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EFFECT OF GEOLOGICAL STRUCTURE AND BLASTING PRACTICE IN FLY ROCK ACCIDENT AT JOHOR, MALAYSIA

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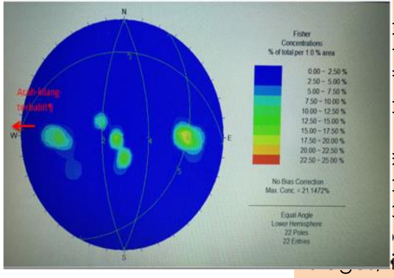

Abstract

Blasting operation is common method in hard rock excavation at civil engineering and mining sites. asting results in the fragmentation along with environmental hazards such as fly rock, ground n, air-blast, dust and fumes. Most of the common accidents associated with blasting are fly rock. A fly rock accident had occurred on 15 July 2015 at a construction site at Johor, a. Due to this accident, nearby factory worker was killed while two other workers were injured after being hit by rock debris from an explosion at construction site, 200 m away e factory. The main purpose of this study is to investigate the causes of fly rock accident on geological structures and blasting practice such as blast design, pre inspection on cal structures, identifying danger zone due to blasting and communication and evacuation nnel before blast. It can be concluded that fly rock could have been controlled in three initial drilling of holes based on blast design, ensure limiting charge for holes having less burden or having geological discontinuity, and selecting proper sequence of initiation of holes.

Keywords: Rock blasting, fly rock accident, geological structure, blasting practice

Abstrak

Kerja letupan adalah kaedah lumrah dalam pengorekan batuan keras di tapak kejuruteraan awam dan perlombongan. Letupan batu akan menghasilkan pecahan batuan dalam saiz yang mudah dikerjakan, disamping mengakibatkan permasalahan alam sekitar dan mengancam keselamatan seperti batu liar, gegaran tanah, letupan udara, habuk dan pembebasan gas merbahaya. Kemalangan melibatkan batu liar telah berlaku pada 15 Julai 2015 di tapak pembinaan di Johor, Malaysia. Akibat kemalangan ini, seorang pekerja di kilang berhampiran telah terkorban manakala dua orang lagi telah tercedera apabila terkena batu liar yang berterbangan dari tapak pembinaan yang terletak 200 m dari kilang. Tujuan kajian ini adalah bagi mengkaji sebab-sebab kemalangan batu liar berdasarkan struktur geologi dan tatacara kerja letupan seperti rekabentuk letupan, pengenalpastian zon penampan, serta komunikasi dan pemindahan pekerja sebelum letupan. Boleh disimpulkan bahawa batu liar boleh dikawal melalui tiga peringkat; penggerudian awal lubang berdasarkan rekabentuk letupan, memastikan had caj untuk lubang yang mempunyai bebanan yang kecil atau mempunyai ketidakselanjaran geologi, dan memilih urutan lubang yang betul untuk memulakan letupan.

Kata kunci: Letupan batu, kemalangan batu liar, struktur geologi, tatacara letupan

1.0 INTRODUCTION

In hard rock excavation for civil construction and mining sites, explosives are the best economic and cheapest source for rock fragmentation. Hence, blasting is common method used. Small amount of energy is utilised and rest is wasted in the form of ground vibration, fly rock, back breaks, air blast and etc. [1]. Fly rock due to rock blasting has been serious problem causing danger to human beings and damage to property [2]. Environmental hazards of surface blasting are mainly due to fly rock, lack of adequate security in blasting area, misfire and premature blast [3]. During 21 year period of from 1978 to 1998 in surface mines, the major causes of blast injuries were due to fly rock and lack of security accounted for 68.2 % of total blast injuries [4]. The main causes of fly rock in limestone quarry were geological conditions, inadequate stemming length and back break from previous blast [5]. Maximum fly rock distance in study at limestone quarries showed distance of 300 m and safe distance recommended is 500 m [2].

Blast area is the area in which injury to persons may occur due to surface blasting involving flying material or gases from explosives [6-9]. Blast area shall depend on geology of area to be blasted, blast geometry (hole diameter, depth, spacing, burden and angle of hole), type of stemming and length, maximum charge per delay, powder factor, delay system, type and amount of explosives. Blaster shall be given training for determining blast area [10]. In the present paper, a fly rock accident is first reported and then the possible reasons for that are discussed.

2.0 HISTORY OF FLYROCK ACCIDENTS

869 blasting accidents in US [11] surface mines studied for a period of 16 years from 1978 to 1993 where an annual average of about 58 nonfatal injuries were caused by mine blasting accidents and 4.75 fatalities per year for the period 1990-1993. The main causes of blasting accidents were blast area security and fly rock [3] for two decades (1978 to 1998) for US surface mines where there were 19 fatalities, 167 nonfatal injuries in coal mines and 26 fatalities and 200 non-fatal injuries in non-coal/metal mine. The main reason for fly rock accidents was due to weakness in geo-mechanical strength of rock having least resistance where explosives energy could blow rocks easily.

Geological factors such as sudden change in geology can cause mismatch between explosive energy and rock resistance resulting in fly rock e.g. mud seams or voids lead to high explosives energy concentration [4]. Low stability at blasting face may be caused in a particular direction due to discontinuity or cracks. Geological condition was major cause of fly rock accident in Masai, Johor in 2013 [12].

Various accidents which occurred in coal mines were due to lack of adequate security, not taking shelter by persons in blasting area, inadequate training for blasting personnel [4]. In case of fly rock accident in Masai Johor, other major causes were competency of persons, blast design, not given attention for close distance of nearby residents [12].

3.0 FLYROCK ACCIDENT IN MALAYSIA

3.1 Background

On July 2015, rock blasting contractor held a rock blasting work at a construction site in Johor. The rock blasting work was for levelling construction site in the area. However, on the day the blasting, an unprecedented catastrophe occurred in which a part of the rock mass approximately 2,000 m^3 from blasted granite flew away for a distance up to 200 m from the blasting face. From site survey, it was found that the size of the fly rock varied from 5 cm^3 to 0.3 m^3. Figure 1 shows the location of the areas involved.

As a result of the explosion, unexpected fly rock covered surrounding area of the location. This unexpected accident killed a worker and injured two others. Workers involved were about 150 m to the west of the blasting location. Several vehicles were also destroyed and damaged. Some small fragments flew to a factory in southwest (about 50 m away). Figures 2 to 4 show the effect of the blasting.

Figure 1 Location showing direction of fly rock

Figure 2 Location of the arrows shown in red and the effects of wild stone with orange arrows (150 m from the blast location)

Figure 3 The effect of damage – Vehicles damaged (150 m from the blasting site)

Figure 4 A nearby factory

3.2 Environmental Conditions

The area surrounding the blast site is shown in Figure 5. The blasting area marked with a red star and the radius of 100 m from the area where the blasting carried out are marked with a yellow circle line.

Figure 5 Position of the blast location and 100 m radius area of the wild rock drift direction from the blast

3.3 Design Hole and Explosives

A company reported that, a total of 21 holes were drilled with burden x spacing as 4.9 m x 5.2 m and stemming of 3.7 m. The blast design and type of explosives used (provided by contractor) is shown in Figure 6, while the location of the blasting is shown in Figures 7 and 8.

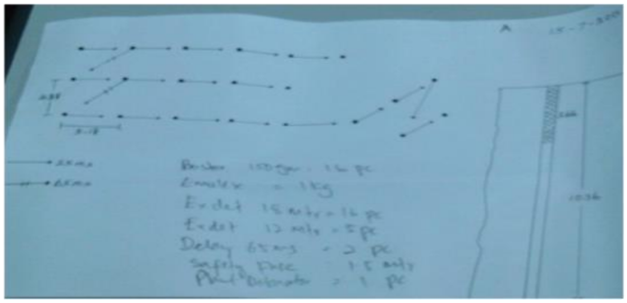

Figure 6 Design of blast reported by contractor

Figure 7 The location of the blasting site (pictured on July 18, 2015)

Figure 8 Inspection carried out on site. Red arrow indicates the direction of joint dominance (to the west)

With observations on site and the information supplied by the contractor, the estimated volume of blasted rock mass is 3,000 m^3, while the amount of explosive used was 1 tonne. Powder factor used in the blast was 0.33 kg/m^3. It takes into account the 21 drill holes which identified the cause of the accident. Also identified from the inspection site, the source of this fly rock was from the line of drill holes in the front line. It was also observed the throw factor from second and third rows did not move far (Figures 9 to 11).

Figure 9 Status of rows of holes 2 and 3 after blast (not moved far)

Figure 10 The rock split in lines 2 and 3 and not moved far

Figure 11 Share of first hole that destroyed – believed to cause fly rock

3.4 Geological Structure

The study was conducted at a geological structure of the rock mass affected to obtain presence information and orientation discontinuities that exist. The study was conducted after the incident, but the structure of rock left behind can still be used as a guide. Picture of rock face involved is shown in Figure 7. It should be noted that the quarry blasted and opened a site where serial blasts had been carried out. This means that the previous explosions had created the new discontinuities and cracks and fissures leave a larger aperture (up to 5-10 cm).

A total of 4 sets of fractures have been identified to exist at the blast site. This discontinuity occurred naturally and there are also new cracks as a result of the work of previous explosions. However, the joint set to the west is the most significant (dominant). As a result of the field measurement on traces of structures, a stereonet was drawn as shown in Figure 12.

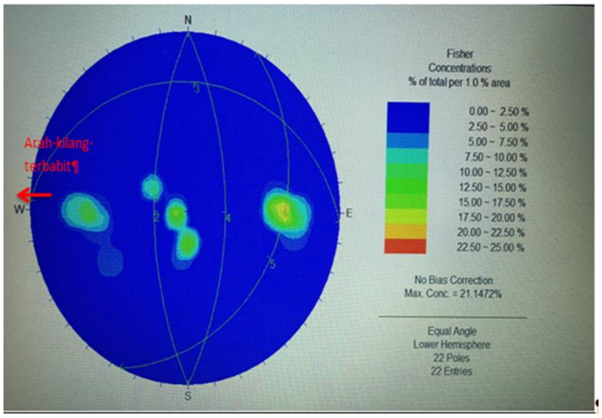

Figure 12 Analysis of discontinuity indicating instability direction towards the factory

Local geology plays an important role. Orientation of joint, extended cracks and unfavourable orientation could posed danger. Explosive loading should be modified to suit the compensate changes in geology.

3.5 Blast Design

A number of fly rock accidents had occurred in Malaysia. In 2013, a fatal accident happened in Masai, Johor [12]. Both blasting sites are close to population and require special considerations for fly rock management. For such sites, a well-planned blast design and good understanding on the geological characteristics are paramount important.

Fly rock happened when mismatch distribution of explosive energy, strength of rock mass and confinement of charge. Proper blast design has to take into account on the geological structure (weakness plane) and proper adjustment on powder factor should be made in the design. During charging, trained blasting personnel and blast designer should closely supervise the work to ensure the designs are followed.

It has been reported in India that fly rock travelled 550 m during a blast [16] was due to insufficient burden, stemming and improper fire delay sequence. In addition, factors like existence of fissures, joints, weakness plane and voids has much contributed to the accident. This case has highlighted the importance to adjust the energy distribution with the geological abnormalities.

Regarding blast design, it can be concluded that fly rock could be have been controlled in three (3) stages:

i. Initial drilling of holes based on blast design
ii. Inspecting holes on the day of blasting and limiting charge for holes having less burden or having geological discontinuity
iii. Selecting proper sequence of initiation of holes. From Figures 9 and 10, it can observed that row 2 and 3 did not move. This could have been due to cut off of holes due to less time to move front row.

3.6 Demarcation of Fly Rock Danger Zone

Based on demarcation of fly rock danger zone [17], joint properties and characteristics, slope face condition, presence of weak zone and voids are the uncontrollable factors that contribute to fly rock. Geological structures are the uncontrollable parameters for fly rock. All parameters included in blast design are considered as controllable parameters. The safety rule developed as factor of safety (FSH) [17] for blasting, which considers blast design and rock condition. From the chart (fly rock distance versus factor of safety), the factor of safety (FSH) for the present case study is < 0.5 and the fly rock is classified as unsafe.

Here are several factors that contribute to uncontrolled blasting and can be classified into:

i. Discontinuity studies conducted found that the fracture or instability of the dominant rock is towards the west
ii. The discontinuity exists naturally and also as a result of previous blasting. This can be visualized from characteristics of the fracture.
iii. The close proximity of the blasting site to sensitive area is another factor to be given attention. The shortest distance between the quarry face blasting areas with factories, is 150 m and 50 m only. Among the things that can be done is limit the number of holes for a more controlled blasting.

3.7 Support Vector Machine

Support vector machine (SVM) is a new model developed that can be used for predicting fly rock distance [18]. SVM network was developed by collecting 234 blast data sets from Soungun Copper Mine, Iran with 187 data sets for training and 47 for testing. In the SVM model, the inputs parameters are hole length, spacing, burden, stemming, powder factor and specific drilling while the output is fly rock distance. The actual fly rock distance in the present case study is 150 m and the predicted distance by using SVM is 98.8 m. The variance suggested other geological factors such as orientation of dominant joints and rock mass properties that need to be included in the prediction.

3.8 Blasting Practice

Various aspects which are listed below should be emphasised:

i. communication between nearby personnel before blasting

ii. competent blasting supervisor should inspect the area during charging and prior firing
iii. evacuation of all personnel in the blast zone area

4.0 CONCLUSION

There are several factors that contribute to uncontrolled blasting and can be classified into structure of the rock and close proximity. Further information is detailed as follows:

(a) Discontinuity studies conducted found that the fracture or instability of the dominant rock is towards the west
(b) The discontinuity exists naturally and also as a result of previous blasting. This can be visualised from characteristics of the fracture.
(c) The close proximity of the blasting site to sensitive area is another factor that which was not given attention. The shortest distance between the quarry face blasting areas with factories, is 150 m and 50 m only. Among the things that can be done is limit the number of holes for more controlled blasting.
(d) It can be concluded that fly rock could be have been controlled in 3 stages. First, initial drilling of holes based on blast design need to be considered. Then, inspecting holes on the day of blasting and limiting charge for holes having less burden or having geological discontinuity need to be carried out. Finally, selecting proper sequence of initiation of holes.
(e) Various aspect regarding blast management practices need to be established. Among factors are only competent personnel should be allowed to perform blasting works, good communication and pre blast inspection.

Thus it can be concluded that in present case study geological structure of rock-discontinuity of rock in west contributed to fly rock and blasting practice of blast design, communication, security arrangement, evacuation of persons from blasting zone, resulted into fly rock accident.

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