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Directional Controlled Blasting for Extraction of Composite Strata in An Indian Coal Mine

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Abstract

Extraction of thin coal seam and associated overburden using drilling and blasting is a cost expansive task. In such scenario, the separate excavation of each stratum needs blasting of shallow deep holes. The shallow deep hole blasting comes with many associated safety and productivity threats such as – flyrock ejection, frequent marching of machinery, extra manpower effort etc. The simultaneous excavation of thin strata with overburden can be an alternative to this problem. However, simultaneous excavation may lead to the problems of dilution. Accordingly, a directional controlled blasting is a need to restrict the throw of the blasted material from each stratum within the desired distance. This paper has dealt with the methodology to excavate two numbers of coal seams with two layers of associated overburden simultaneously. The scientific methodology consisting of near field vibration assessment and empirical formulation based approach was used to design the blast. The optimal burden and charge factor estimation were carried out for different strata using this approach. The charging quantification and delay sequence arrangements were designed to suit the requirements of material movements. The blast for the excavation of composite strata was conducted using the devised blasting patterns. The blasting outputs were excellent in terms of the throw of the blasted materials and fragmentation.

Keywords: Composite Strata; Dilution Control; Throw Optimization; Coal Seam; Blast Design

Introduction

The excavation of composite strata having different layers of coal and overburden is an important challenge for the blast designers. The challenge becomes even more vital from the perspective to maintain the productivity and reduce the production cost. Some of the Indian coalfields have such stratified thin seam deposits. The planned and scientific excavation of such deposits with an aim to control the directional throw could be an alternative for its productive excavation. The major scientific approach used by the blast designers in bench blasting is based on the principle of burden movement using the explosive energy. The optimum burden for a blast face can certainly lead to the control of throw of the blasted materials, the reduction in back break and thereby maximization of explosive energy utilization. Findings of the previous researchers have correlated the burden with different blast design parameters and rock mass properties [1-6].The directional controlled blasting for a composite stratum needs the strata wise segregation of the optimal burden. The charging quantification and delay sequencing are other major parameters which affects the directional movements of the blasted rock.

Researchers in the field of rock excavations have dealt with different directional controlled blasting techniques applied at various coal, mineral and strategic civil excavation sites. The scientific approaches dealt by these researchers mainly encompass the charging quantification, explosive quality suitability and proper delay sequencing of the blast-holes. These parameters are mainly decided on the basis of interaction of explosive energy with the in-situ rock mass. Mandal et al have made a presumption in their findings that the throw of the blasted rock mass will be related to their respective density [7]. The charging quantity and delay sequence for coal and overburden strata was decided on the basis of this presumption. Kumar et al have discussed about the through seam blasting technique for excavation of layered strata [8] Hu et al. Have decided the quantity of explosive for crack initiation under different strata conditions on the basis of explosion pressure formula [9]. The similar technique is used in the blasting procedure for mineral extraction. The objective in mineral excavation is to reduce the ore dilution. Preece & Silling have used the blast hole delay sequencing optimisation for segregation of ore and waste in the mineral blasting [10]. Bhagat et al have used the directional controlled blasting technique to stabilize unstable slopes at a railway site [11]. Authors have estimated the blasted rock throw using empirical formulations. Accordingly, the optimum burden to restrict the throw up to a desired distance was estimated.

In large scale blast of overburden strata of an opencast mine; presplit blasting technique is also based on controlling the throw of the material. Sometimes, cast blasting technique is used in such cases [12; 13]. Among different techniques to predict the throw of the blasted material, the near field vibration based technique is most popular. The technique aims to restrict the vibration within a critical limit to propagate the blast induced crack beyond the desired profile. Accordingly, different vibration prediction techniques [14 -28] can be used for estimation of optimum burden to control throw of the blasted material up to a designated distance.

The following paper has dealt with the practical case study for designing the blasting parameters for excavation of composite strata.

Experimental Site Details

The experimental study for extraction of composite strata was conducted at Quarry AB of West Bokaro colliery of M/s Tata steel Limited located in the central portion of West Bokaro coalfield. The area falls in Kedla block of Ramgarh district, Jharkhand, India. The block is bounded by latitudes 23^{0}48’16” to 23^{0}48’57” & longitudes 85^{0}33’07” to 85^{0}34’34” and falls in Survey of India toposheetno. 73E/5. A view of the location of the experimental site is shown in (Figure 1).

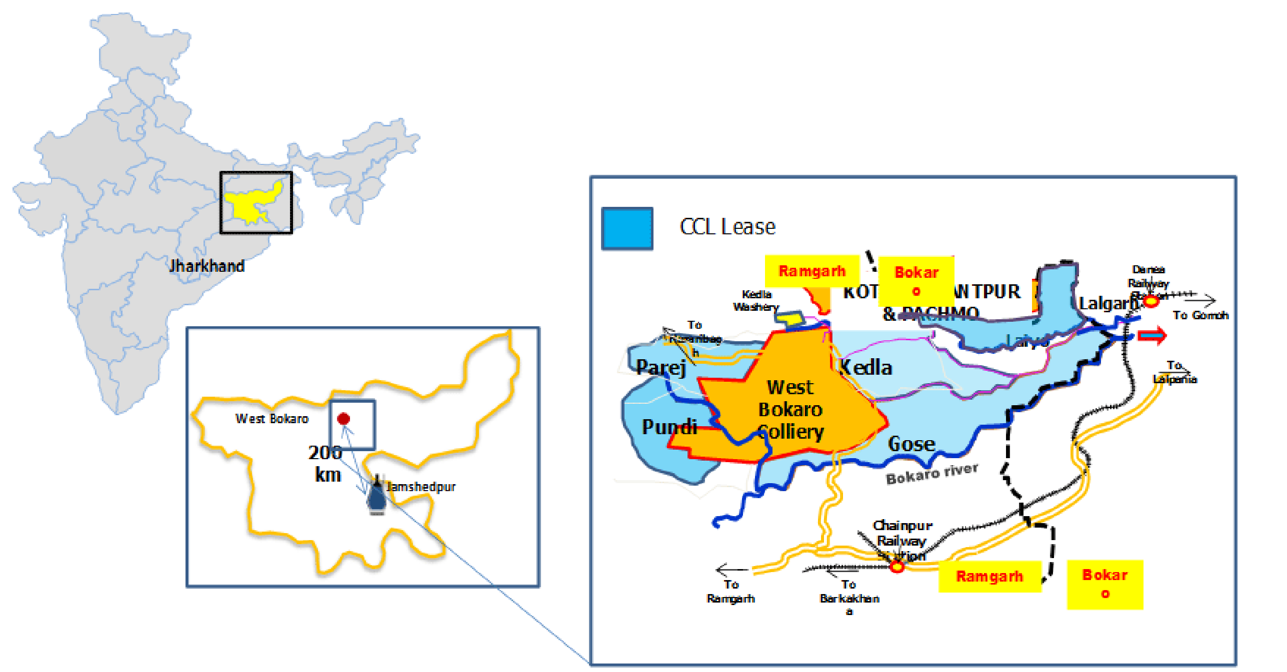

Figure 1: Location of the experimental site

Geology

Deposition of coal in west bokaro division refers to Barakar formation of Jurassic age. Block consists of a total of 14 coal seams with interbedded fine to course sandstone, shale and carbonaceous shale. The sectional representations of different coal seams and the associated rock type is shown in Table 1. The rock encountered at the mine consists of intercalated beds of sandstone, shale and coal seam belonging to Barakar stage of Damodar series of lower Gondwana system. The coalfield is permo-carboniferous. The general dip of the beds is 2º - 5º towards southeast but it undergoes great variation locally due to faulting, warping, thickening and thinning of the strata. A total of 46 faults are interpreted in the block. Most of the faults are normal faults and trending in NW-SE direction with varying throws and directions. Out of these, 10 faults are Major ones with throw ranging between 40-170m,15 faults in the range of 15 to 40m, 14 faults in the range of 10 to 15m and 6 faults have less than 10m throw.

Overview of the problem

The experimental blast face of the mine was carrying thin coal seams with thin partings. The coal seam VIII and IX was separated with the partings of Shale layers. The minimum thickness of the coal and parting strata was as less as 0.5 m. An overview of composite strata of the blasting bench of the mine is shown in Figure 2.

The separate excavation of these strata was a problem from the perspective to maintain the production pace. The main issues that was encountered while separate excavation of these strata were as follows:

a) The excavation of thin coal seams using drilling and blasting was difficult, as it may lead to the problem of flyrock ejection because of lesser depth of the blast-holes.

b) The coal loss was encountered while dozing of the blasted face.

c) Periodic small blast needed deputations of persons at critical points to prevent inadvertent entry of man/machine.

d) Reduction in number of blast in turns reduces the delay associated with each blast, converting the blasting delay time into operational hours.

e) Frequent marching of excavators and drill machines may lead to overall loss in the cost of production, as marching will lead to extra fuel consumption. The productive run hours of the machineries can also be improved by avoiding the frequent marching.

Accordingly, the simultaneous excavation of coal seams and partings were planned to address the mentioned issues. The scientific methodology was devised for the excavation.

Table 1: Lithological section of west Bokaro block.

Lithology	**Thickness(m)**
Soil	3 – 4 m
Medium to coarse grained weathered sandstone	3 – 4 m
Medium to coarse grained partially weathered sandstone	2.5 – 6 m
Carbonaceous shale, shale and sandstone interbedded	5 – 25 m
Seam XIV	**3 – 6 m**
Carbonaceous shale, shale, sandstone, and one thin locally developed seam with one thin local coal band (XIII A)	20 – 25 m
Seam XIII, mixed with carbonaceous shale partings	**4 – 7 m**
Interbedded shales, carbonaceous shales and sandstone with 6 thin locally developed coal seams (XIIA, XIIB, XIIC, XIID, XIIE, XIIF)	10 – 30 m
Seam XII	**1 – 4 m**
Interbedded shales, carbonaceous shales and sandstone with 8 thin locally developed coal seams (XIA, XIB, XIC, XID, XIE, XIF, XIG, XIH)	40 – 60 m
Seam XI	**2 – 5 m**
Interbedded shales, carbonaceous shales and sandstone with 5 thin locally developed coal seams (XA, XB, XC, XD, XE)	35 – 50 m
Seam X with carbonaceous shale parting	**2 – 5 m**
Carbonaceous shale at places one local band, intercalations of sandstone and shale	1 – 12 m
Seam IX	**0.5 – 3 m**
Carbonaceous shale and interbedded shales	0 – 5 m
Seam VIII	**0.5 – 7 m**
Interbedded shales, carbonaceous shales and sandstone	5 – 20 m
Seam VII with 0.20 – 0.80 m carbonaceous shale	**8 – 10 m**
Shale, fine to coarse grained sandstone	10 – 25 m
Seam VI	**3 – 7 m**
Fine to coarse grained sandstone, carbonaceous shale and shale with 2 locally developed coal seams (VA & VB)	5 – 20 m
Seam V with carbonaceous shale parting	**3 – 5 m**

Interbedded shales, carbonaceous shale and sandstone with one thin locally developed coal seam/band (IVA)	15 – 20 m
Seam IV	**1 – 4 m**
Fine to coarse grained sandstone and interbedded shale with one thin local coal band (IIIA)	5 – 25 m
Seam III mixed with 0.5 – 1 m carbonaceous shale	**3 – 5 m**
Interbedded shales, carbonaceous shale and sandstone with one thin locally developed coal seams (IIA)	20 – 40 m
Seam II mixed with 0.5 – 1 m carbonaceous shale	**1 – 4 m**
Fine to coarse grained sandstone and shale	35 – 50 m
Seam I	**0.2 – 2 m**
Medium to coarse grained sandstone. Gritty sandstone with intermediate shale; Conglomerate at bottom	50 – 60 m
Unconformity	
Granitic Gneiss basement	

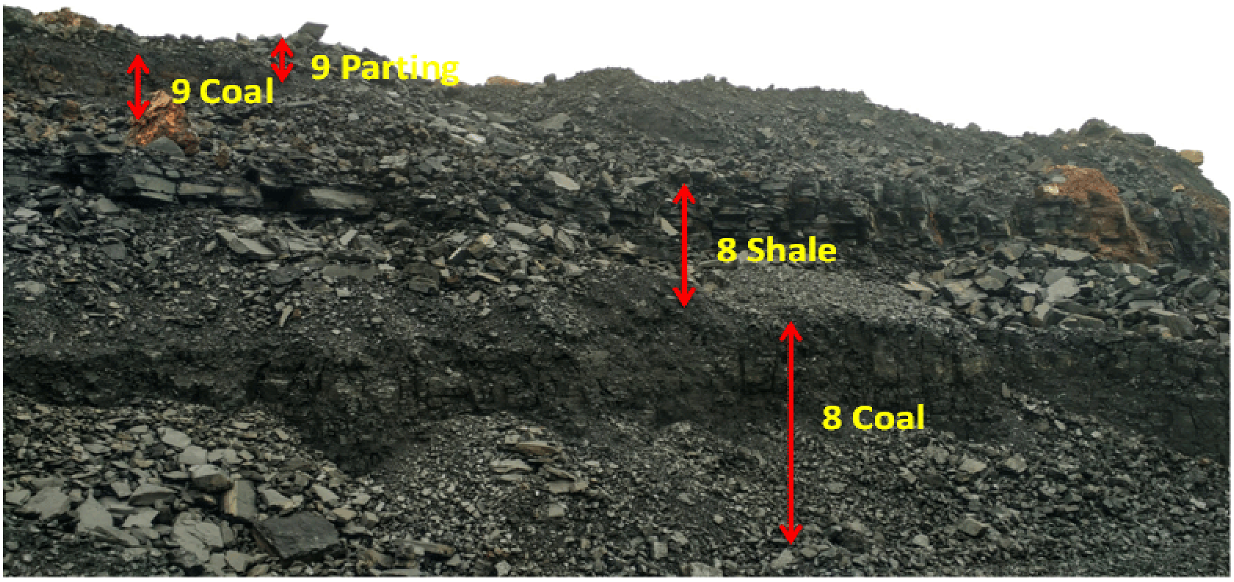

Figure 2: Overview of composite strata present at the experimental site

Methodology

The optimum burden-spacing and charge factor for VIII Coal, VIII Shale, IX Coal and IX parting strata were decided on the basis of desired throw of the blasted material to avoid dilution. The near field vibration assessment and empirical estimation based approach was used to estimate the optimum burden. The near field vibration prediction was done using the established blast vibration predictor for the mine. The flow chart of the methodology used for deciding the blast design parameters for this blast is shown in Figure 3. Since, the initiation of the blast holes was in bottom, the lesser throw of the material was planned for VIII Coal and VIII Shale. Accordingly, the lower charge factor was planned for blasting in VIII Coal and VIII Shale strata than IX Coal and IX parting strata. The charge factor for the blast of coal strata was taken lesser in comparison with the overburden strata. The charge factor determination for coal and overburden was planned on the basis of the density of the respective rock strata. As, it has been presumed that the coal strata will show comparatively higher throw than the overburden strata under similar charging conditions. This presumption was also validated with the vibration predictor equation for blast of the respective strata. The details of the drilling and charging parameters used for excavations of different rock types of the composite strata are given in (Table 2).

The delay sequencing of the blast holes was planned to reduce the dilution. Initially, the individual decks of each stratum were initiated using electronic delay detonators. The method was very effective from the perspective of movement of the blasted rock. But, the use of four electronic detonators in a single blast hole was very expansive. Accordingly, the electronic detonators were replaced with non-electric detonators. The movement of different strata were controlled by charge factor instead of delay timings. However, in the revised design using non-electric detonators also, the delay sequencing was done to ensure blast of single hole at a time, when blast holes are closely spaced. The purpose of ensuring the blast of single hole was to avoid any chances of dilution by interaction between the blasted materials. A view of delay sequencing of blast holes using non electric detonator is shown in (Figure 4).

Table 2: Drilling and charging parameters used for excavation of different rock strata.

Seam	Depth (m)	Burden (m)	Spacing (m)	No. of holes	Blasted Volume (m3)	Explosive (Kg)	Charge Factor (Kg/m3)
IX Parting	1	2	3	100	600	500	0.83
IX Coal	1.5	3	3	100	1350	500	0.37
VIII Shale	2.5	3	3	100	2250	1000	0.44
VIII Coal	2.5	4	4	100	4000	700	0.17

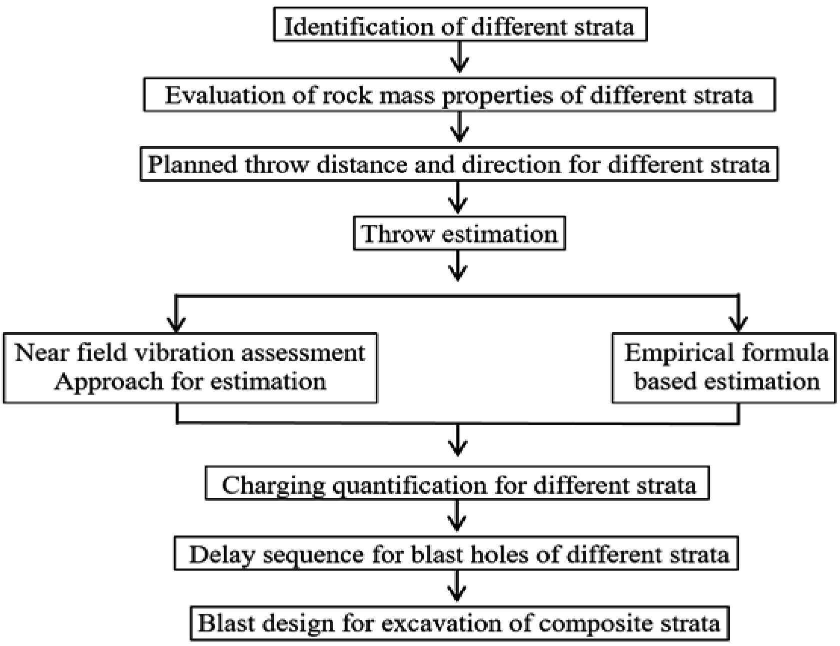

Figure 3: Flow chart of the methodology adopted for designing blasting parameters for excavation of composite strata.

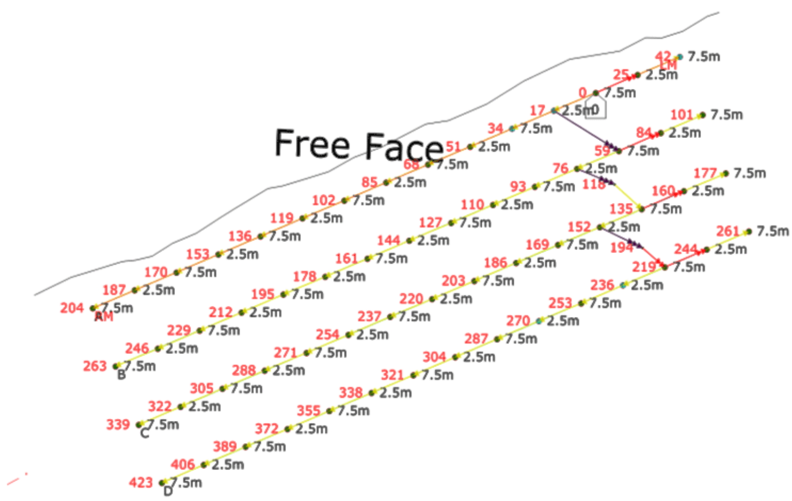

Figure 4: Delay sequencing of blast holes for excavation of composite strata using non-electric detonators.

Results and Discussion

The blast was conducted at the experimental site for the excavation of the composite strata using planned methodology. The charge quantification was done using near field vibration assessment and empirical formula based estimation. The designed powder factor as per Table 2 was used for the blast of different strata. The connection of the charged blast holes was carried out to separate the closely spaced blast holes with different charge weight per delay. However, the control on throw of the blasted rock from different strata was achieved using charge factor based segregation.

The analysis of the blasting output shows that the directional throw of the blasted material was under control. The blasted material had excellent fragmentation to suit the requirement of excavators. A view of blasting outputs of different strata from the experimental blast is shown in Figure 5. The blasting methodology adopted to achieve this output has also helped in increasing the productivity of the excavators and utility of the drilling machines. The overall exposure of the raw coal has been significantly increased by this method. The comparative cost analysis shows that the mine management has been able to save around 0.24 million USD per month by using this excavation methodology. The break-up of savings under different heads is given in (Table 3).

Table 3: Financial benefits by using the excavation methodology for complete extraction of composite strata in a single round.

Parameters	Amount saved per month (in USD)
Increased running hours of equipment	61560
Diesel saving	1870
Increase in under carriage life	450
Explosive saving (PF) and Drill meter savings	13937
Extra Coal excavated	162977
TOTAL	**240794**

Figure 5: View of blasting outputs of different rock strata

Conclusion

The excavation of composite strata consisting of different nature of rocks in different layers is a vital challenge for the blast designers. The simultaneous extraction of all the strata is beneficial in order to reduce the cost of production of the mine. However, the dilution control in simultaneous extraction is one of the hurdles. This hurdle can be dealt by the scientific approach to control the desired throw of the blasted rock. Near field vibration assessment and empirical relation based assessment are two major scientific approach to estimate the throw of the blasted rock mass. This approach has been used in this paper for simultaneous excavation of two coal seams and two associated overburden strata. The charge factor and blasting geometry of all the four strata were designed on the basis of expected throw. The overburden strata were given more charge factor compared to the coal strata, as the coal having lesser density tend to show more throw under similar charging condition. Since the bottom initiation of the blast-holes was planned, more charge factor was given to the top layer of the strata compared to the bottom layer to avoid the chances of dilution. The non-electric initiation system was used for the blast of the composite strata, as the movement of the respective layers were controlled by charge factor. The blast was conducted at the experimental site with the designed blasting parameters. The blasting outputs were excellent in terms of rock fragmentation, throw of the blasted rock, dilution control etc. The mine management has been able to save monthly operational cost of around 0.25 million USD using this technique of blast.

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References

1. Rustan R A. Burden, spacing and borehole diameter at rock blasting. International Journal of Surface Mining, Reclamation and Environment. 1992;6(3):141-149. doi: 10.1080/09208119208944329

2. Langefors U, Kihlström B. The Modern Technique of Rock Blasting. Almqvist and Wiksell/Gebergsfrlag AB, Stockholm. 1978.

3. Ash R L. The mechanics of rock breakage, standards for blasting design. Pit and Quarry. 1963;56(3):118–122.

4. Konya C J, Walter E J. Surface Blast Design. Prentice Hall, New Jersey, USA. 1990.

5. Langefors U, Kihlström B. The Modern Technique of Rock Blasting. 3rd edition. John Wiley and Sons, New York. 1979.

6. Jimeno C , Jimeno E L, Carcedo F J A, Balkema A A. A review of Drilling and Blasting of Rocks. Int. Jour. Sur. Min., Recl. and Env. 1995;10(1):V-VI. doi: 10.1080/09208119608964786

7. Mandal S K, Singh M M, Singh R B. Segregation of coal by single–shot blasting of composite strata in opencast mines. Mining Technology. 2001;110(1):69-72. doi: 10.1179/mnt.2001.110.1.69

8. Kumar S, Himanshu V K, Mukherjee T K, Bhadra M. Extraction of Contiguous seam and overburden using Through Seam Blasting Technique. Proceedings of International Conference on NexGen Technologies for Mining and Fuel Industries (NxGnMiFu-2017).

9. Hu J, Zhang X, Gao Y, Ma Z, Xu X, Zhang X. Directional presplit blasting in an innovative no-pillar mining approach. Journal of geophysics and engineering. 2019;16(5):1-19. doi: 10.1093/jge/gxz053

10. Preece D S, Silling S A. Ore loss and dilution studies of surface mineral blasting with 3D distinct element heave models. 42nd Annual conference on explosive and blasting technique. International society of explosives engineers (ISEE). 2016.

11. Bhagat N K, Mishra A K, Singh M M, Rana A, Singh P K. Innovative Directional Controlled Blasting Technique for Excavation of Unstable Slopes Along a Busy Transportation Route: A Case Study of Konkan Railway in India. Mining, Metallurgy & Exploration. 2020;37:833-850.

12. Singh P K, Roy M P, Paswan R K, Dubey R K, Drebenstedt C. Blast vibration effects in an underground mine caused by open-pit mining. International Journal of rock mechanics and mining science. 2015;80:79-80. doi: 10.1016/j.ijrmms.2015.09.009

13. Paswan R K, Sarim Md, Roy M P, Kumar S. Blast induced damage and role of discontinuities on Pre-split blasting at Rampura-Agucha Pb-Zn open pit mine. Proceedings of international conference on NexGen Technologies for Mining & Fuel Industries (NxGnMiFu-2017). At New Delhi, India. 2017.

14. Moris G. Vibration due to blasting and their effects on building structure. The Engineer. London. 1950.

15. Blair B E, Duvall W I. Evaluation of gauges for measuring displacement, velocity and acceleration of seismic pulses. USBM RT 5073. 1954.

16. Himanshu V K, Roy M P, Mishra A K, Paswan R K, Panda D, Singh P K. Multivariate statistical analysis approach for prediction of blast induced ground vibration. Arabian Journal of Geosciences. 2018;11:460. doi: 10.1007/s12517-018-3796-8

17. Agrawal H, Mishra A K. Modified scaled distance regression analysis approach for prediction of blast induced ground vibration in multi-hole blasting. Journal of Rock Mechanics and Geotechnical Engineering. 2018;11(1):202-207. doi: 10.1016/j.jrmge.2018.07.004

18. Agrawal H, Mishra A K. An innovative technique of simplified signature hole analysis for prediction of blast-induced ground vibration of multi-hole/production blast: an empirical analysis. Natural Hazards. 2019.

19. Duvall W I, Johnson C F, Meyer A V C. Vibrations from blasting at Iowa limestone quarries. USBM RI 6270. 1963.

20. Ambraseys N R, Hendron, A J. Dynamic behaviour of rock masses: rock mechanics in engineering practices. Wiley, London. 1968. doi: 10.1371/journal.pone.0082056

21. Ghosh A, Daemen J K. A simple new blast vibration predictor. Proc. 24th US Symp. Rock Mechanic. Texas, USA. 1983.

22. Kahriman A. Prediction of particle velocity caused by blasting for an infrastructure excavation covering granite bedrock. Min Res Eng. 2001;10(02):205-218. doi: 10.1142/S0950609801000622

23. Kahriman A. Analysis of ground vibrations caused by bench blasting at can open-pit lignite mine in Turkey. Environ Geol. 2002;41(6):653-661. doi: 10.1007/s00254-001-0446-2

24. Giraudi A, Cardu M, Kecojevic V. An assessment of blasting vibrations: a case study on quarry operation. Am J Environ Sci. 2009;5(4):468-474. doi: 10.3844/ajessp.2009.468.474

25. Cardu M, Dompieri M, Seccatore J. Complexity analysis of blast-induced vibrations in underground mining: a case study. Min Sci Tech. 2012;22(1):125-131. Doi: 10.1016/j.ijmst.2011.06.013

26. Cardu M, Mucci A, Uyar G. Investigating the effects of bench geometry and delay times on the blast induced vibrations in an open-pit quarry. GEAM. 2015;52(1):45-56.

27. Roy P P. Vibration control in an opencast mine based on improved blast vibration predictors. Min Sci Tec. 1991;12(2):157-165. doi: 10.1016/0167-9031(91)91642-U

28. Roy P P. Putting ground vibration predictors into practice. Colliery Guardian. 1993;241(2):63-67.