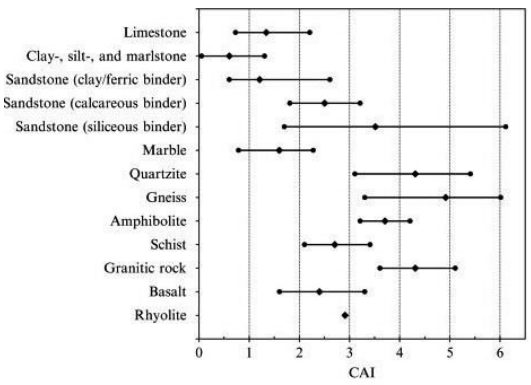

Fig 4:*Typical value of CAI for various type of rock (Lianyang Zhang, 2017,Plinninger et.al, 2003, Maloney S, 2010., Deliormanli A H , 2012)*

breaking and selection of breaking methods. Geotechnical drilling gives us site specific data, not for whole alignment data. If hard rock encountered in drilling then it would be suggested to go for geophysical test for accurate subsurface strata.

During the ground excavation at MIDC underground station (Mumbai Metro line -03 project), hard basalt (Rock class 2) encountered at shallow depth and the progress becomes 5-10% of normal progress, mechanical breakdown were happened frequently. The machine operator and his team had applied all the possible affords but unable to achieve the progress. Due to residential area, full face blasting is not allowed and finally project authorities had gone for other options of rock breaking such as controlled blasting for developing the cracks in rockfollowed by hydraulic breaker applied for rock removal. The CAI index of basal is falling in between 1.5-3.5 and greater than 3.5 for Trachyte rock. But breaking would be depend on joint spacing and in Marol Naka, Trachyte had less jointed rock and project authorities taken the controlled blasting but at Sahar Station Scissor Crossover where joint spacing were closed and due to site limitations high capacity rock breaking machine used which given slow progress but done smoothly.

Breaking of rock for the high tension tower, high rise buildings, bridges, needs sufficient depth for foundation and sometimes.It would be difficult to achieve the depth due to failure or very slow rock breaking in hard rock then other non-explosive methods such as Chemical or plasma blasting methods would be suitable for developing cracks in hard rock.

4. CONCLUSION AND SUGGESTIONS

There are many challenges in rock breaking methods in highly dense populated Mumbai urban area such as limited working space, less noise and vibration, restricted blasting permission and alternate bands of hard and soft rock. Following conclusion and suggestions recommended which will be beneficial for other rocky urban area also:

1) There is difference in rock strength observed in borehole data and insitu rock. So it is suggested to consider and ready for the geological surprises also.
2) Impact of the operational pressure of machine depends on type of breaking machine. Correct selection of Chisel and the hydraulic breaker can increase the rate of rock breaking and increase the machineries life.
3) Proper study of CAI is important as it affects the site progress and life of machineries tools.
4) The site progress is affected due to wrongly placed Chisel, so Chisel should be change as per encountered rock condition.
5) As various side limitations happened in the urban area, we should be ready with other rock breaking options for save the project time and cost.
6) Geologyplays important role in the rock breaking and an experience geologist can help in breaking of the hard rock by define the CAI during the planning of rock breaking.

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