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Application of Dynamic Numerical Code for Rock Blasting

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***Abstract:** The development of rock blasting technology is dynamic in nature and concepts of blast theory were customized from time to time based on field results. A number of physical models were tested and verified to comprehend effect of explosive types, blast geometry, rock types etc. Field experiments are time consuming as well as costlier too and many a times it is not possible to conduct field trials with varying parameters due to production pressure. Although, advance field instrumentation technology have been developed to monitor the rock blasting phenomenon but still there are more critical parameters which cannot be measure from field experimentation because of short duration of time. As a results, numerical modeling tool are now considered to be versatile and expedient to simulate the prototype more efficiently. This paper mainly focuses on the results of dynamic numerical modeling using Abaqus/explicit tool to understand rock mass respond and its breakage mechanism, energy utilization history etc. In this paper, a field condition was simulated for single and multiple hole blast to understand the wave propagation mechanism around the blast vis-à-vis effective energy utilization.*

***Keyword:** Rock blasting, Dynamic numerical modelling, Abaqus/explicit, Energy utilization*

I. INTRODUCTION

The rock blasting is the prime method to break the rock mass which is very complex phenomena and controlled by many parameters. The main objective of rock blasting is to break the rock mass as per required size and minimize the blasting ill effects. Therefore, it is important to predict the rock fragmentation and damage in the surrounding rock mass so that the effect of various blast parameters can be studied and limiting the number of expensive field experiment (Saharan et al. 2017, and Sazid 2017, Sazid et al. 2016). Although various field studies with advanced instrumentation have been conducted in field experiments but it is still not clear about the internal changes in the phenomena. The large scale experiments in the field may not feasible due to various uncontrolled parameters as well as time consuming to understand the mechanism (Sazid et al., 2012; Sazid et al., 2011). Due to extreme complexities of the phenomena in rock breakage the majority of blasting models today are relied on numerical tools which promoting the understanding of the physical processes involved in rock breakage and providing critical information useful for enhancement of explosive energy utilization (Sazid and Singh 2015).

This paper describes the constitute model which is used by numerical tool for predicting the rock damage due to explosive loading. The present study also involved results of signature and multiple blast holes to understand the blast wave propagation mechanism and its damage effects surrounding the rock mass.

II. BLAST DAMAGE CONSTITUTE MODELS

Blast damage constitute models are founded on micro cracks which have been reported in many publication (Grady and Kipp, 1980; Taylor et al., 1986; Throne et al., 1990; Kuszmaul, 1987; Bawden et al., 1993). According to the concepts of continuum mechanics, for isotropic materials, when a material point is subjected to stresses, it changes in volume due to the volumetric portion of the stresses and in shape due to its deviatoric parts (Malvern, 1969). The volumetric strain θ is determined by the pressure P at that point and the bulk modulus K of the material

$$\theta = \frac{P}{3K}$$

The volumetric strain θ is the variable that determines whether the microcracks will be activated and grow. When a rock material is subjected to a tensile stress, it can support that stress and does not fail unless the value of the stress is larger than its static tensile strength. This is accounted for by setting a critical value θc for the volumetric strain θ,i.e., when θ is less than θc, the microcrack system in the material point remains stable, when θ exceeds θc, micro cracks are activated according to the actual level of θ. Furthermore, if a stress whose value is well above the static tensile strength is applied to a rock material, the rock material does not fail if the time duration for the stress is too short. As pointed out by Bawden et al. (1993), in dynamic loading, the stress can exceed the material strength, but it may not damage the material if its duration is too short. Blast damage is accumulated as a function of time and applied stress. This fact is supported by the experimental work of Li et al. (1994) who tested the dynamic strength of several types of rock materials under impulsive loading and concluded that, for a given rock sample and stress level, a critical time is required for fracture to occur. From the view point of microcrack activation and growth, micro cracks may be activated by a high stress level and show a tendency for further growth. However, complete growth is possible only when the time duration of the stress is long enough. The above can be expressed by a mathematical formula:

$$C_d = \propto (\theta - \theta_c)^{\beta} t$$

where C_d is defined as the fraction of volume which has been influenced by cracks,

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$\propto$, β and θ_c are material constants whose physical meaning was interpreted by various researchers. Rock materials encountered in blasting practice generally contain visible joints, beddings or other macro flaws which may have significant influence on the physical processes involved in rock blasting. In the present model, the rock mass is highly simplified by assuming that it is an isotropic, homogeneous and continuous medium.

The stated of stress of a material point is treated in two modes (shear and tensile) under dynamic failure mode and depending on the value of volumetric strain compared to the critical value. Shear failure mode is determined for plastic yielding, whereas tensile failure for tensile loading. Shear model either used for the Mises or the Johnson-Cook plasticity models, whereas equation of state (EOS) is also supported additionally in tensile failure model. Tensile failure criteria were used for rock mass failure model in numerical results of this paper. The theory of rock breakage under dynamic loading in numerical simulation has been reported by Sazid and Singh (2012).

III. SINGLE HOLE BLAST RESULTS

The above constitutive model was applied in Abaqus/explicit numerical tool and analyzed the behavior of rock mass under high impulsive loading of explosive energy. Movement of shock wave energy and its variation with detonation velocity has been represented in this model. Point load charge with axisymmetric section has been used in this model (fig.1). The movements and reflection from free faces of shock energy with different intensity of pressure rings are shown in fig. 2. It was found that rock blasted material kinetic energy increased with velocity of detonation energy of explosive. More applied explosive energy generates more cracks around the rock mass (fig.3) but trend of energy distribution were same encountered in all phases. The details of rock and explosive properties were referred from Sazid and Singh (2012).

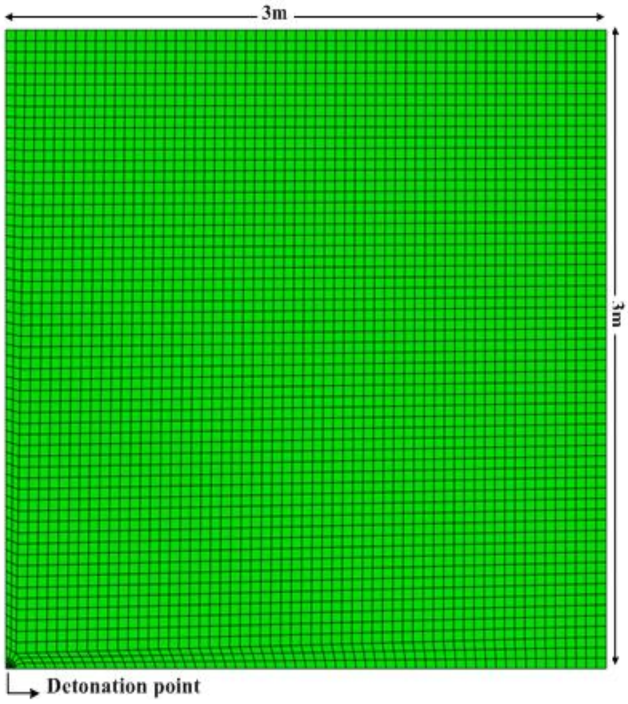
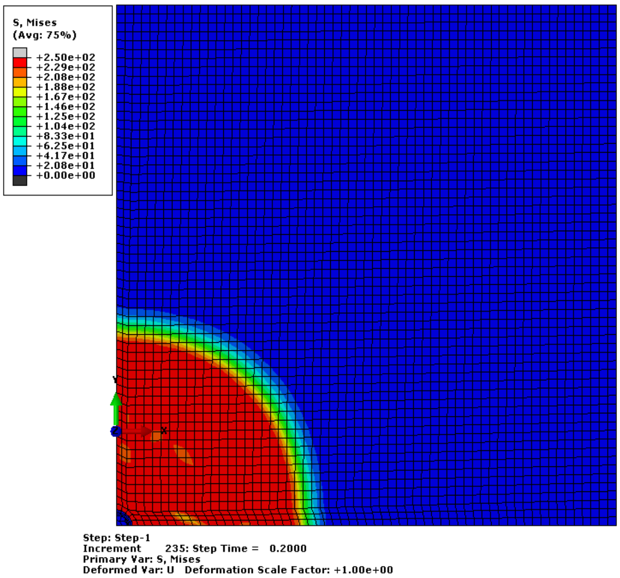
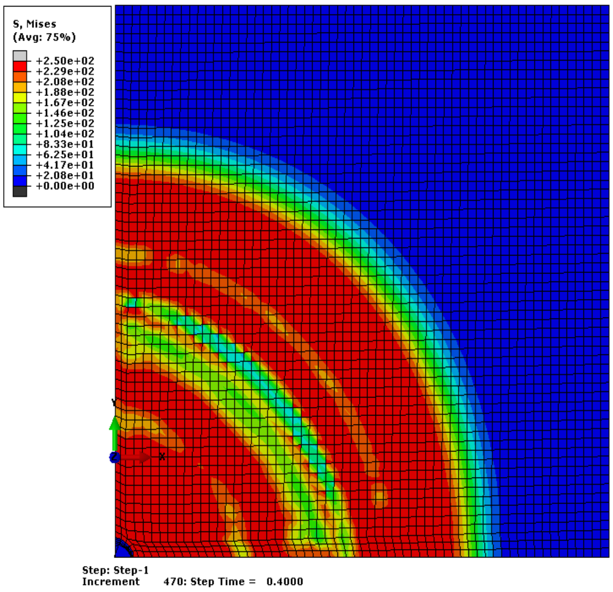


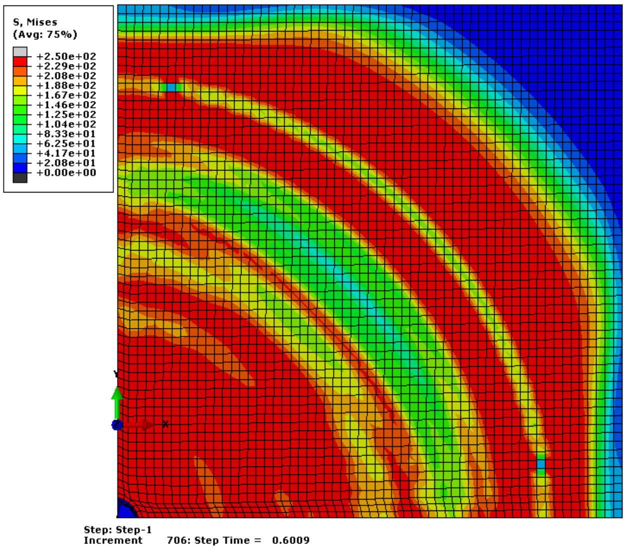
Fig. 1 Geometry of single blast hole model



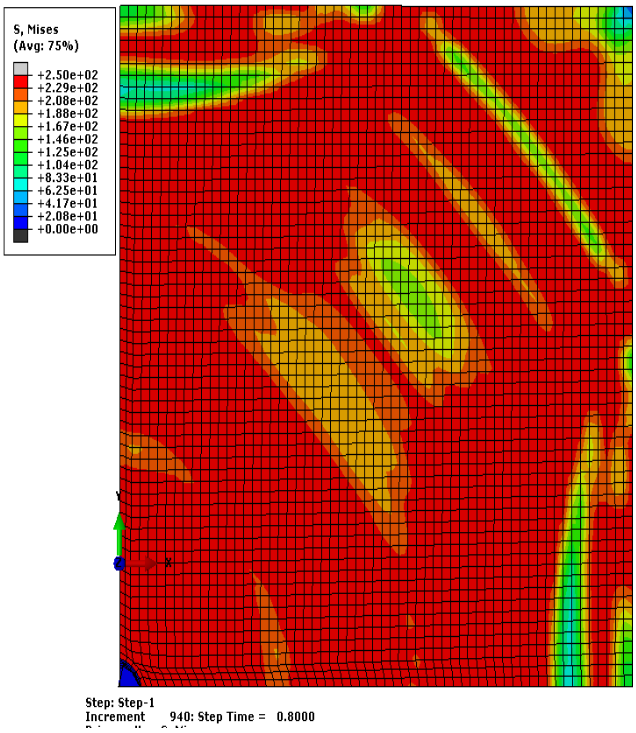
(a) t = 0.20×10^{-3} Second



(b) t = 0.40×10^{-3} Second



(c) t = 0.60×10^{-3} Second



(d) t = 0.80×10^{-3} Second

Fig. 2 Progression of Stresses as wave and reflected from free faces

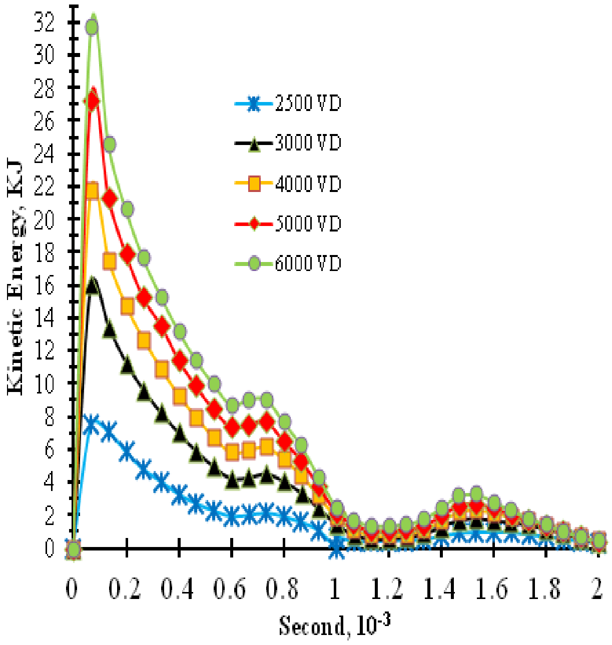


Fig. 3 Variation of kinetic energy of blasted material with detonation velocity

Bench blast model with axisymmetric section has been also described in this section. It can be observed that the explosive energy in the form of pressure rings travels towards the free faces and reflected as tensile wave. The rock mass started to generates cracks where tensile stresses value reached above the tensile strength of the rock mass (Singh et al., 2012; Singh et. al., 2013; Kainthola et. al., 2012; Sarkar et. al, 2009). The movement of shock wave energy and fragmented material are shown in fig 4 & 5.

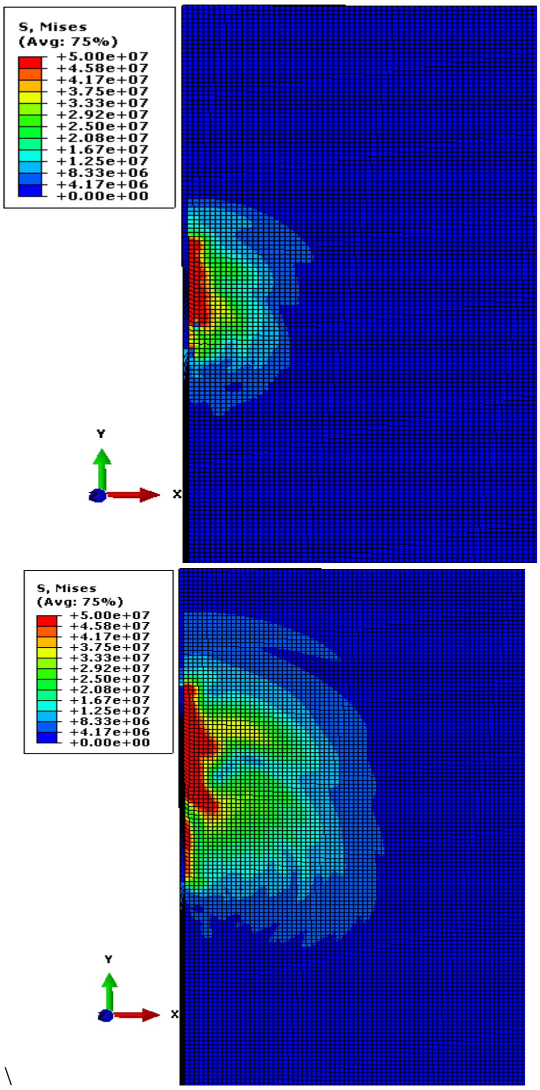


Fig. 4 Movement of shock wave energy with different intensity

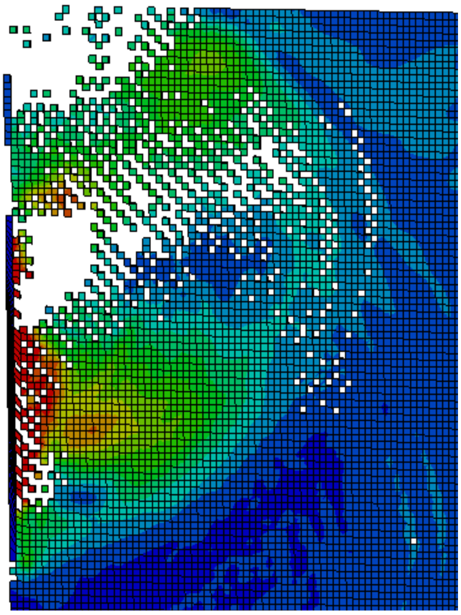


Fig. 5 fragmented blast material model

IV. MULTI HOLE BLAST RESULTS

Two blast holes with same initiation time were considered for dynamic numerical simulation. Centre point of both blast holes were targeted for analysis. The geometry of blast holes were shown in Fig. 6. It can be revealed from numerical simulation results central area damage zone developed during superimposed of two blast hole shock wave energy (fig. 7). Excessive damage represented the wastage of explosive energy. Therefore, optimum explosive energy can be obtained either by increasing spacing between holes or decreasing velocity of detonation of explosive. Furthermore, the rock class was also effect the central damage zone area (Sazid et al. 2012). Variation of developed pressure from more to less be found in rock class V to I (fig. 8).

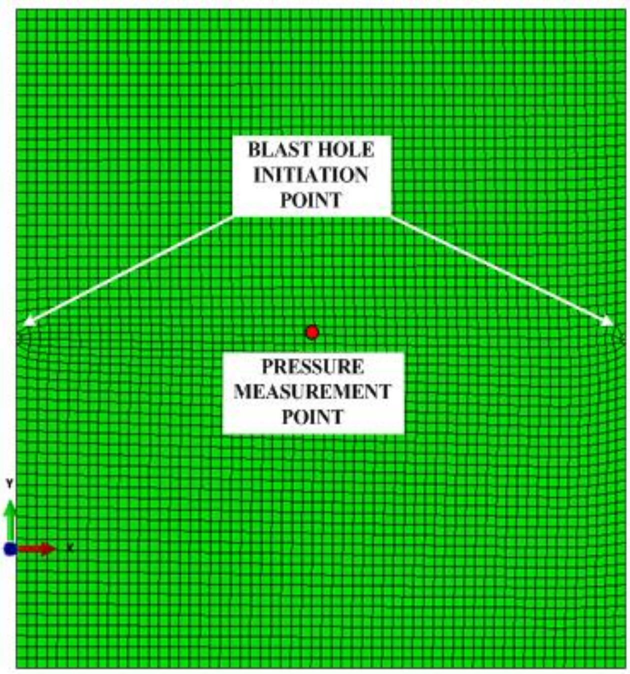
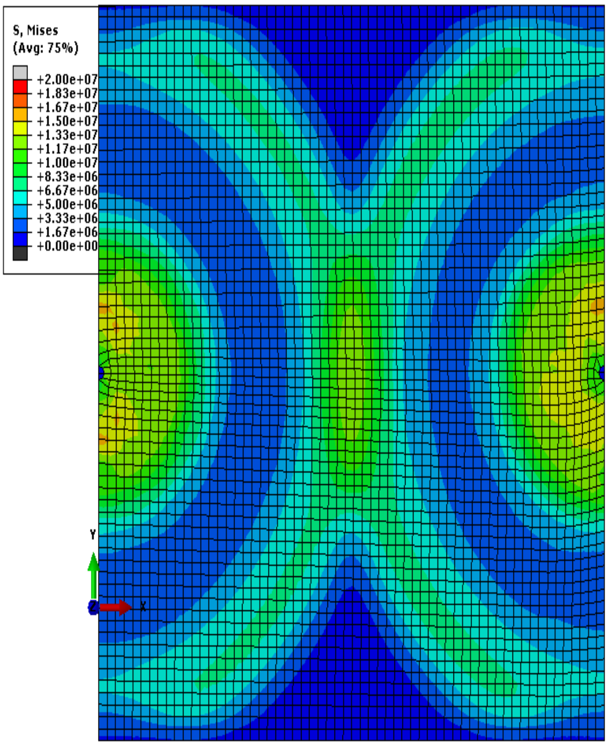


Fig. 6 Geometry of two blast hole model



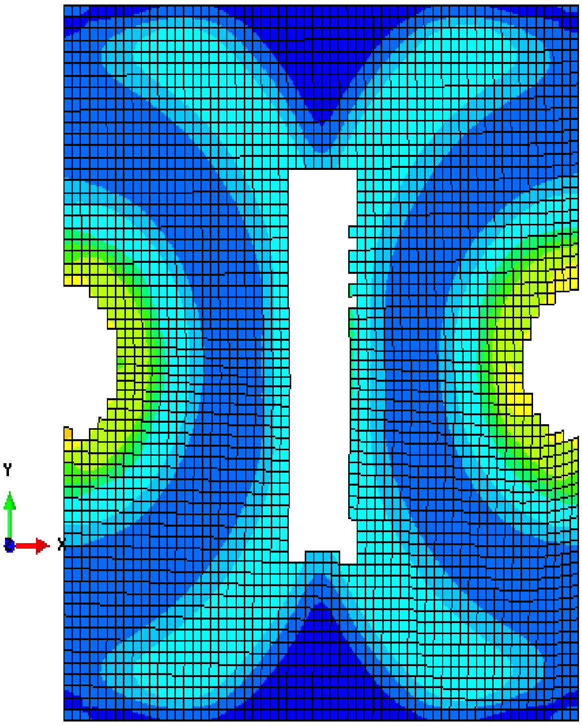


Fig. 7 Movement of shock wave energy and damage at superimposition of energy

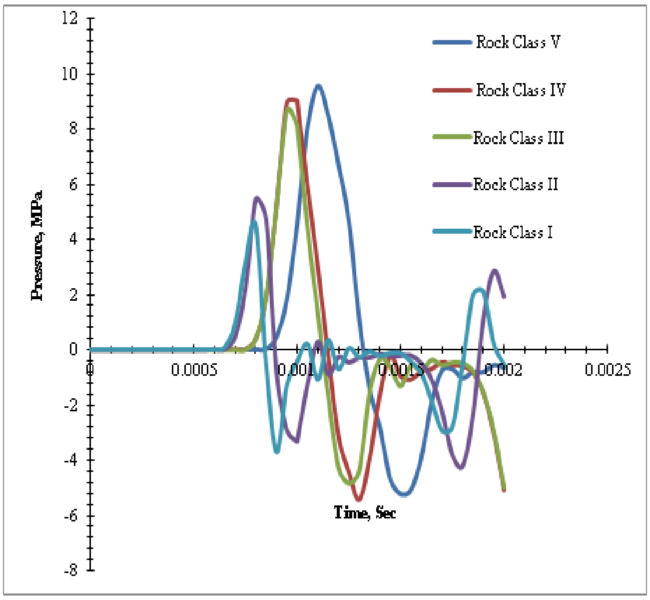


Fig. 8 Pressure Variation with Rock Class

V. CONCLUSIONS

This paper introduced the blast damage constitute model and numerical results of rock blasting. Field testing of rock blasting is not economical and feasible all time and most of parameters are not possible to monitor during microsecond events of rock blast. Therefore, dynamic numerical tools are very effective and easiest way to analysis and control the rock blasting. Abaqus/explicit numerical results with single and multi-blast holes were showed the behavior of shock wave energy and utilization of explosive energy.

REFERENCES

1. Bawden, W.F., Katsabanis, P.D. and Yang, R. (1993). Blast damage study by measurement and numerical modeling of blast damage and vibration in the area adjacent to blast hole. Innovative mine design for 21st century, Proc. Int. Cong. on Mine Design, Kingston, Canada, 23-26.
2. Grady, D. E. and Kipp, M.E. (1980). Continuum modeling of explosive fracture in oil shale. Int. J. Rock Mech. Min. Sci. & Geomech. 17, 147-157.
3. Kainthola, A., Singh, P. K., Wasnik, A. B., Sazid, M., & Singh, T. N. (2012). Finite element analysis of road cut slopes using Hoek and Brown failure criterion. Int J Earth Sci Eng, 5(5), 1100-1109.
4. Kuszmaul, J.S. (1987). A new computational model for fragmentation of rock under dynamic loading. 2nd Int. Sym. on Rock Fragmentation by Blasting, Keystone, Colorado. 412-423.
5. Li, X.B., Chen, S.R. and Gu, D.S. (1994). Dynamic strength of rock under impulse loads with different stress waveforms and durations. J. Central South Institute of Mining & Metallurgy, 25(3).
6. Malvern, L.E. (1969). Introduction to the mechanism of a continuous medium. Prentice-Hall, Eaglewood Cliffs.
7. Saharan M.R., Sazid M. and Singh T.N. (2017). Explosive Energy Utilization Enhancement with Air-Decking and Stemming Plug, 'SPARSH', Procedia Engineering, 191, 1211-1217. https://doi.org/10.1016/j.proeng.2017.05.297.
8. Sarkar, K., Sazid, M., Khandelwal, M., & Singh, T. N. (2009). Stability analysis of soil slope in Luhri area, Himachal Pradesh. Min Eng J, 10(6), 21-27.
9. Sazid M. and Singh T.N. (2015). Numerical assessment of spacing–burden ratio to effective utilization of explosive energy, International Journal of Mining Science and Technology, 25(2), Pages 291-297, https://doi.org/10.1016/j.ijmst.2015.02.019
10. Sazid M., Saharan M.R. and Singh T.N. (2016). Enhancement of the Explosive Energy Utilization with the Application of New Stemming Contrivance. International Journal of Innovative Science and Modern Engineering (IJISME), 4(2), 1-5. DOI: 10.13140/RG.2.1.2573.8327
11. Sazid, M. (2017). Effect of Underground Blasting on Surface Slope Stability: A Numerical Approach. American Journal of Mining and Metallurgy, 4(1), 32-36. doi:10.12691/ajmm-4-1-2
12. Sazid, M. and Singh, T.N. (2012). Two-dimensional dynamic finite element simulation of rock blasting. Arb. J. Geo. 6(10), 3703-3708. DOI: 10.1007/s12517-012-0632-4
13. Sazid, M., Saharan, M. R., & Singh, T. N. (2011). Effective Explosive Energy Utilization for Engineering Blasting – Initial Results of an Inventive Stemming Plug. 12th ISRM Congress, Beijing, China. https://www.onepetro.org/conference-paper/ISRM-12CONGRESS-2011-227
14. Sazid, M., Singh, T. N., & Saharan, M. R. (2012). Risk Analysis of Mine Dump Slope Stability- A Case Study. Mining Engineers' Journal. 12(7). 11-15. https://www.researchgate.net/profile/Mohammed_Sazid/publication/257924401_Risk_Analysis_of_Mine_Dump_Slope_Stability-_A_Case_Study/links/00b49537451fb6fb48000000.pdf
15. Sazid, M., Wasnik, A. B., Singh, P. K., Kainthola, A., & Singh, T. N. (2012). A Numerical Simulation of Influence of Rock Class on Blast Performance. Int J Earth Sci Eng, 5(5), 1189-1195. https://doi.org/10.13140/rg.2.1.1859.7926
16. Singh, P.K., Wasnik, A.B., Kainthola, A. et al. (2013). The stability of road cut cliff face along SH-121: a case study. Natural Hazards, 68(2), 497–507. DOI: 10.1007/s11069-013-0627-9
17. Singh, T. N., Sazid, M., & Saharan, M. R. (2012). A Study to Simulate Air Deck Crater Blast Formation - A Numerical Approach. International Society for Rock Mechanics. https://www.onepetro.org/conference-paper/ISRM-ARMS7-2012-051
18. Taylor, L. M., Chen, Er-Ping and Kuszamaul, J.S. (1986). Micro-cracks induced damage accumulation in brittle rock under dynamic loading. Computer Mech. in Appl. Mech. and Engg. 55, 301-320.
19. Throne, B.J., Hommert, P.J. and Brown, B. (1990). Experimental and computation investigation of the fundamental mechanisms of cratering. 3rd Int. Sym. on Rock Fragmentation by Blasting, Australia. 26-31.