ASSESSMENT OF POWDER FACTOR IN SURFACE BENCH BLASTING USING SCHMIDT REBOUND NUMBER OF ROCK MASS

Bhanwar S. Choudhary[1], Kumar Sonu[2]

[1]*Assistant Professor,* [2]*B.Tech Student, Department of Mining Engineering, Indian School of Mines, Dhanbad-826004,*
bhanwarschoudhary@gmail.com, kumars.kvlgj@gmail.com

Abstract

Rock mass characterisation helps in selection and optimum usage of explosive in bench blasting. There are various methods to characterize the rock mass but use of Schmidt hammer in rock characterization before blasting may be a good option. Schmidt hammer, since its simplicity and capability of instant data production, has so far been a powerful tool utilized by many researchers to predict compressive strength of rocks. In this light the present study was conducted in opencast coal mines to see the effect of Schmidt hammer rebound number or transformed compressive strength of rocks on powder factor. The correlation was found sufficiently reliable to enable the determination of optimum powder factor for surface bench blast in different rock types maintaining the required blasting results in terms of fragmentation.

Keywords: *Powder factor, Schmidt hammer, Rebound number, Rock mass, Overburden bench*

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1. INTRODUCTION

Rock mass comprises several different rock types and is affected by different degrees of fracturing in varying stress condition. The strength of rock mass decreases with the increase in frequency of joints, bedding planes, fractures, pores and fissures and the deformability of rocks depend on their orientation [1]. Therefore, properties of rock mass are governed by the parameters of rock joints and rock material, as well as boundary conditions. Presence of discontinuities can affect the blasting result up to higher degree and play a very important role in achieving required blasting results with the charged explosive. The aim of rock blasting is to achieve the optimum fragmentation without generation of any other blast induced nuisances. Nuisances may be controlled by use of proper quantity of explosive, its generated energy and finally powder factor. There is a term optimum powder factor, which may be defined as the powder factor required for the optimum fragmentation, throw, ground vibration, etc. for a specified blast condition to minimize the overall mining cost. Presently, the powder factor is established through the trial blasts. However, powder factor may be approximated using rock, blast design and explosive parameters. The powder factor is closely related with the efficient blasting [2]. Higher energy explosives, such as those containing large amounts of aluminum powder, higher density can break more rock per unit weight than lower energy explosives. Most of the commonly used explosive products have similar energy values and, thus, have similar rock breaking capabilities. Soft, low density rock requires less explosive than hard, dense rock. Large hole patterns require less explosive per volume of rock. Poor explosive distribution in larger diameter blast holes frequently results in coarser fragmentation. Massive rock with few existing planes of weakness requires a higher powder factor than a rock unit with numerous, closely spaced joints or fractures. The more free faces a blast has to break to, the lower the powder factor requirement.

To determine the powder factor several approaches have been made by different researchers. These approaches consider those rock mass properties which are the most significant parameters in a rock--explosive interaction. A review of the same has been aimed in this paper and establishes a relationship between powder factor and uniaxial compressive strength (UCS) of the rock which was obtained through rebound number.

1.1 Powder Factor

The quantity of explosive required to fragment 1 m3 or 1 tonne of rock is known as powder factor [2]. It can serve a variety of purposes, such as an indicator of hardness of the rock, or the cost of the explosives needed, or even as a guide to planning a shot. There are several possible combinations that can express the powder factor. Ashby (1981) developed an empirical relationship to describe the powder factor required for adequate blast based on the fracture frequency representing the density of fracturing and effective friction angle representing the strength of structured rock mass [3]. According to Ashby the powder factor of rock with ANFO may be determined either from the graph (Fig.1) drawn for the purpose or from the following equation—

$$\text{Powder Factor} = \frac{0.56 \times \rho \times \tan(\phi + i)}{\sqrt[3]{\text{fracture/meter}}} \text{ kg/cu.m.}$$

Where,
ϕ = Basic Friction angle,
ρ = in-situ density of rock formation,
i = Roughness angle,
(ϕ+i) = friction angle, fracture/meter represents the fracture frequency.

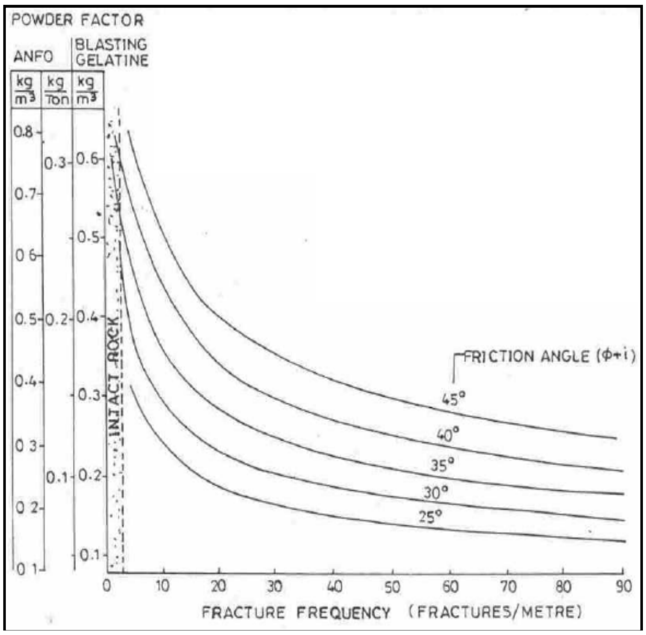

Fig.1: Empirical relation between powder factor, fracture, frequency and joint shear strength [3]

Table 1: Classification of the uniaxial compressive strength of rocks [4,5]

Rock Type	UCS(MPa)	P.F.(kg/m3)
Very Low Strength	1 - 5	0.15 -0.25
Low Strength	5 – 25	0.25-0.35
Medium Strength	25 - 30	0.4 – 0.5
High Strength	50 - 100	0.7 – 0.8
Very high strength	100 - 250	
Extremely high strength	> 250	

1.2 Schmidt Hammer

The Schmidt hammer rebound hardness test is a simple and non-destructive test originally developed in 1948 for a quick measurement of UCS [6] and later was extended to estimate the hardness and strength of rock [7,8]. The mechanism of operation is simple: a hammer released by a spring, indirectly impacts against the rock surface through a plunger and the rebound distance of the hammer is then read directly from the numerical scale or electronic display ranging from 10 to 100. In other words, the rebound distance of the hammer mass that strikes the rock through the plunger and under the force of a spring, indicates the rebound hardness. Obviously, the harder the surface, the higher the rebounds distance. Its rebound is dependent on the hardness of the rock and is measured by the test equipment suggested by ASTM C805-08. By reference to the conversion chart, the rebound value can be used to determine the compressive strength.

This test is quick, cheap and non-destructive. In rock engineering, it is widely used for its simplicity, portability and the capability of instant data production. Today varieties of Schmidt hammers are available for use, such as the models of L-type and N-type. ASTM D5873 describes the procedure for testing of rock. Presently, Schmidt hammer can be used to predict the uniaxial compressive strength of rocks, the performances of tunnel boring machines (TBM), advance speed of drilling machines as well as the evaluation of discontinuities in rock formations. The following three of widely accepted test procedures with different Schmidt hammer rebound techniques were selected and applied on rock samples

Test Procedure: 1- Poole and Farmer [9] suggested that the peak value from at least five continuous impacts at a point should be selected.

Test Procedure: 2- Hucka [10] recommended that the peak value from at least ten continuous impact at a point should be selected.

Test procedure: 3- ISRM [4] suggested that twenty rebound values from single impacts separated by at least a plunger diameter should be recorded and the upper ten values averaged.

Each testing method was repeated at least three times on any rock type and the average value was recorded as the rebound number.

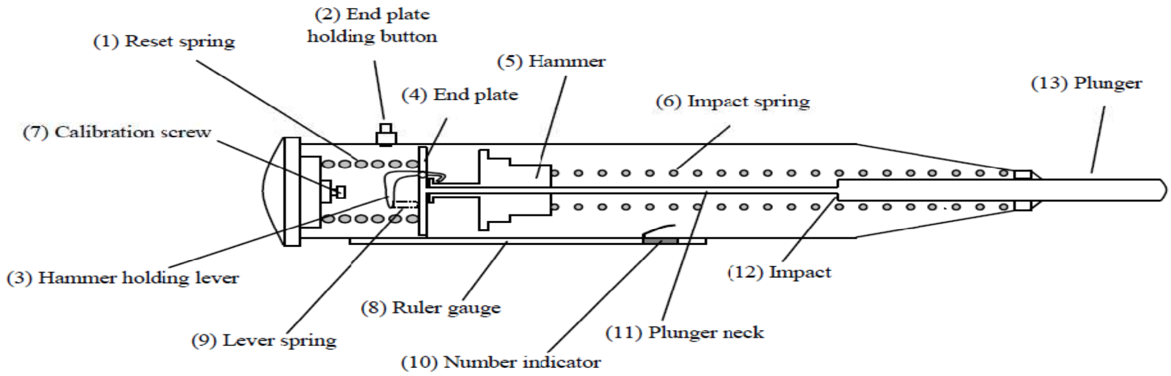

Fig.2: Details of an L type Schmidt hammer [11]

The surface texture significantly affects the rebound (R) number obtained. Tests performed on a rough-textured finish will typically result in crushing of the surface paste, resulting in a lower number. Alternately, tests performed on the same concrete that has a hard, smooth texture will typically result in a higher R-number. Therefore, it is recommended that test areas with a rough surface be ground to a uniform smoothness. This can be achieved easily with a Carborundum stone or similar abrasive stone.

The device itself should be serviced and verified annually or whenever there is a reason to doubt proper performance. Verification of proper performance of the device includes the use of a test anvil. The required dimensions and steel hardness is listed in ASTM C805. Impacting the proper test anvil with a properly functioning device will typically result in rebound numbers of 80 ± 2. If the device is believed to not be functioning properly, it is recommended to send it back to the manufacturer or experienced facility for repairs and re-verification.

2. OBJECTIVE

The objective of this study was to investigate the influence of rock mass strength on explosive requirement for surface bench blasting in different rock types, maintaining the required blasting results in terms of fragmentation

3. FIELD DESCRIPTION AND RESEARCH METHODOLOGY

To meet the stated objective, a field study was conducted on 10 working rock faces (benches) of an opencast coal mine of BCCL, a subsidiary of Coal India Ltd. (CIL). The study benches were 10m and 15m high which were subsequently excavated by 5m3 rope shovels in conjunction with 35 &50 tonne rear dump trucks. Rock strata are highly fractured. It comprises of sandstone, massive sandstone, burnt sandstone, shale, alluvium soil, sillstone. Rock uniaxial compressive strength varies from 24 MPa to 73 MPa. The general strike of formation and associated coal seam is NW-SE and the dip varied from 4 to 5 degree towards South West. Mine’s stripping ratio was approximately equal to 3. The blast holes sizes was 160mm and were blasted by the emulsion explosives.

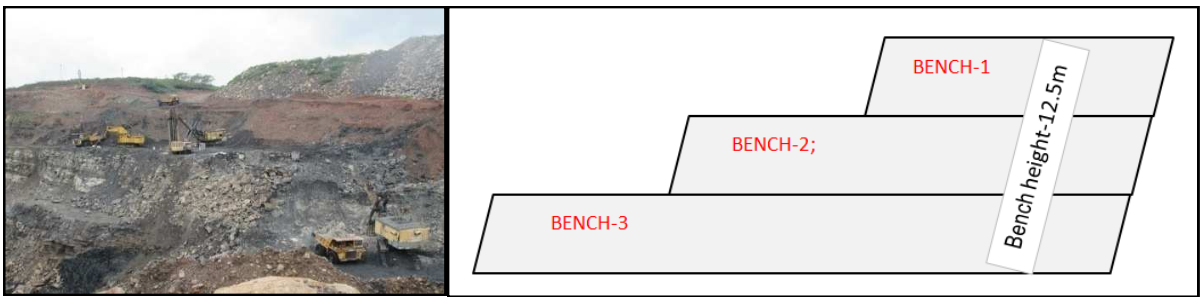

Fig.3: Study mine showing shovel benches

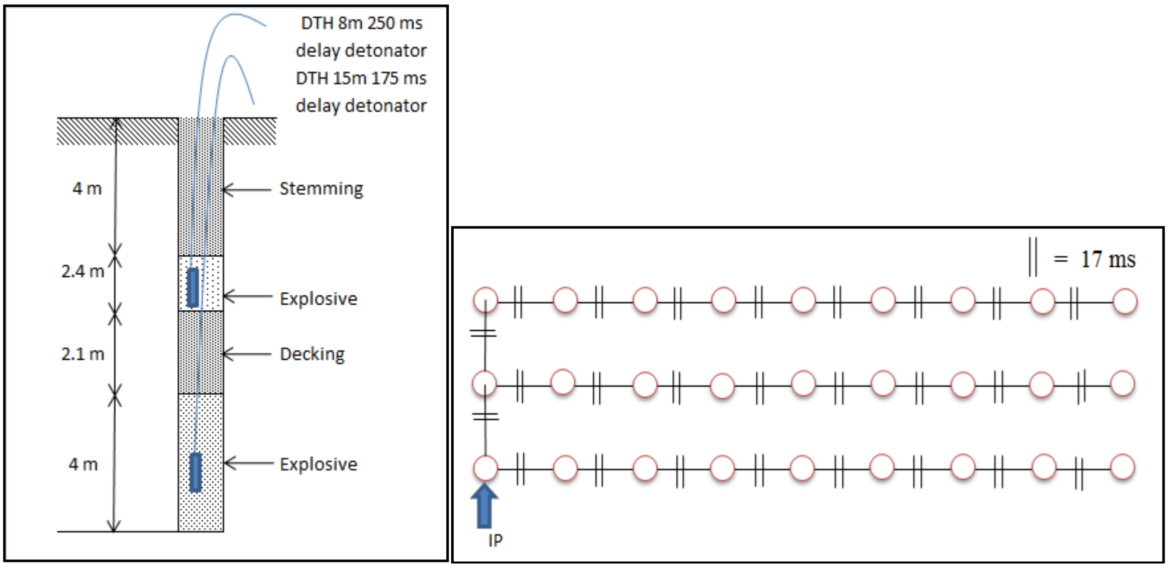

Fig.4: Blast whole section and firing sequence

The tests included the application of an NR-type Schmidt hammer to assess the hardness of the rock in as many points as practicable in the coal production areas. At each point about 20 cm by 20 cm surface of the rock was prepared by cleaning the area and performing about 50 impact in grid pattern on each bench before blasting (fig. 5). Among the numbers obtained, the mean value was considered as the Schmidt number for that bench. This procedure of performing Schmidt test was a compromise to the ISRM suggested method [12] where ten higher numbers are selected from twenty tests in the selected area. It is argued that the ISRM suggested method suffers from some shortcomings due to very selective nature of the procedure [13]. The reasoning behind this is the fact that eliminating a great number of the low numbers inevitably results in erroneous outcomes as low numbers might be the reaction of inherently weak portion of the rock and not merely the effect of test deficiencies.

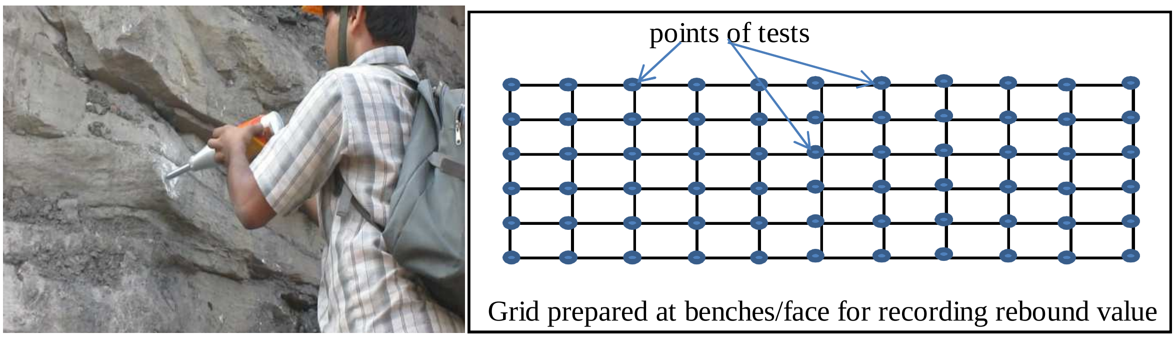

Fig.5: Rock testing with Schmidt hammer at field scale

Table 2: Rebound values and corresponding uniaxial compressive strength (UCS) obtained from conversion chart

Blast No.	Rebound Values	Angle of impact (Deg.)	Average Rebound Values	UCS, MPa
B-1	Varies between 33-46	90	39	32
B-2	Varies between 34-52	90	40	34
B-3	Varies between 34-47	90	41	36
B-4	Varies between 33-53	90	41	36

B-5	Varies between 33-51	90	40	34
B-6	Varies between 36-58	0	45	50
B-7	Varies between 36-61	0	46	52
B-8	Varies between 36-68	0	46	52
B-9	Varies between 36-60	0	47	54
B-10	Varies between 38-61	0	49	57

4. RESULTS AND DISCUSSIONS

The study was conducted for the 10 blasts. To calculate the uniaxial compressive strength (UCS) of the rock, 50 impact value in grid pattern on each bench were recorded (fig. 5). In this mine all the blasts were drilled on square drilling pattern and fired on row to row firing pattern with inter-row and inter whole delays. A representative drilling and firing pattern is given in Fig. 4. The blast holes were bottom initiated with shock tube initiation system. These data are given in table 1 and table 2.

Table 3:-Blast design parameters at overburden benches for blast B1 to B5

Parameters	B-1	B-2	B-3	B-4	B-5
Burden (m)	4	4.5	4	4.5	3.5
Spacing (m)	4.5	5	4.5	5	4
Hole depth (m)	12.5	14	12.5	14.5	15
Sub-grade (m)	1.25	1.4	1.25	1.45	0.5
No. of holes	7	12	8	14	25
Bench height (m)	11.25	12.6	11.25	14.05	14.5
Length of bench (m)	18	30	18	35	20
Width of bench (m)	8	9	8	9	17.5
Types of explosive	SME+ Primer	SME+ Booster	SME+ Primer	SME+ Booster	SME+ Booster
Explosive Quantity (kg)	1085	2200	1280	3120	4675
Primer/Booster (Kg)	8.4	3.6	9.6	4.2	7.5
Rebound Number(N)	39	40	41	41	40
UCS(MPa) of rock mass (from rebound value)	32	34	36	36	34
P.F(kg/m3)	0.77	0.65	0.80	0.91	0.91
Excavated volume of rock (m3)	1418	3402	1620	3443	5150
Fragmentation assessment by visual inspection	Good	Good	Good	Good	Not satisfactory
Excavator (Shovel) cycle time (sec)	24	25	26	25	26

Table 4:- Blast design parameters at overburden benches for blast B6 to B10

Parameters	B-6	B-7	B-8	B-9	B-10
Burden(m)	4	4.5	4	3.5	3.5
Spacing(m)	4.2	5	4.5	4	4
Hole depth(m)	12.5	14.5	14.5	14	15
Sub-grade (m)	1.25	1.45	1.45	1.4	0
No. of holes	27	16	9	14	30
Bench height (m)	11.25	13.05	13.05	12.6	15
Length of bench (m)	37.8	40	13.5	28	24
Width of bench(m)	12	9	12	7	17.5
Types of explosive	SME+ Primer	SME+ Booster	SME+ Booster	SME+ Primer	SME+ Primer
Explosive Quantity (kg)	4260	3420	1935	2660	5610

Primer/Booster (Kg)	37.6	4.8	2.7	19.6	9
Rebound Number (N)	45	46	46	47	49
UCS(MPa) of rock mass (from rebound value)	50	52	52	54	57
P.F(kg/m3)	0.84	0.73	0.92	1.08	0.89
Excavated volume of rock(m3)	5103	4698	2114	2470	5619
Fragmentation assessment by visual inspection	Good	Good	Good	Good	Good
Excavator (Shovel) cycle time (sec)	27	25	26	25	26

4.1 Relationship between Rebound Number (N) of Rock and Powder Factor (PF)

Rebound number (N) versus (vs) powder factor (PF) relationship for analyzed blasts is deduced from tables 3 and 4. The results are plotted graphically and are shown in Fig.6

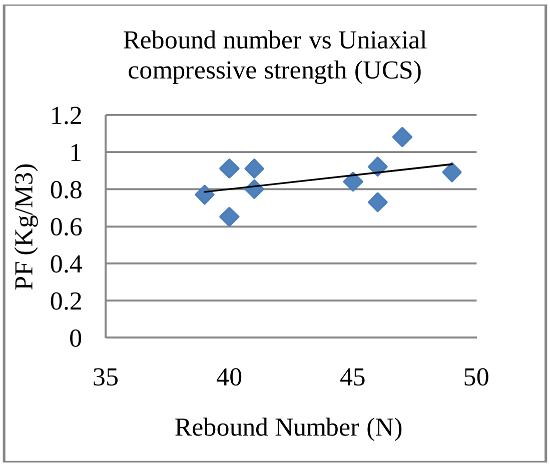

Fig.6: Rebound number (N) of rock vs Powder factor

It is evident from the figure 6 that the powder factor is increases as the Schmidt hammer rebound number is increases. Increase in rebound means rock mass is compact which requires more chemical energy to break. Therefore, more explosives were charged in the holes to get the required blasting results in terms of improved fragmentation.

4.2 Relationship between Uniaxial Compressive Strength (UCS) of Rock and Powder Factor (PF)

Uniaxial compressive strength vs PF relationship for analyzed blasts is deduced from tables 3 and 4. The results are plotted graphically and are shown in Fig.7.

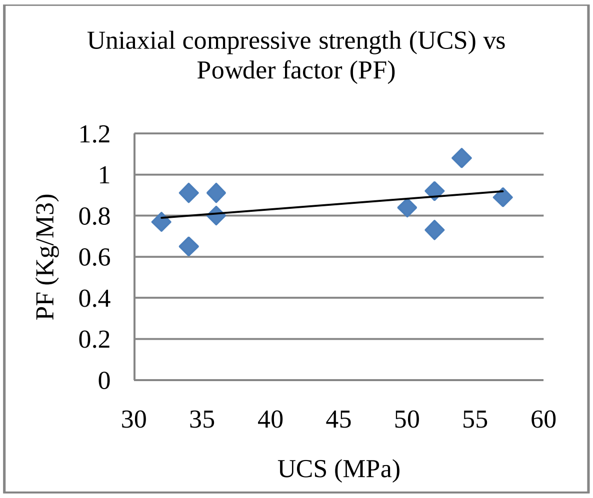

Fig.7: Uniaxial compressive strength (UCS) of rock vs Powder factor (PF)

It is evident from the figure 7 that the powder factor is increases as the uniaxial compressive strength of rock is increases. Increase in UCS means rock mass is strong which requires more explosive energy to break. Therefore, more explosives were charged in the holes to get the required blasting results in terms of improved fragmentation. It was also observed that the cycle times of the excavators were remain almost constant due to the uniformity in obtained fragment sizes in each blast.

CONCLUSIONS

Blasting is still the cheapest means of breaking rock. The suitable results of blasting can only be obtained when the rock is properly understood. It is well known that rock nature changes from bench to bench and mines to mines. Therefore, rock mass characterization for each bench is essential to optimise the blasting results. Rock mass characterisation can also help in selection and optimum usage of explosive to improve the overall economy of the project. The use of Schmidt hammer in rock characterising before blasting may be a good option.

In this study it was observed that to maintain the rock fragmentation for best utilization of excavators the quantity of explosive for breaking the same volume of rock or powder factor is increases as the rebound value or uniaxial compressive strength is increases.

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BIOGRAPHIES

Dr. B.S. Choudhary is working as Assistant Professor in the Department of Mining Engineering, ISM, Dhanbad since 2010. He has more than 6 years industrial experience in surface and underground metal mining. His areas of expertise include mine planning, drilling and blasting technology, underground metal mining and underground space technology. He has a PhD in Mining Engineering.

Kumar Sonu is student in the Department of Mining Engineering, Indian School of Mines, Dhanbad. He took admission by qualifying IIT Joint Entrance Examination in the year-2011.