ASSESSMENT OF BLASTABILITY INDEX IN MASSIVE LIMESTONE FROM RAWANG QUARRY, SELANGOR

HAIZAM HAMIDUN

UNIVERSITI TEKNOLOGI MALAYSIA

ASSESSMENT OF BLASTABILITY INDEX IN MASSIVE LIMESTONE
FROM RAWANG QUARRY, SELANGOR

HAIZAM HAMIDUN

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ABSTRACT

The demand for construction materials produced by quarry rises in tandem with urbanization. Selangor is one of the highly populated states in Malaysia with residential projects now located very close or even next to quarry. Due to the fact that limestone consists of numerous weak spots in rock masses, it has always been thought that limestone quarry operation is riskier than common granite quarry operations. Geologically, limestone formation in Rawang sits uncomfortably on top of the older metamorphic rocks with its own unique joints system. The goal of the study was to identify the rock mass properties in massive limestone profile from a quarry in Rawang, Selangor and its relation to blast design as well as effects on the surrounding environment due to blasting. For a systematic study, the quarry face was divided into four (4) sections i.e., section A, section B, section C, and section D. The site mapping showed significant findings where section A is considered high potential of having excessive flyrock as it has the most joint number (J), joint plane spacing (JPS) and joint aperture (JA) with 31, 559.8 mm and 28.5 mm, respectively. When blasthole intersected with many joints, explosive energy escape through joints causing sudden drop in blasthole pressure and open joints extend up to the face thus creating high possibility of flyrock during blasting. The degree of difficulty to fragment rock in terms of Blastability Index (BI) was also calculated based on the geological mapping data. The results show that BI ranged from 49.18 to 59.26 percent throughout all study sections indicating that the rock mass at the quarry was easy to be blasted as per Blastibility Quality System (BQS). The calculated BI was also justified the suitability of blast design used during blasting at the quarry. The new site constants i.e., K and β for the study area were also calculated with USBM predictor at 40 and 1.0, while Langefors-Kihlstrom (LK) predictor at 6.8 and 1.07, respectively. Although at maximum charge per delay (W_{max}) the blasting was being carried out safely with very minimal effects to the surrounding areas. Finally, correlations between all earlier findings such as BI, blast design and environment effects i.e., peak particle velocity (PPV) measured and predicted were justified the significant relation of rock mass properties and ground vibration effect due to blasting operation at the quarry.

ABSTRAK

Permintaan untuk bahan binaan yang dihasilkan oleh kuari meningkat seiring dengan pembangunan di pusat bandar. Selangor merupakan salah satu negeri berpenduduk tinggi di Malaysia dengan pembangunan projek perumahan kini terletak sangat dekat atau hampir bersebelahan dengan sempadan kuari. Fakta yang mengatakan bahawa batu kapur terdiri daripada banyak titik lemah pada sifat batuan, selalu dianggap bahawa operasi kuari batu kapur adalah lebih berisiko daripada operasi kuari granit. Secara geologinya, formasi batu kapur di kawasan Rawang terletak di atas batuan metamorf yang lebih tua secara tidak selesa dengan sistem kekar tersendiri. Matlamat kajian ini adalah untuk mengenal pasti sifat batuan batu kapur di profil masif di kuari yang terletak di Rawang, Selangor dan kaitannya dengan reka bentuk letupan serta kesan terhadap alam sekitar akibat operasi peletupan. Bagi kajian yang sistematik, muka kuari telah dibahagikan kepada empat (4) bahagian iaitu bahagian A, bahagian B, bahagian C dan bahagian D. Pemetaan tapak menunjukkan penemuan yang signifikan di mana bahagian A muka kuari dianggap berpotensi tinggi untuk menghasilkan *batu terbang* yang berlebihan kerana ia mempunyai jumlah tertinggi bilangan kekar (J), jarak satah kekar (JPS) dan kekar apertur (JA) dengan masing-masing 31, 559.8 mm dan 28.5 mm. Apabila lubang letupan bersilang dengan banyak kekar, tenaga letupan keluar melalui kekar menyebabkan penurunan mendadak dalam tekanan lubang letupan dan kekar terbuka memanjang ke muka kuari sekali gus mewujudkan kemungkinan tinggi batu terbang semasa letupan. Tahap kesukaran untuk memecah batu dari segi Indek Kebolehletupan (BI) juga dikira berdasarkan data pemetaan geologi. Keputusan kiraan BI berjulat antara 49.18 hingga 59.26 peratus di semua bahagian kajian menunjukkan sifat batuan di kuari ini adalah mudah untuk diletupkan mengikut Sistem Kualiti Letupan (BQS). BI yang dikira juga mewajarkan kesesuaian reka bentuk letupan yang digunakan sepanjang kajian letupan di kuari. Pemalar tapak baharu iaitu, nilai K dan β untuk kawasan kajian juga dikira dengan peramal USBM pada 40 dan 1.0, manakala peramal Langefors-Kihlstrom (LK) masing-masing pada 6.8 dan 1.07. Walaupun pada kadar caj bahan letupan maksimum setiap lambatan (W_{max}), letupan telah dijalankan dengan selamat dan kesan yang sangat minimum kepada kawasan sekitar. Akhir sekali, korelasi antara semua penemuan awal seperti BI, reka bentuk letupan dan kesan peletupan pada persekitaran iaitu, "peak particle velocity (PPV)" diukur dan ramalan menunjukkan hubungan yang signifikan antara sifat batuan dan kesan gegaran tanah akibat operasi letupan di kuari.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
AI	-	Artificial Intelligence
AOp	-	Airblast Overpressure
ASTM	-	American Society for Testing and Materials
BI	-	Blastability Index
DOE	-	Department of Environment Malaysia
GSI	-	Geological Strength Index
ISEE	-	International Society of Explosive Engineers
ISRM	-	International Society for Rock Mechanics
JMG	-	Jabatan Mineral & Geosains Malaysia
J	-	Joints
LK	-	Langefors-Kihlstrom
OGL	-	Original Ground Level
PF	-	Powder Factor
PLI	-	Point Load Index
PPV	-	Peak Particle Velocity
RMD	-	Rock Mass Description
RL	-	Reduced Level
SD	-	Scaled Distance
SHRN	-	Schmidt Rebound Hammer
SPSS	-	Statistical Package for Social Science software
UCS	-	Uniaxial Compressive Strength
USBM	-	United State Biro of Mine
UTM	-	Universiti Teknologi Malaysia

LIST OF SYMBOLS

L_{max}	-	Maximum projectile distance of flyrock
$Is_{(50)}$	-	Corrected, point load strength index
MPa	-	Megapascal
dB(L)	-	Decibel
ST	-	Stemming
B	-	Burden
S	-	Spacing
W	-	Maximum explosive charge per delay
D	-	Distance between blast site and monitoring point
m	-	Meter
mm	-	Millimetre
gm/cc	-	Gram per centre cubic
%	-	Percent
t/m^3	-	Ton per cubic meter
mm/s	-	Millimetre per second
kg	-	Kilogram
kg/m^3	-	Kilogram per cubic meter
Nm	-	Newton meter
W_{max}	-	Maximum explosive charge per delay
W_{min}	-	Minimum explosive charge per delay

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CHAPTER 1

INTRODUCTION

1.1 Background

The demand for construction materials rises in tandem with urbanization (Arvind et al., 2017). Although most quarries are in rural or semi-rural areas, a few older quarries remain in operation in urban areas. Continuing population growth, social, industrial, and economic developments that necessitate more construction materials are just a few of the reasons why the older quarry is still in use, despite increasing complaints from the surrounding residents (Anthony and Calvin, 2019). To protect the public from potential impacts posed by quarry activities, stricter regulations have been imposed in order to control and minimize the consequences.

In 2013, a tragic quarry blasting incident in Masai (located in Seri Alam near Pasir Gudang, Johor) had once made national headlines. The massive explosion rained down rocks and boulders on the nearest industrial park, which was located 700 meters away from the blasting site. It was a fatal incident in which a factory worker died, ten people were seriously injured, 18 cars and 14 factories were damaged (Mohamad et al., 2013).

In general, limestone quarries in Malaysia are concentrated in Perak, with a few others in Selangor and Pahang (JMG, 2006). Most of these quarries are part of an integrated cement production plant, so the structures are usually located next to each other. Some of the quarries has been developed since decades ago and had once been the area's leading economy. However, over time many new developments have been constructed around the limestone quarry area and some of them even located very close or next to quarry's boundaries. Of late, the quarry new neighbors have begun to feel uncomfortable with quarry routine blasting operations and started sending complaints to authorities. Therefore, it is critical to investigate the factors that may result in generating excessive blast effects to environment. This research is focus on identifying rock mass properties factor in affecting the blast design and its effects on the surrounding environment. To facilitate the study, a number of site investigations and laboratory tests were conducted. Two empirical models were also used to predict the environmental impact before final analysis and discussion were made. A limestone quarry in Selangor was chosen as the case study location. Blasting is a common technique used in quarrying, mining, and some civil engineering construction. Blasting is the controlled use of explosive materials to break up rock mass for excavation purposes, and the end result is commonly referred to as a rock-cut.

Environmental effects may occur at nearby settlements or other building structures, such as schools, houses, dams, or tunnels. The most visible environmental effects of quarry blasting operations are fly rock, ground vibration (PPV), and airblast overpressure (AOp) (Kuzu, 2008). The design of a blasting operation is critical in the fragmentation of rock for quarrying, mining, and civil engineering projects. When a blasting operation is carried out, the ground absorbs more than 85% of the released energy in the form of negative effects such as PPV, AOp, and flyrock (Khandelwal and Singh, 2009; Armaghani et al., 2016). The geological conditions in the blasted bench have a significant impact on the blasting operation's success and can cause flyrock to surrounding areas (Sastry, et al. 2015). Bedding planes in non-homogeneous rock layers can cause a variety of problems, including rock overhangs, unexpected muck pile height, toe problems, back breakage, and fragmentation differences, which can lead to excessive PPV, AOp, and Flyrock to surrounding areas if not properly controlled (Sastry et al., 2015).

In view of effects to the surrounding environment due to blasting especially quarries located very close to public buildings, an urban limestone quarry was chosen as a case study. Although the terrible blasting incident was occurred in a granite quarry but it still can be a good reference for a limestone quarry as both quarries shared many similarities in terms of rock physical characteristic.

1.2 Problem Statement

The potential environmental effects of blasting activities must be studied, primarily if the quarry is located near residential areas. Blasting effects such as airblast overpressure (AOp), ground vibration (PPV), and flyrock must be properly controlled and predicted to have the least impact on the environment. Blasting activities, if not properly controlled, can result in serious injury or death.

Many researchers agree that rock mass properties have great influence on the operation of rock explosion (Franklin et al., 1971; Lantham and Lu, 1998). When tropical rock masses such as limestone are subjected to climate change, the complexity of these parameters becomes critical, resulting in varying degrees of weathering and significantly alter the properties of limestone. Consequently, a limestone quarry would have various rock mass properties at certain distances or elevations and normally will affecting the blast monitoring results significantly. Therefore, the mapping works of rock mass properties and determining its relationship with blasting operation at the chosen study area are deemed important for better understanding in controlling the blasting effects thus reducing complaints from residents in surrounding environment.

1.3 Research Objectives

To have a better understanding on factors that causing excessive environmental effects due to quarry blasting operations. In order to perform this study, objectives are outlined as follows:

(a) To determine the rock mass properties involved in blasting works in limestone quarry.

(b) To empirically predict blast effect based on maximum and minimum explosive charge per delay, W_{max} and W_{min}.

(c) To investigate the effect of rock mass properties and blast design to the ground vibration (PPV) due to blasting.

1.4 Scope of Work

A limestone quarry in Rawang, Selangor was chosen because of its central location. The quarry, which is part of an integrated cement plant, has always been the target of complaints from nearby residents on blast effects due to blasting operations. The quarry is well developed, with a variety of bench heights in highly weathered rock.

Limestone is a type of carbonaceous rock. This study includes a review of the rock properties of sedimentary weathered rock that had previously been identified through numerous research studies. Based on this review, a method for investigating and identifying the rock mass properties in the quarry face was chosen. In order to have presentable data, the quarry face was divided into four sections. The segment that covered the majority of the active blasting area was divided into four sections: Section A (SA), Section B (SB), Section C (SC), and Section D (SD). Datasets such as multiple type of joints, and rock hardness were recorded at all sections. The collected samples were later sent to a laboratory for analysis.

The study was also involved blasting activities at all sections (A to D) on the quarry face. Impacts from the blasting operations were monitored and systematically recorded for further analysis. There are several stages involved in blasting i.e., before, during and after blasting. A total of 25 blast events was involved in this study. Furthermore, the blasting effect was assessed using two empirical methods: ground vibration (PPV) and deriving K and β for new site-specific constants. Subsequently, the final output was compared with the allowable limits established by the country's blasting regulators i.e., the Department of Mineral & Geosciences Malaysia (JMG) and the Department of Environment (DOE) Malaysia. Several correlations were established using the Statistical Package for Social Sciences (SPSS) software's analysis such as Linear Regression and General Linear Model. Therefore, the influence of rock mass properties and blast design to the environment was finally investigated and justified.

1.5 Significance of Research

Many researchers have been working on predicting blast effects for site-specific rock face for a long time. However, the study's accuracy was limited to that specific study area and was largely determined by a variety of controllable and uncontrollable parameters. The following are the anticipated benefits and advantages of the research study:

(a) The study shows the present condition of rock mass properties at the quarry through site investigation.

(b) The study will determine the prediction of blast effect to surrounding environment based on W_{max} and W_{min} and comparison with allowable limits set by relevant authorities.

(c) The study will justify the influence of rock properties and blast design on routine blasting operation and how its effecting ground vibration (PPV).

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