Parametric Analysis of Mine Bench Blasting using High Speed Video Camera

Channabassamma N.*, Avchar Akhil, Sastry Vedala Rama, Tripathi Anup Kumar and Sahana P.
Department of Mining Engineering, National Institute of Technology Karnataka, Surathkal, Mangaluru -575025, INDIA
*cbvagnal@gmail.com

Abstract

This study presents a comprehensive parametric analysis of mine bench blasting through the utilization of high-speed video camera technology. Mine bench blasting is a critical operation in the extraction of minerals and understanding its parameters is essential for optimizing safety, efficiency and environmental impact. The research employs a high-speed video camera, specifically the S-Motion Model by AOS Technologies, Switzerland, capable of recording at 1000 frames per second. Here we carried out the sensitive parametric analysis like dependency of burden rock movement on ejection of stemming gaseous, stemming ratio, stemming height and total explosive charge using Proanalyst image processing software.

Through the analysis, we identified key trends and correlations that contribute to control rock movement, stemming gas ejection and optimizing explosive charge distribution. This comprehensive understanding provides valuable insights for improving the overall effectiveness and precision of future blasting operations, thereby contributing to enhanced operational outcomes and safety in mining or construction activities.

Keywords: Burden rock velocity, High speed video camera, Stemming ejection height, Total explosive quantity

Introduction

Blasting has become an accepted technique worldwide for rock fragmentation[6,13]. Without use of explosives, most of mining ventures and construction projects would not be feasible or economically justified[11]. Rock is blasted either to break ore or waste or to create space in most of the cases like mining and quarrying operations[18]. Rock is blasted to break large blocks for some civil engineering applications, mining operations and results are affected by the conditions under which blasting is carried out[10,18]. To achieve optimum fragmentation and utilization of explosive energy in rock blasting, high speed photography has become a powerful technique in blast design[3]. Some researchers have used high speed photography to evaluate blasts in surface mines. High Speed Motion Picture Technique was also used to evaluate explosive energy. The high-speed video camera operates at 50 to 1200 frames per second. The high-speed video system is a powerful diagnostic tool for quantitative and qualitative study of surface mine blast parameters[3,14].

Review of Literature

Stemming assumes a paramount role in the efficient utilization of explosive energy during rock blasting, as underscored by research conducted[16,17]. The practice involves filling the upper section of a blasthole with inert material to contain explosives, facilitating a controlled release of gas energy during detonation for optimal rock fracture and displacement[7]. Beyond its direct impact on energy consumption, stemming's environmental significance cannot be overstated[4]. The absence or improper execution of stemming can result in the premature escape of detonation gas before the explosion, leading to inadequate rock fragmentation and the wasteful dissipation of explosive energy. Environmental ramifications encompass ground vibrations, excessive noise, airborne rock debris, back breaks and air blasts.

Insights from the study further illuminate the correlation between stemming column height and the ejection of gases from the blasthole[12]. Their findings underscore the need for meticulous consideration of stemming column height to optimize blasting outcomes, emphasizing the delicate balance required to achieve effective results while minimizing adverse environmental effects[15].

While the aforementioned studies provide comprehensive insights into the critical role of stemming in rock blasting, there exists a notable research gap concerning the integration of burden rock movement, particularly in correlation with stemming height, stemming ratio and explosive energy. The current research highlights the importance of the parameters in energy consumption, fragmentation and environmental impact.

Study Area

The investigations were carried out in opencast mine no. II, Godavarikhani, the major mechanized opencast mine of Singareni Collieries Company Limited and it falls within South Godavari basin in Andhra Pradesh, South India. This mine is located at about 22 km from Ramagundam railway station, which is situated on Kazipet- Balharsha station of South-Central Railway. The block is connected well with both state capital Hyderabad and the district headquarters Karimnagar, which are at distances of about 225 km and 65 km respectively.

Material and Methods

High-speed video camera: High speed motion picture photography (figure 1) has become a powerful diagnostic tool and technique to study, analyze, evaluate and help in the blast designs in the last few years[2]. High speed cameras or

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video allow one to see aspects of the blast that cannot be seen directly through our naked eyes. Significantly video can be analyzed in two different ways or methods which are qualitative and quantitative. The very first and modest way of video evaluation is qualitative analysis and it is dependent on the criteria of the observer. This type of evaluation does not involve any absolute measurements. The purpose of qualitative analysis is to review accomplished motions which are fast for the human eye or are too difficult to observe at a glance[5].

The second kind of evaluation which is quantitative analysis, is based on video recording. This approach helps in performing a detailed analysis of the object's movement patterns and reduces the risk of injury[9] such as sports and intense exercise activities[8]. The high-speed video camera which was said to record the blasts is S-Motion Model camera built by AOS Technologies, Switzerland, which can record at 1000 frames per second and provides results on the spot[1]. Blasting operations are recorded and viewed using AOS Image studio software.

Methods: Proanalyst is a motion analyzing software used to measure the maximum ejection height of gaseous energy through stemming zone, to track down the burden rock movement, to measure the displacement and the angle of the rock particles etc. Data which is obtained from AOS sequence application was fed into Proanalyst software as AVI video format. Then the calibration of video using known distance generally burden distance or bench height is taken as shown in figure 2. The escape of gas energy through stemming zone was then measured to its maximum height attained in all the blasts as in figure 3.

Figure 4 shows a blast 1 analyzed through Proanalyst software. The blast was also tracked using Proanalyst software to find the velocity of rock movement while blasting is shown in figure 5. From the analysis made by Proanalyst software, using the time taken by a rock particle to reach certain distance travelled, the velocity of burden rock movement is calculated.

Figure 1: High speed video camera of 1000fps capacity

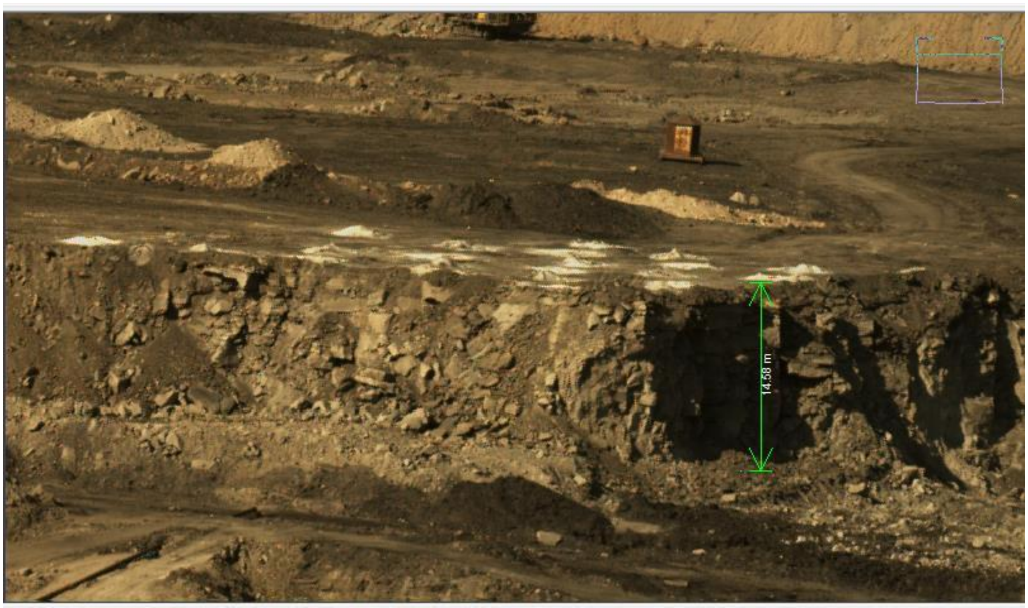


Figure 2: Height of bench using Proanalyst software

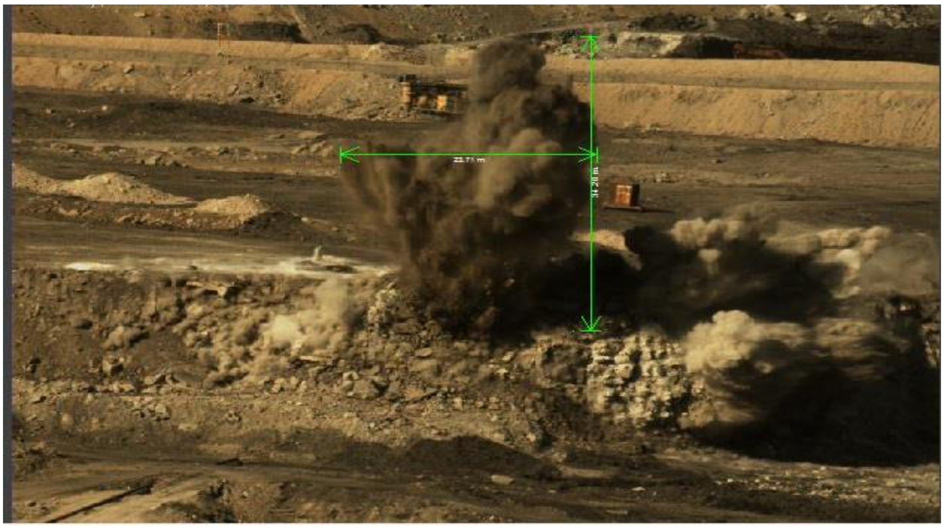


Figure 3: Measuring the maximum height of the gas energy.

Figure 4: Tracking of blast using Proanalyst software.

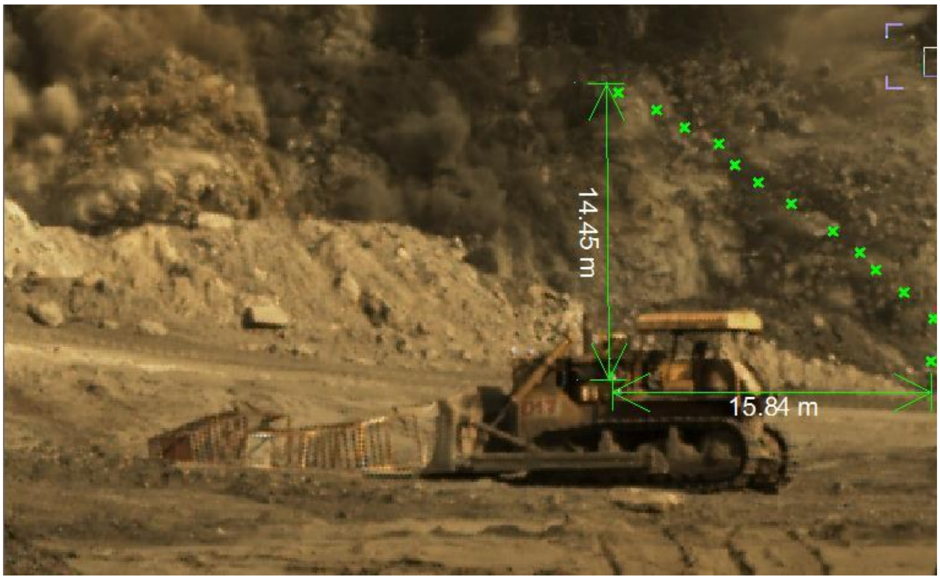


Figure 5: Distance of rock movement from a point during blast using Proanalyst software.

Hence, from the analysis made by Proanalyst software, for the time of 376ms (the time taken by a rock particle to reach the distance of 15.84m), the velocity of rock movement is obtained as 42.127m/s.

Results and Discussion

The table 1 presents specifications for ten distinct blasting scenarios, designated as blast numbers 1 through 10. Table also provides a summary of the parameters for blasts executed using wagon drills to drill blast holes with a diameter of 250 mm. The depth of these blast holes ranged from 13 m to 15 m. In the context of mining or similar operations, several key parameters are detailed for each blast. The bench height, representing the vertical distance between levels, varies between 13 and 14.5 meters across the different blasts. The burden, or the horizontal distance between blastholes, is consistently set at 6 meters, as is the spacing between blastholes. The number of blastholes per blast ranges from 20 to 44. Explosive parameters are also specified, with the explosive amount per hole varying between 268 and 350 kilograms.

The total explosive charge for each blast is calculated based on the number of blastholes, with values ranging from 6900 to 13700 kilograms. Stemming, the material placed on top of the explosive column, is detailed with lengths varying between 4.5 and 8 meters. Stemming ratios, indicating the ratio of stemming length to blasthole length, show fluctuations from 0.32 to 0.62. The stemming ejection height, or the height at which stemming is ejected during blasting obtained from the image processing Proanalyst software, it is shown in figure 3 of blast 1 and ranges from 10.86 to 45.48 meters in all other blasts. Finally, the burden rock velocity calculated from the blast is specified, varying from 15.38 to 42.12 meters per second. These comprehensive specifications provide a detailed overview of the blasting conditions for each scenario, offering valuable insights for optimizing and analyzing blasting operations in the given context.

A regression analysis was conducted on various blast parameters including stemming ratio, stemming height, ejection height of stemming gaseous and total explosive charge. The analysis utilized the Proanalyst image processing technique to calculate burden rock movement. In figure 6a, the correlation between ejection height and stemming height is depicted, revealing a strong correlation coefficient of 0.877.

It is observed that as stemming height increases from 4.5m to 8m, the ejection height of gaseous decreases from 45.48m to 10.86m. This suggests an increase in the confinement of gaseous in loose strata with rising stemming height, leading to optimal utilization of the explosive charge.

Figure 6b illustrates the correlation between burden rock movement and ejection height showing a correlation coefficient of 0.882. The plot indicates that as ejection height decreases, burden rock movement increases, implying more effective utilization of gaseous energy in breaking and moving rock particles.

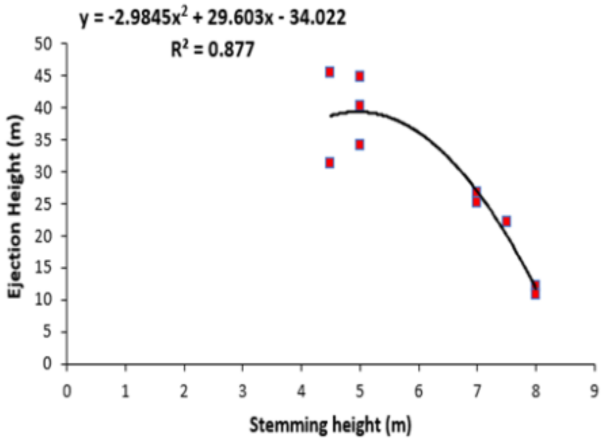
In figure 6c, the correlation between burden rock movement and stemming height is presented with a positive correlation coefficient of 0.9525. This positive correlation suggests that gaseous energy is fully utilized in advancing the movement of rock particles. Figure 6d demonstrates the correlation between burden rock movement and total explosive charge, revealing a positive correlation coefficient of 0.8686. An increase in explosive charge is associated with an observed increase in burden rock movement.

The correlation between burden rock movement and stemming ratio is depicted in Figure 6e, with a correlation coefficient of 0.9332. It is evident that a stemming ratio of 0.33 corresponds to a burden rock movement of approximately 15.38m/s, while a stemming ratio of 0.62 results in a movement of 42.12m/s.

Table 1
Summary of various parameters of blasts

Specifications	Blast Number									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Bench height (m)	14.5	14	13	14	14	13.9	14	13	14	13.5
Burden (m)	6	6	6	6	6	6	6	6	6	6
Spacing (m)	8	8	8	8	8	8	8	8	8	8
No. of blastholes	28	41	44	20	29	30	27	40	30	36
Explosive/ Hole (kg)	350	314	311	345	293	340	323	268	306	280
Total Explosive Charge (kg)	9800	12900	13700	6900	8420	10315	8800	10700	9200	10100
Stemming (m)	5	8	8	4.5	4.5	7	5	7.5	5	7
Stemming Ratio	0.34	0.57	0.62	0.33	0.35	0.50	0.36	0.58	0.36	0.52
Ejection height of gaseous (m)	34.23	12.22	10.86	45.48	31.25	26.67	44.89	22.13	40.25	25.31
Burden Rock velocity (m/s)	25.3	39.74	42.12	15.38	20.23	35.02	19.01	38.01	22.02	32.12

Regression Analysis of various parameters.



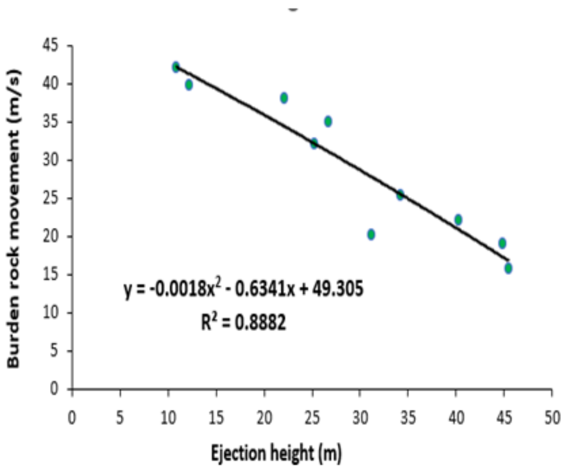
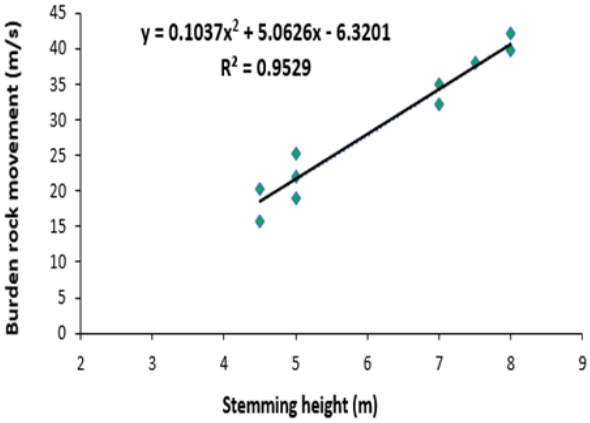


Figure 6a

Figure 6b



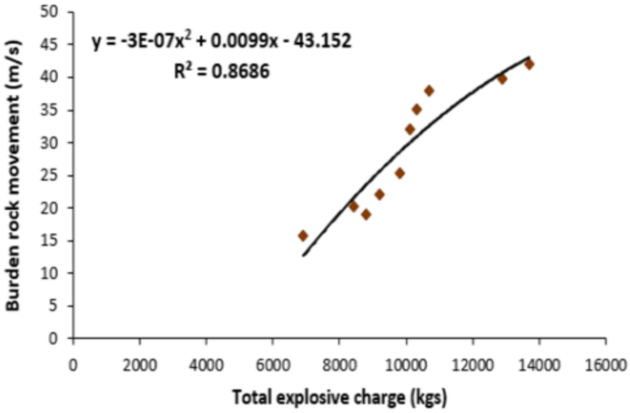


Figure 6c

Figure 6d

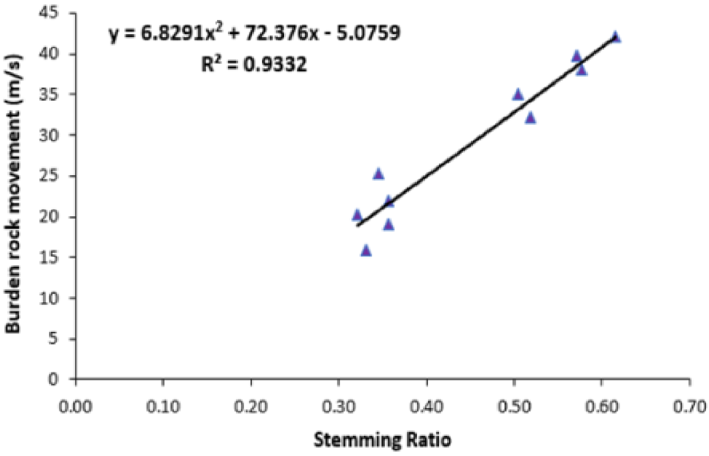


Figure 6e

Figure 6a: Plot of ejection Height vs stemming height, Figure 6b: Plot of burden rock movement vs ejection height, Figure 6c: Plot of burden rock movement vs stemming height, Figure 6d: Plot of burden rock movement vs total explosive charge and Figure 6e: Plot of burden rock movement vs stemming ratio

Conclusion

In conclusion, our comprehensive regression analysis, utilizing various blast parameters such as stemming ratio, stemming height, ejection height of stemming gaseous and total explosive charge, provided valuable insights into the dynamics of burden rock movement. Figure 6a highlighted a strong correlation (0.877) between ejection height and stemming height, revealing that an increase in stemming height leads to a decline in gaseous ejection height. This suggests enhanced confinement of gaseous energy in loose strata, optimizing the utilization of explosive charge. Additionally, figure 6b demonstrated a correlation (0.882) between burden rock movement and ejection height of gaseous, indicating that lower ejection heights contribute to increased rock particle movement, showcasing effective utilization of gaseous energy. Positive correlations in figures 6c, 6d and 6e (0.9525, 0.8686 and 0.9332, respectively) underscore the efficient utilization of gaseous energy in advancing rock particles concerning stemming height, total explosive charge and stemming ratio. These findings collectively provide valuable insights for optimizing blast parameters and maximizing the efficiency of rock fragmentation processes in mining operations.

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