Powder Technology 263 (2014) 66–73

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Assessment of firing patterns on moderately strong and weak sandstone cover rocks in a surface mine

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ARTICLE INFO

Article history:
Received 13 August 2013
Received in revised form 11 February 2014
Accepted 11 April 2014
Available online 29 April 2014

Keywords:
Effective spacing
Effective burden
Firing pattern
Fragment size
Excavator performance
Powder factor

ABSTRACT

The present paper highlights the application of three different types of firing pattern on two different types of sandstone overburden benches of a large coal mine in India. The study reveals that firing pattern influences the effective spacing to burden ratio at the time of detonation. By changing the firing pattern, effective burden (B_e) changes and the ratio of effective spacing (S_e) to effective burden (B_e) during the firing is also subject to change in comparison to drilled spacing to burden ratio (S/B). Hence, the S_e/B_e ratio vis-à-vis firing pattern must be used to design the blast rounds. The results have been derived on the digital image analysis based fragment size characterization, excavator performance and evaluation of powder factor values on blasted muck piles. Skewed V-type firing yielded the best results in comparison to straight V-type and normally practiced diagonal firing pattern on the moderately strong sandstone benches, whereas, the existing diagonal firing pattern appears to be satisfactory on weak (weathered and gritty) sandstone benches.

1. Introduction

Proper fragmentation is the primary objective of any successful blasting program [1]. To this end, it is consequential to state that by the suitable application of partly and fully controllable blasting parameters, the blast outcome energy can be deployed more efficiently for improving the fracturing, fragmentation, piling and overall economics of rock blasting. Besides, the environmental side effects of the blast are also minimized. In this light, the firing pattern decides the movement and direction of rock by creating free face for subsequent blast holes/rows. Extensive work has been reported on different types of firing pattern (row to row, diagonal, V-type and skewed V-type) [2]. The researchers suggest that each firing pattern has its own application. Proper use of pattern vis-à-vis the blast requirements can provide optimal blast performance in terms of fragmentation, throw, wall control etc. Firing pattern influences the effective spacing to burden ratio at the time of detonation. By changing it, effective burden (Be) changes and the ratio of effective spacing (Se) to burden (Be) during the firing is also subject to change in comparison to drilled spacing to burden ratio (S/B) [3].

In this light, the present paper aims at critically investigating the firing patterns on moderately hard as well as weak and friable sandstone overburden rocks of a large surface coal mine of India.

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http://dx.doi.org/10.1016/j.powtec.2014.04.049

2. Case description and research objectives

A number of blasts were conducted in the surface coal mine of the Northern Coalfields Ltd. (NCL), Singrauli, India, for evaluating and improving the fragmentation on the sandstone overburden benches. The study mine, situated on a high plateau ranging from 300 to 500 m above the MSL, is the largest coal mine of India in terms of total annual excavation volume. The mine falls in the Singrauli coalfields where the rocks are of Gondwana formation having coal bearing Barakars within it. The strike of the deposit is along E–W with broad swings and dipping gently (1–3°) in northerly direction.

A representative borehole section of the mine (Fig. 1) depicts the relative disposition of seams and partings. The parting between the seams and above the seam has been divided into number of benches. Although the drill log shows ten benches in the mine, the west section of the mine (where the case study was conducted) consisted of VII bench as the topmost bench. The dragline bench, as shown in the borehole section, over the Turra seam was worked by 15/90 and 24/96 draglines in horizontal tandem. The height of this bench ranged from 32 to 34 m, at certain places the height reached up to 40–45 m. The rest of the over and inter-burden was worked in 14–22 m high benches by use of 10 m^3 electric, rope shovel in conjunction with 85/120 ton rear dump trucks. The extraction of coal seams was also done by shovel–truck combination. Rope shovels 4.6 m^3 and 10 m^3 were deployed in conjunction with 50/85 ton rear dump trucks for extraction of coal from 13 to 15 m high coal benches. The explosive used in the mines was straight emulsion doped with 12–20% ammonium nitrate prills on site.

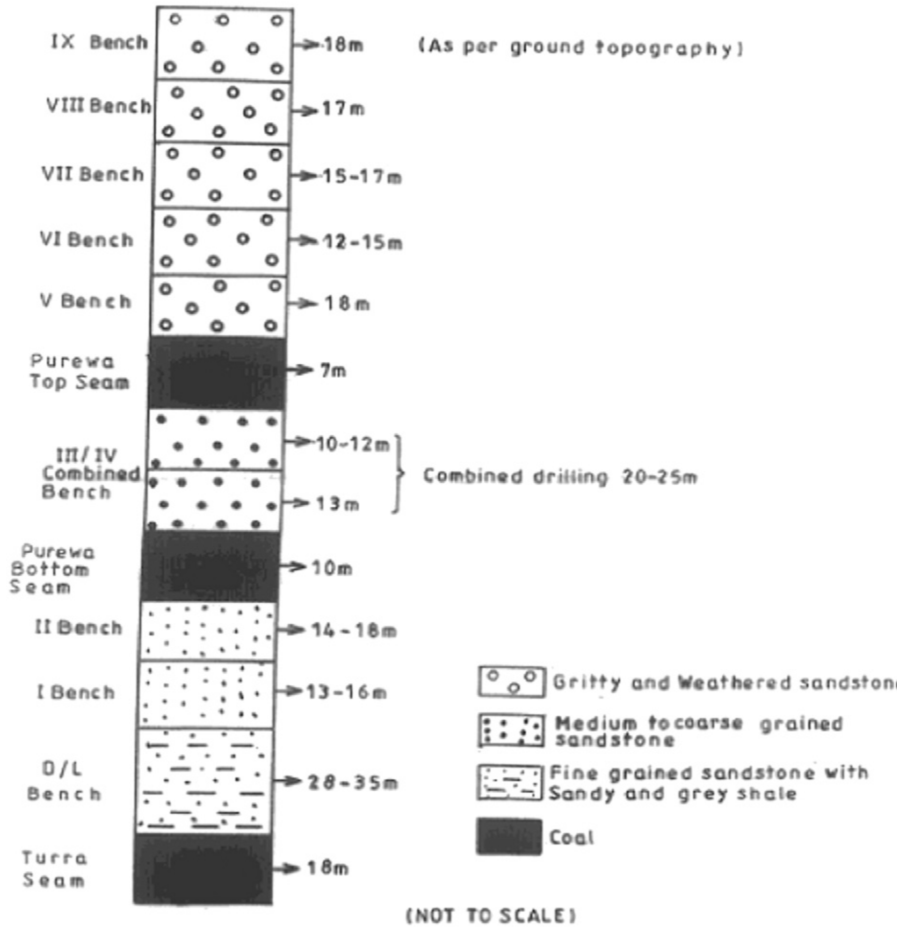

Fig. 1. Borehole section.

Table 1
Strength parameters of sandstone benches under study.

Nomenclature of the benches	Nature of rock	Strength ranges in MPa		
		Compressive strength	Tensile strength	Shear strength
Shovel bench no. II	Fine grained sandstone	12.5–20	0.8–2.0	1–7
Shovel bench no. VI	Gritty and weathered sandstone	4–10	0.5–1.5	0.7–1.95
Shovel bench no. VII	Gritty and weathered sandstone	4–10	0.5–1.5	0.7–1.95

The fragmentation studies presented in the paper were conducted on II bench, VI bench and VII bench of the mine. The strength properties of the rocks for these study sandstone benches are given in Table 1.

On the shovel bench II three blasts, as normally practiced by the management, were closely monitored. All these blasts were fired on the straight diagonal firing pattern with almost identical blast design parameters. Consequent to the evaluation of diagonally fired blast performance, V-type firing and skewed V-type firing patterns were then attempted for improved results on this bench. On the shovel benches VI and VII four diagonally fired blasts were conducted, documented and evaluated. Representative drawings of the firing patterns (diagonal type, straight V-type and skewed V-type), for four different blasts, are illustrated in Figs. 2–5 respectively. Inter-row delay sequence is self-explanatory in the Figs. 2–5, which also reveals the absence of hole-to-hole delays.

A scrutiny of Table 1 clearly reveals that the benches VI and VII are almost similar in nature, being very weak due to weathered and gritty sandstone. Nevertheless, at the top of the VI bench 3–5 m thick band of hard ferruginous sandstone with high compressive strength of about 63 MPa was observed.

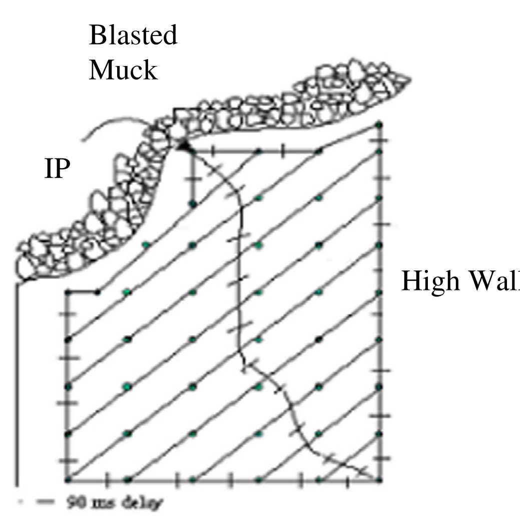

Fig. 2. Diagonal firing pattern for week sandstone.