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EFFECT OF BLAST INDUCED ROCK FRAGMENTATION AND MUCKPILE ANGLE ON EXCAVATOR PERFORMANCE IN SURFACE MINES

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ABSTRACT

Purpose. A fit excavator in a surface mine gives a trouble free production. To maintain the condition and safety of an excavator, proper sizes of rock fragmentation and muckpile parameters are crucial besides its maintenance. Optimum size of fragmentation and muckpile shape parameters increases the production hours of an excavator so study was conducted to investigate the effect of blast induced rock fragmentation and muckpile angle on excavator performance.

Methods. The study was conducted in two different surface coal mines namely A and B of India. Drilling, blasting and shovel-Dumper combination were used in mines for overburden removal and as well as coal production. The trial blasts were conducted in surface mines to investigate the effect of rock fragmentation and muckpile angle on excavator performance.

Findings. The results obtained from this study indicate that the fragmentation size should be optimum with respect to bucket size of the excavator so that the excavator can load more material in less time. Also, muckpile should be loose, with proper muckpile angle. The results of this study show that the cycle time of the excavator is minimum at fragment size of 0.30 – 0.45 and 0.15 – 0.20 m for mine A and B respectively and muckpile angle in the range of 52 – 58 degree for both mine.

Originality. This study is a field based study and the results are based on the data collected and analyzed. Similar type of studies have been done by few researchers though to improve the productivity of the mine for different conditions. The results are condition, machinery, method and mine specific.

Practical implications. This study was conducted for surface coal mines but it is applicable for limestone and stone quarry also.

Keywords: *surface mine, mean fragmentation size, muckpile angle, explosive, blasting, excavator*

1. INTRODUCTION

Drilling and blasting is an important rock excavation operation in mines. The fragmented rock generated by the drilling and blasting process affects not only the local productivity and unit costs of the mining it even influences the performance of the subsequent operations such as (McGill & Freadrich, 1994; Doktan, 2001; Singh & Yalçın, 2002; Khomenko, Kononenko, & Myronova, 2013). Marton and Crookes (2000) reported the reduction in productivity level of face excavator due to large and blocky material. Jhanwar, Chakraborty, Ani Reddy, & Jethwa (1999) and Chakraborty et al. (2004) reported the idle running time of face shovels for preparation of blasted muck to be also related to the degree of fragmentation. It was suggested on the basis of field trials, that shovel operation and productivity monitoring may be expressed in terms of equipment operating and maintenance costs, which, in turn, may be related as a function of blast fragmentation (Mackenzie, 1967; Michaud & Blanchet, 1996; Singh, Baijal, & Fasihuddin, 1999; Doktan, 2001). Brunton, Thornton, Hodson, & Sprott (2003) reported that by reducing the excavator dig time and increasing bucket payload, significant improvements can be made in both productivity and unit operations cost. Simulation work reported in the literature by them indicates that a 20% improvement in digging time may result in only a three per cent improvement in load and haul productivity and unit cost. At the same time, a 10% improvement in bucket payload will directly translate to a 10% improvement in load and haul productivity and unit cost.

However, age and specifications of excavating machines and the skills of the operators are the factors which need consideration (Aler, Du Mouza, & Arnould, 1996). Besides this, the lost time that is not directly related to the condition of muckpile, such as waiting for transport units, machine breakdowns, clean-up operations, excavator marching etc. have to be also duly considered (Singh, Baijal, & Fasihuddin, 1999). Hanspal, Scoble, & Lizotte (1995) reviewed the physical, chemical and mechanical features of muckpile and reported the field studies of muckpile and loading system performance. The field analysis showed the control exerted by the size distribution and compaction on loading machine performance. Frimpong, Kabongo, & Davies (1996) investigated the effect of powder factor on dragline productivity. It was observed that increasing powder factor enhances fragmentation and hence dragline productivity, but increasing energy output beyond an optimum region results in reduced bucket fill factor. Rzhevsky (1995) related the optimum fragmentation with respect to excavator bucket size as follows:

$$X_{op} = (0.15 - 0.2) \cdot B_c^{\frac{1}{3}}, \qquad (1)$$

where:

X_{op} – optimum fragment size, m;

B_c – nominal bucket capacity, m^3.

Fragmentation of rockmass dependents upon a series of factors that may include rock properties, geology, topography especially free surface conditions, explosive characteristics and finally design of the blast. The efficiency of an excavator is directly related to:

– fragmentation size: cycle time is directly depends on the fragmentation size. If the fragmentation size is too small then cycle time will be affected by the diggability and if the fragmentation size are too large then the loading time will be affected;

– mine parameters: bench height, bench width, weather condition, underground water, haul distance (waste and mineral), ground conditions, job efficiency factor are some example of mine parameters;

– type of excavator: bucket capacity, vehicle weight, payload, digging height, ground pressure, power, bucket cycle time, speed, bucket fill factor, operating life, truck capacity etc. are the example of equipment criteria;

– geological and geotechnical factors: type of formation, mineral density, waste density, bedding thickness, uniaxial compressive strength, swell factor, elasticity modulus, blasting condition and average size distribution after blasting are the example of geological and geotechnical factors;

– skilled person: excavator cycle time also affected by the operator of the excavator. The excavator should be operated by a skilled person, otherwise it may affect the cycle time of the excavator. The operator should also be mentally and physically fit for day to day excavation operation;

– digging and hauling: after blasting, the digging operation should be done in such a way that the rock fragments not only fits into the bucket of the excavator but also it should reduce the bucket loading time. If the size of the fragments in the muckpile is larger than the bucket, it will not only reduce the productivity but also increase secondary blasting cost and equipment maintenance cost;

– bucket fill factor: it is a function of average material size, bucket size and the effective digging force. For the same average material size and the effective digging force, the bucket fill factor will increase with the increase of bucket size. Also, for the same bucket size and the effective digging force, the bucket fill factor will increase with the decrease of average material size;

– swell factor: it is the ratio of in-situ volume to the fragmented volume for same mass of the material. Mathematically it may be expressed as 100/(100 + % swell). Percentage swell is a function of degree of fragmentation and. As the degree of fragmentation increases, the percentage swell also increases limited to a maximum value defined by the material characteristics;

– swing factor: it is a cycle time correction factor to take into account the angle of swing that the shovel bucket has to make for loading the dumper. The swing angles and the corresponding swing factor values as given in Table 1.

Table 1. Swing factor value at respective angle of swing (degree) (Das, 2008)

Angle of swing (deg.)	45	60	75	90	120	150	180
Swing factor	0.84	0.90	0.95	1.00	1.10	1.20	1.30

Muckpile shape parameters are throw, drop and lateral spreading (Fig. 1). Throw, drop and lateral spreading of the muckpile are essential parameters for effective excavator operation and looseness of the blasted muck (Choudhary & Rai, 2013). Greater throw and drop spreads the muckpile laterally, which largely facilitates the digging of the muck by the pay loaders (Choudhary, 2011). Lopez Jimeno, Lopez Jimeno, & Carcedo (1995) described the selection of equipment on the basis of muckpile parameters. Case-I shows large clean up area, low productivity with rope shovel, high productivity with wheel loader and very safe for equipment operation. Case-II shows minimal clean up area, high productivity with rope shovel, and low productivity with wheel loader and dangerous for equipment operation. Case-III shows low clean up area, acceptable productivity and safe for equipment operation. The cases are shown in Figure 2.

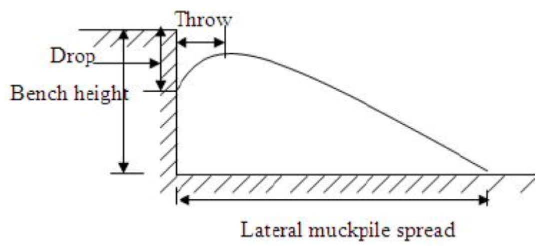


Figure 1. Parameters of muckpile shape

Reliable evaluation of fragmentation is a critical mining problem (Esen & Bilgin, 2000). The digability and the handling of ore by an excavator directly depend upon the fragmentation size of the blasted material (Choudhary & Rai, 2013). The digging time is only a minor fraction in the overall truck cycle time and diggability of an excavator depends upon the muckpile shape (Hawkes, Spathis, & Sengstock, 1995).

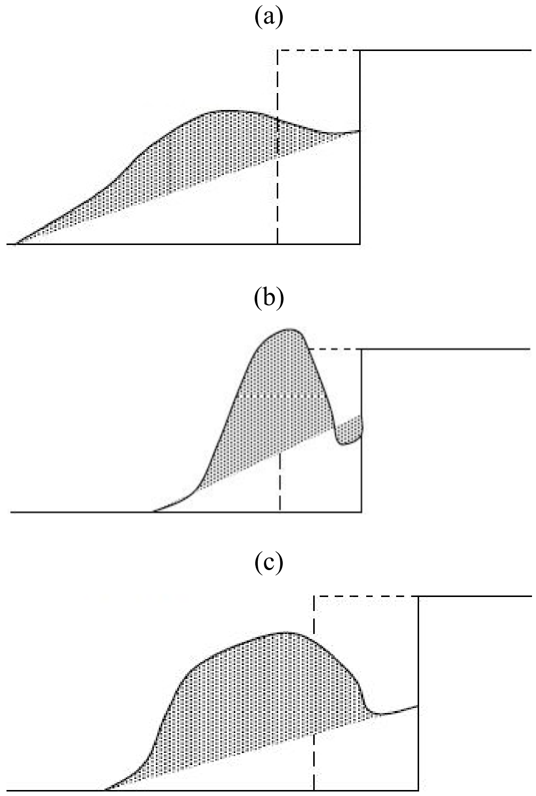


Figure 2. Different muckpile profile after blasting: (a) Case-I; (b) Case-II; (c) Case-III

Singh, Yalçın, Glogger, & Narendrula (2003) investigated the significance of size distribution in mucking operations by determining different scooping parameters. According to their study both the mean particle size and index of uniformity play a significant role in muck scooping operations. Higher scooping rates and lower energy consumptions were observed in muckpile with a smaller mean particle size and flatter size distribution curve.

Singh and Narendrula (2006) conducted a study to examine the effects of the looseness, angle of repose, size distribution and moisture content of the blasted material on the production rate of a wheel loader. They have found that looseness in the muck increases with the increase in the value of the mean particle size and index of uniformity of the fragmented rock. It was concluded that the bucket fill factor and rate of production decreased with increasing values of mean particle size and index of uniformity.

2. OBJECTIVES OF THE STUDY

The main objective of this study is to investigate the influence of blast induced rock fragmentation and muckpile angle on excavator performance in surface mines.

3. CASE DESCRIPTION

To accomplish the said objective field studies and field data acquisition were conducted at two different surface mines.

Mine A. It is a 3.4 million tonne coal producing surface mine. Drilling, blasting and shovel-Dumper combination are used in mine for overburden removal and as well as coal production. The density of sandstone was 2.5 gm/cc. The compressive strength of the sandstone was about 100 – 180 N/mm^2. The explosive used in blast hole was Site Mixed Emulsion (SME) with cast booster of 100 gm each and shock tube initiation system with delay sequence of 17 and 25 ms. All blast holes were drilled in square pattern with 256 mm diameter. The blasted material was loaded by 10 m^3 bucket capacity electric rope shovel on 85 tonne dumper.

Mine B. It is a 3.7 lakh tonne coal producing surface mine. Drilling, blasting and shovel-Dumper combination are used in mine for overburden removal and as well as coal production. The density of sandstone was 2.5 gm/cc. The overburden bench consists of massive sandstone. The compressive strength of the sandstone overburden was about 12.00 to 23.28 MPa and its tensile strength was about 0.45 to 1.82 MPa. The explosive used in blast hole was SME with cast booster of 100 gm each and shock tube initiation system with delay sequence of 17 and 25/42 ms. All blast holes were drilled in square pattern with 160 mm diameter. The blasted material was loaded by 2.5, 2.8 and 4.0 m^3 diesel operated hydraulic backhoe on 25 tonne dumper.

The details of drilling and firing pattern for both the mines are almost similar shown in Figures 3 and 4.

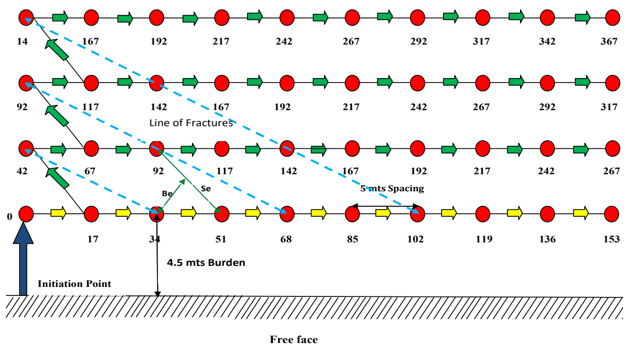


Figure 3. Firing pattern with delay sequence

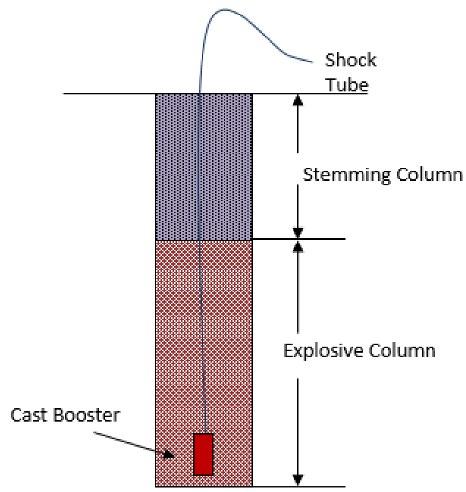


Figure 4. Blast hole charging pattern

4. RESEARCH METHODOLOGY

In order to fulfill the research objective many full scale blasts were conducted under the similar strata (same bench) and explosive (SME) with shock tube initiation system.

Muckpile angle assessment. After blasting, before excavation operation starts, a side view image of the entire muckpile was taken along with a reference scale and maintaining the horizontal line for the camera (Fig. 5) to determine the muckpile angle. Those side view images for the blasts were imported into the Fragalyst® software for angle measurement. While other muckpile shape parameters, lateral spread, throw and drop for each blast were measured immediately after the blast using tape measurements.

Figure 5. Muckpile shape parameters

Excavator cycle time. Several researchers (Singh, Baijal, & Fasihuddin, 1999; Marton and Crookes, 2000; Kanchibotla, 2001) have indicated the relationship between diggability of loading machines with respect to degree of fragmentation in the muckpile. Hence, the cycle time of the excavator excavating the muckpile was categorically recorded throughout the excavation history such that realistic cycle time data could be taken as an index to the blast performance. Precise stopwatch was for this purpose.

Fragmentation assessment. Digital image analysis technique was used in the present study by the capturing of scaled digital images of the blasted muck pile to quantify the fragment size and its distribution. In order to cover the entire muck pile, the images were captured at a period interval of 1-hour throughout the excavation history of the muck pile, giving due cognizance to the recommendations made by several researchers (Maerz, Franklin, Rothenburg, & Coursen, 1987). The captured images were analyzed by Fragalyst™, a commercial, state-of-art image analysis software. The fragmentation analysis is shown in Figure 6.

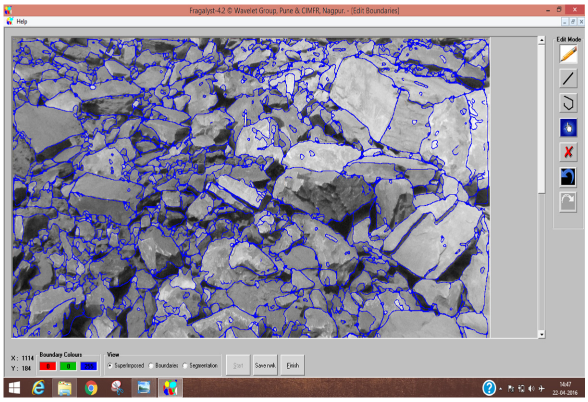
5. RESULTS AND DISCUSSIONS

The study was conducted at two different surface mines to investigate the influence of blast induced rock fragmentation and muckpile angle on excavator performance. The images were captured during the excavation process for evaluation of fragmentation for each blast. The field observations and the fragmentation results are tabulated in Table 2 and 3.

5.1. Relation between mean fragment size and cycle time of the excavator

The mean fragments size vs excavator cycle time relationships (Figs. 7 and 8) for analyzed blast round for both the mines have been deduced from Tables 2 to 3.

(a)



(b)

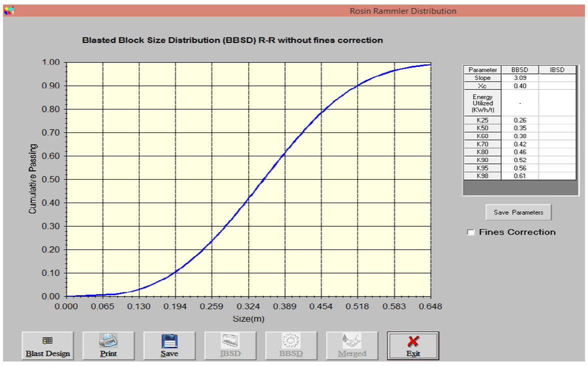


Figure 6. Fragmentation analysis

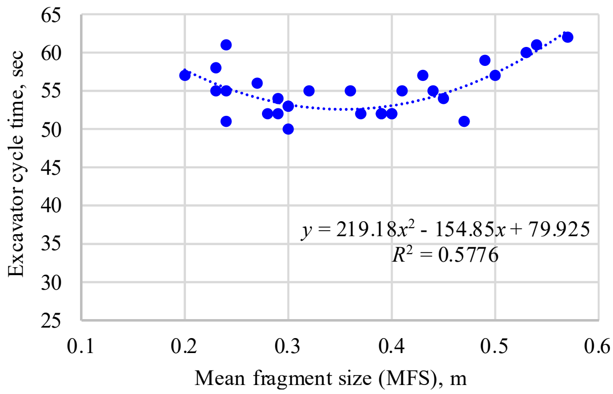


Figure 7. Relation between MFS and excavator cycle time of mine A

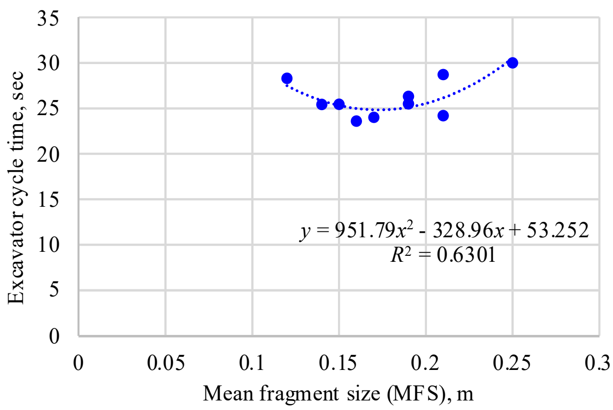


Figure 8. Relation between MFS and excavator cycle time of mine B

Table 2. Details of blast data (observed and analysed) for Mine A

No.	Blasting parameters	AB-1	AB-2	AB-3	AB-4	AB-5	AB-6
1	Hole diameter, mm	256	256	256	256	256	256
2	Average hole depth, mts	12	12	13	13	13.5	14
3	Burden, mts	4.5	4.5	4.5	4.5	4.5	4.5
4	Spacing, mts	5	5	5	5	5	5
5	Stemming, mts	5.6	5.6	5.8	5.7	5.8	6.1
6	No. of holes	30	35	35	37	40	42
7	No. of rows	4	5	5	5	5	6
8	Explosive per hole, kg	384	413	318	446	437	474
9	Total explosive, kg	11520	14440	11120	16506	17480	19908
10	Delay, ms	17/25	17/25	17/25	17/25	17/25	17/25
12	Muckpile angle, deg.	58.9	48.75	48.35	52.3	56.3	58.41
13	Avg. cycle time, sec	56.6	53	55.2	53.6	53.2	58
14	Avg. mean fragment size, m	0.336	0.292	0.380	0.370	0.350	0.446

Fragmentation and cycle time results

Blast	K_{25}, mts	K_{50}, mts	K_{98}, mts	Cycle time, sec
BLAST 1	0.34	0.53	1.27	60
	0.09	0.24	1.21	61
	0.08	0.23	1.86	58
	0.12	0.29	1.61	52
	0.25	0.39	0.98	52
BLAST 2	0.06	0.20	1.73	57
	0.2	0.39	1.43	52
	0.15	0.3	1.09	50
	0.20	0.28	0.48	52
	0.22	0.29	0.50	54
BLAST 3	0.36	0.57	1.48	62
	0.16	0.32	1.29	55
	0.15	0.30	1.17	53
	0.10	0.24	1.52	55
	0.31	0.47	1.05	51
BLAST 4	0.12	0.24	1.10	51
	0.23	0.41	1.35	55
	0.23	0.40	1.28	52
	0.25	0.44	1.32	55
	0.20	0.36	1.40	55
BLAST 5	0.18	0.37	1.31	52
	0.10	0.23	1.30	55
	0.28	0.45	1.12	54
	0.25	0.40	1.07	52
	0.14	0.30	1.35	53
BLAST 6	0.33	0.49	1.16	59
	0.32	0.50	1.15	57
	0.11	0.27	1.87	56
	0.25	0.43	1.20	57
	0.34	0.54	1.28	61

It is evident from the Figures 7 and 8 that as the mean fragment size increases, the excavator cycle time reduces up to a certain mean fragment size (K_{50}), beyond which it increase with K_{50} in both the mines irrespective of the excavator. For mine A the fragment sizes (K_{25} to K_{98}) varies from 0.06 to 1.87 m and cycle time of shovel from 50 to 62 sec. The cycle time of the excavator is minimum at fragment size of 0.30 – 0.45 m (from Rzhevsky formula the OFS for the 10 m^3 bucket size is 0.40 m). For mine B fragment sizes (K_{25} to K_{98}) varies from 0.08 to 0.71 m and cycle time of shovel from 24 to 30 sec. The cycle time of the excavator is minimum at fragment size of 0.15 – 0.20 m (from Rzhevsky formula the OFS for the 2.4/4 m^3 bucket size is 0.20 – 0.23 m). Lower size of fragments increases the digging time of excavator because at lower size more fines are generated which work as binding of the blasted muck as well as increase in volume of the material unduly. Similarly, separation and handling of large size fragments increases the cycle time of excavator. During the study it was also observed that improper muckpile, excessive congested broken material also effects the cycle time.

5.2. Relation between average cycle time and muckpile angle

The muckpile angle vs excavator cycle time relationships (Figs. 9 and 10) for analyzed blast round for both the mines have been deduced from Tables 2 to 3.

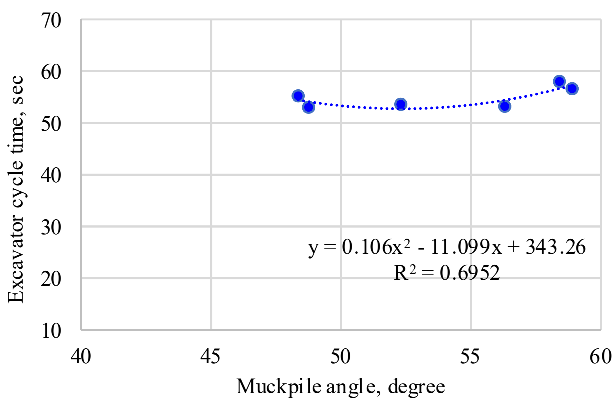


Figure 9. Relation between muckpile angle and average cycle time of excavator for mine A

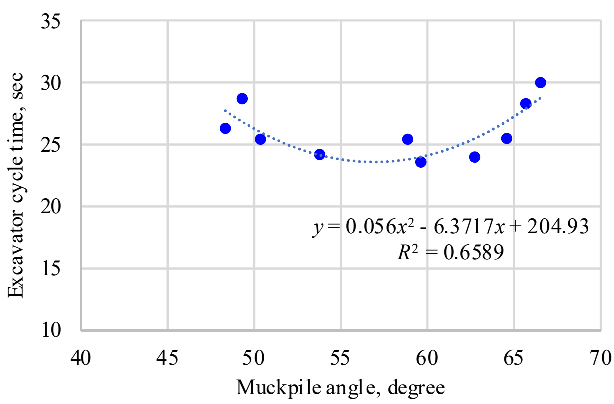


Figure 10. Relation between muckpile angle and average cycle time of excavator for mine B

It is evident from the Figures 9 and 10 that as the muckpile angle increases, the excavator cycle time reduces up to a certain muckpile angle, beyond which it increase with muckpile angle in both the mines irrespective of the excavator. The excavator cycle time is optimum when the muckpile angle is in the range of 52 – 58 degree.

Table 3. Details of blast data (observed and analysed) for mine B

No.	Blasting parameters	BB-1	BB-2	BB-3	BB-4	BB-5	BB-6	BB-7	BB-8	BB-9	BB-10
1	Hole diameter, mm	160	160	160	160	160	160	160	160	160	160
2	Average hole depth, mts	5.8	6.0	5.8	5.7	5.2	5.4	5.9	5.6	5.8	6.1
3	Burden, mts	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
4	Spacing, mts	3	3	3	3	3	3	3	3	3	3
5	Stemming, mts	4.6	4.5	4.0	4.1	4.4	4.4	4.1	4.0	4.2	4.9
6	No. of holes	50	35	47	47	35	47	45	40	30	40
7	No. of rows	3	2	3	3	2	3	3	2	3	3
8	Explosive per hole, kg	29	30	44	39	38	18	44	39	39	29
9	Total explosive, kg	1470	1050	2072	1842	1320	851	1984	1568	1176	1176
10	Delay, ms	25/92	17/42	17/42	17/42	17/42	25/92	17/42	17/42	25/92	17/42
11	Avg. cycle time, sec	25.4	28.7	25.5	23.6	28.3	30.0	24.2	24.0	26.3	25.4
12	Muckpile angle, deg.	50.35	49.30	64.58	59.62	65.68	66.53	53.77	62.73	48.33	58.85
	Fragmentation, m										
13	Lower, K_{25}	0.08	0.10	0.10	0.10	0.10	0.15	0.09	0.09	0.10	0.09
	Mean, K_{50}	0.14	0.21	0.19	0.16	0.12	0.25	0.21	0.17	0.19	0.15
	Higher, K_{98}	0.36	0.71	0.62	0.47	0.46	0.69	0.42	0.48	0.55	0.51

In case of lower muckpile angle there was more spread of the muckpile which took more time to fill the bucket while in case of higher muckpile angle the compaction of muck, rolling of broken rock created more time to fill the bucket.

6. CONCLUSIONS

From the study it is concluded that:

1. The excavator cycle time is effected by the blast induced fragmentation. The fragmentation size should be optimum with respect to bucket size of the excavator so that the excavator can load more material in less time. In this study the cycle time of the excavator is minimum at fragment size of 0.30 – 0.45 and 0.15 – 0.20 m for mine A and mine B respectively.

2. Muckpile shape parameters effect the excavator cycle time. In this study muckpile angle was considered and found that the excavator cycle time is optimum when the muckpile angle is in the range of 52 – 58 degree.

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REFERENCES

Aler, J., Du Mouza, J., & Arnould, M. (1996). Evaluation of blast fragmentation efficiency and its prediction by multivariate analysis procedures. *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*, *33*(2), 189-196. https://doi.org/10.1016/0148-9062(95)00055-0

Brunton, I., Thornton, D., Hodson, R., & Sprott, D. (2003). Impact of blast fragmentation on hydraulic excavator dig time. *Fifth Large Open Pit Mining Conference*, 39-48.

Chakraborty, A., Raina, A., Ramulu, M., Choudhury, P., Haldar, A., Sahu, P., & Bandopadhyay, C. (2004). Parametric study to develop guidelines for blast fragmentation improvement in jointed and massive formations. *Engineering Geology*, *73*(1-2), 105-116. https://doi.org/10.1016/j.enggeo.2003.12.003

Choudhary, B.S. (2011). *Assessment of fragmentation in limestone quarry blasts*. Ph.D. Thesis. Varanasi, India: Banaras Hindu University.

Choudhary, B.S., & Rai, P. (2013). Stemming plug and its effect on fragmentation and muckpile shape parameters. *International Journal of Mining and Mineral Engineering*, *4*(4), 296-311. https://doi.org/10.1504/ijmme.2013.056854

Das, S.K. (2008). *Surface mining technology*. Dhanbad, India: Lovely Prakashan.

Doktan, M. (2001). Impact of blast fragmentation on truck shovel fleet performance. *Proceedings of the 17th International Mining Congress and Exhibition of Turkey*, 375-379.

Esen, S., & Bilgin, H.A. (2000). Comparing systems – Validation of Fragscan, WipFrag, and Split. *Proceedings of the Fragblast-5 Workshop on Measurement of Blast Fragmentation*, 151-155.

Frimpong, M., Kabongo, K., & Davies, C. (1996). Diggability in a measure of dragline effectiveness and productivity. *Proceedings of the 22nd Annual Conference on Explosives and Blasting Techniques*, 95-104.

Hanspal, S., Scoble, M., & Lizotte, Y. (1995). Anatomy of a blast muckpile and its influence on loading machine performance. *Proceedings of the 21st Conference on Explosives and Blasting Techniques*, 57-67.

Hawkes, P.J., Spathis, A.T., & Sengstock, G.W. (1995). Monitoring equipment productivity improvements in coal mines. In *EXPLO 95 Conference* (pp. 127-132). Brisbane, Australia: AusIMM.

Jhanwar, J.C., Chakraborty, A.K., Ani Reddy, H.R., & Jethwa, J.L. (1999). Application of air decks in production blasting to improve fragmentation and economics of an openpit mine. *Geotechnical and Geological Engineering*, (417), 37-57.

Kanchibotla, S.S. (2001). Optimum blasting? Is it minimum cost per broken rock or maximum value per broken rock? *Procs. Explo-2001, Hunter Valley*, 35-40.

Khomenko, O., Kononenko, M., & Myronova, I. (2013). Blasting works technology to decrease an emission of harmful matters into the mine atmosphere. *Annual Scientific-Technical Collection – Mining of Mineral Deposit*, 231-235. https://doi.org/10.1201/b16354-43

Lopez Jimeno, C., Lopez Jimeno, E., & Carcedo, F.J (1995). *Drilling and blasting of rocks*. London: CRC Press, Taylor & Francis Group.

Mackenzie, A.S. (1967). Optimum blasting. *Proceedings of the 28th Annual Minnesota Mining Symposium*, 181-188.

Marton, A., & Crookes, R. (2000). A case study in optimizing fragmentation. *The AusIMM Proceedings*, (1), 35-43.

McGill, M., & Freadrich, J. (1994). The effect of fragmentation on loader productivity. *Proceedings of the 5th State of the Art Seminar on Blasting Technology, Instrumentation and Explosives Application*, 713-724.

Maerz, H.N., Franklin, J.A., Rothenburg, L., & Coursen, D.L. (1987). Measurement of rock fragmentation by digital photoanalysis. *Proceedings of the 5th International Congress of International Society for Rock Mechanics*, 687-692.

Michaud, P.R., & Blanchet, J.Y. (1996). Establishing a quantitative relation between post blast fragmentation and mine productivity – A case study. *Proceedings of the Rock Fragmentation by Blasting*, 389-396.

Rzhevsky, V.V. (1995). *Opencast mining unit operations*. Moscow: Mir Publishers.

Singh, S.C., Baijal, B.D., & Fasihuddin, M. (1999). Introduction of advanced blasting technology at Noamundi iron mines. *Tata Search Magazine*, 171-175.

Singh, S.P., & Narendrula, R. (2006). Factors affecting the productivity of loaders in surface mines. *International Journal of Mining, Reclamation and Environment*, *20*(1), 20-32. https://doi.org/10.1080/13895260500261574

Singh, S.P., & Yalçın, T. (2002). Effects of muck size distribution on scooping operations. *Proceedings of the 28th Annual Conference on Explosives and Blasting Techniques*, 315-325.

Singh, S.P., Yalçın, T., Glogger, M., & Narendrula, R. (2003). Interaction between the size distribution of the muck and the loading equipment. *Proceedings of the 4th International Conference on Computer Applications in Mineral Industries*, 1-13.

ВПЛИВ ВИБУХОВОГО РУЙНУВАННЯ ПОРОДИ І КУТА ЇЇ НАВАЛУ НА ПРОДУКТИВНІСТЬ ЕКСКАВАТОРА НА КАР’ЄРАХ

Б.С. Чоудхарі

Мета. Дослідження впливу вибухового руйнування породи і кута її навалу на продуктивність та безпеку роботи екскаватора.

Методика. Дослідження проводилися на базі двох вугільних кар’єрів в Індії – A і B. У комплексі були використані технології буріння, підривання, риття та відвалоутворення для видалення порід розкриття та видобутку вугілля. У кар’єрах були проведені експериментальні вибухи для того, аби вивчити вплив вибухового руйнування породи і кута її навалу на продуктивність екскаватора.

Результати. Встановлено, що ступінь подрібнення породи повинен бути оптимальним по відношенню до розміру ковша екскаватора для можливості завантаження більшої кількості породи за менший час. Також важливо, щоб навал мав оптимальний кут і був досить рихлим. В результаті даного дослідження з’ясувалося, що мінімальний час одного циклу роботи екскаватора відповідає наступному ступеню подрібнення: 0.30 – 0.45 м у кар’єрі A та 0.15 – 0.20 м у кар’єрі B, відповідно при куті навалу 52 – 58 градусів в обох кар’єрах.

Наукова новизна. Для геотехнологічних умов відкритої розробки вугільних родовищ Індії виявлені нові закономірності зміни продуктивності видобутку від умов, механізмів та обладнання, методу виїмки та стану кар’єра.

Практична значимість. Використання встановлених закономірностей дозволить оптимізувати технологічні параметри при проектуванні вибухових і видобувних робіт на кар’єрах з розробки різних видів корисних копалин (вугілля, будівельних матеріалів та ін.).

Ключові слова: *кар’єр, середній розмір подрібнення, кут навалу, вибухова речовина, вибухові роботи, екскаватор*

ВЛИЯНИЕ ВЗРЫВНОГО РАЗРУШЕНИЯ ПОРОДЫ И УГЛА ЕЕ НАВАЛА НА ПРОИЗВОДИТЕЛЬНОСТЬ ЭКСКАВАТОРА В ОТКРЫТЫХ КАРЬЕРАХ

Б.С. Чоудхари

Цель. Исследование влияния взрывного разрушения породы и угла ее навала на производительность и безопасность работы экскаватора.

Методика. Исследования проводились на базе двух угольных карьеров в Индии – A и B. В комплексе были использованы технологии бурения, взрывания, рытья и отвалообразования для удаления вскрыши и добычи угля. В карьерах были произведены экспериментальные взрывы для того, чтобы изучить влияние взрывного разрушения породы и угла ее навала на производительность экскаватора.

Результаты. Установлено, что степень измельчения породы должна быть оптимальной по отношению к размеру ковша экскаватора для возможности загрузки большего объема породы за меньшее время. Также важно, чтобы навал имел оптимальный угол и был достаточно рыхлым. В результате данного исследования выяснилось, что минимальное время одного цикла работы экскаватора соответствует следующей степени измельчения: 0.30 – 0.45 м в карьере A и 0.15 – 0.20 м в карьере B, соответственно при угле навала 52 – 58 градусов в обоих карьерах.

Научная новизна. Для геотехнологических условий открытой разработки угольных месторождений Индии выявлены новые закономерности изменения производительности добычи от условий, механизмов и оборудования, метода выемки и состояния карьера.

Практическая значимость. Использование установленных закономерностей позволит оптимизировать технологические параметры при проектировании взрывных и добычных работ на карьерах по разработке различных видов полезных ископаемых (угля, строительных материалов и др.).

Ключевые слова: *карьер, средний размер измельчения, угол навала, взрывчатое вещество, взрывные работы, экскаватор*

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