International Journal of Mining Science and Technology 25 (2015) 595–599

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Trend analysis and comparison of basic parameters for tunnel blast design models

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ARTICLE INFO

Article history:
Received 11 December 2014
Received in revised form 21 January 2015
Accepted 15 February 2015
Available online 9 June 2015

Keywords:
Blasting pattern
Tunnel blast design models
Specific drilling
Specific charge

ABSTRACT

One of the most important factors influencing on a tunnel blast efficiency is the proper design of blasting pattern. Among blasting parameters, blasthole diameter and tunnel face area are more significant so that any change in these parameters could finally affect on specific charge and specific drilling. There are mainly two groups of methods for tunnel blast design categorized based on the parallel cuts and angular cuts. In this research, a software for tunnel blast design was developed to analyze the effect and sensitiveness of blasthole diameter and the tunnel face area on blasting results in different blast design models. Using the software, it is quickly possible to determine specific charge, specific drilling and number of blastholes for each blast design model. The relations between both of blasthole diameters and the tunnel face area with the above parameters in different blast design models were then investigated to yield a set of equations with the highest correlations to compare the methods. The results showed that angular method requires more blasthole numbers than parallel method in similar condition (blasthole diameter and tunnel face area). Moreover, the specific charge values yielded by the two methods are approximately the same and very close together.

1. Introduction

There are some methods to design blasting pattern in tunnel faces and underground spaces. Notable attempts are currently underway to attain an appropriate blasting pattern and subsequently desired results. It is obvious that such pattern could lead to a significant reduction in blasting costs through lowering of any further corrections achieved by trial and error approach.

Tunnel blast methods can generally be classified as two groups: parallel cuts and angular cuts. The current research work investigates variation of effective parameters such as blasthole diameter and tunnel face area on blasting results in tunnels. In this regard, the relations between these parameters (blasthole diameter and tunnel face area) with a total number of blastholes, the number of blastholes per unit area of the tunnel, specific charge and specific drilling in different blast design models were investigated to yield a set of equations with the highest correlations to compare the methods. These investigations were carried out for 5 models from parallel hole cuts group and 4 models from angular hole cuts group leading to two sets of charts for comparing the relation between parameters in each method. The models to be investigated are energy balance, Swedish and NTNU models. The paper firstly outlines tunnel blast design models and then in the next section the software developed based on the models is introduced. Afterward, blast design parameters are calculated and achieved results are ultimately analyzed and compared together to determine the best results.

2. Brief description of tunnel blast design models

2.1. Energy balance model

Energy balance model (EBM) is a theoretical model developed based on energy transfer principle in which energy transfer law is a function of rock and explosive properties [1]. In this method, the tunnel face area is divided into three parts; opening or cut part (I), advance or production part (II) and profiling part (III), as shown in Fig. 1. It is stated that EBM has ever been applied to both parallel and angular hole cuts.

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http://dx.doi.org/10.1016/j.ijmst.2015.05.012
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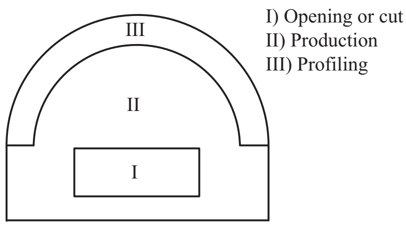

Fig. 1. Tunnel sections in energy balance model [1].

2.2. Swedish models

Longfors and Kihlstrom [2] presented a blast design based on dividing the tunnel face into several sections. After them, some researchers made further modifications and developed new models and equations in accordance with Langefors's primary idea. In these models, the tunnel face area is divided into five sections as seen in Fig. 2. These sections include cut, stoping sections, contour and lifters [3]. In this context, four-section cut type (Fig. 3) is considered as one of the most applicable parallel hole cuts. As typical Swedish models, there are some models such as Holemberg, Gustafsson, Olofsson, Konya and Lopez's models in which Konya and Gustafsson's models are used for both parallel and angular hole cuts, Holemberg and Olofsson's models as parallel hole cuts, and Lopez's models as angular hole cuts [4–6].

2.3. NTNU model

NTNU blast design model is an empirical model developed by the department of civil and transport engineering in Norwegian University of Science and Technology and used as a parallel hole cut. In this method, the tunnel face area is divided into cut, stoping (easers), lifters (invert), row nearest contour and contour. Smooth blasting with double contour blasting is recommended, i.e., the charging density in the contour and row near the contour is reduced. The essential parameters to be determined prior to design are as follows [7,8]:

- Rock mass blastability.
- Drill hole diameter.
- Drill hole length.
- Skill level of the tunnel crew.

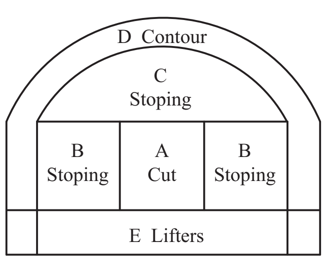

Fig. 2. Tunnel sections.

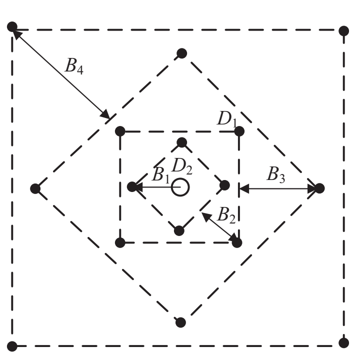

Fig. 3. Four-section cut type design [3,5].

3. Software developed to design blasting pattern

In order to do trend analysis and comparison of basic parameters for tunnel blast design models, a software was programmed based on visual basic code. The software consists of 900 code lines and is able to run in Windows 7 without installation of any specified program. The input parameters for the software are drill hole diameter and tunnel face area. Using the proposed software, the blast design parameters-total number of blastholes (n), the number of blastholes per unit area of the tunnel (Sa), specific charge (Sc) and specific drilling (Sd)-can be quickly calculated according to defined blasting models, as shown in Fig. 4. Energy balance (TOE-P), Olofsson, Konya-P, Holemberg and NTNU models used as parallel hole cut methods and Energy balance (TOE-A), Konya-A, Lopez and Gustafsson models used as angular hole cut methods through analysis. It should be stated that other input parameters considered similar by default, including:

- Tunnel section shape: rectangular with w/h ratio of 1.5, number of empty hole for parallel methods: one 102 mm-diameter hole per each cut, wedge-cut or V-cut has been used for angular methods.
- Explosive characteristics are as below:

Explosive type: Emolite, specific gravity: 1450 kg/m^3, detonating pressure: 1007 MPa, specific energy: 4.52 MJ/kg, impedance: 9.5×10^6 kg/(m^2 s), weight ratio to ANFO: 1.1.

- Rock geomechanical properties are as follows:

Rock type: limestone, specific gravity: 2600 kg/m^3, impedance: 10.4×10^6 kg/(m^2 s), surface energy: 1.47×10^{-3} mJ/m^2, tensile strength: 6 MPa, rock constant for Holemberg model (c): 0.4, rock blastability for NTNU model: good.

Moreover, according to previous studies, average hole length assumed 3.2 m and half of the tunnel width for parallel and angular hole cuts, respectively. Meanwhile, advance rate for all methods considered as 90% of length of holes which are parallel to tunnel axis.

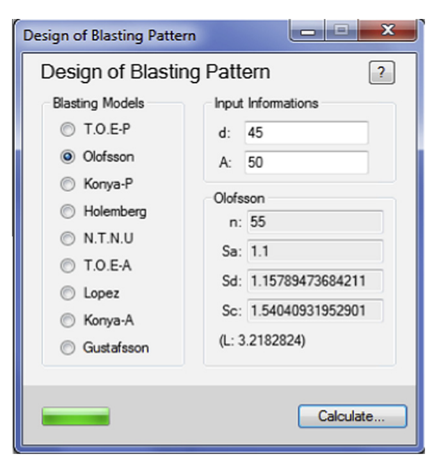

Fig. 4. An example of blast design using proposed software.