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CAUSES OF DYNAMIC OVERBREAK AND CONTROL MEASURES TAKEN AT THE ALBORZ TUNNEL, IRAN

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ABSTRACT: Drilling and blasting is widely used in underground excavation projects, where the amount of damage to the surrounding rock mass is crucially important, due to its impact on the safety of working environment and operational costs,. The causes of overbreak in the Alborz Tunnel of Iran are evaluted. In this regard, ten rounds of presplitting and 11 rounds of smooth blasting methods were carried out to determine the dominancy of ground condition over the blasting pattern characteristics. Further study was undertaken to identify the most important parameters of ground condition affecting the overbreak area. These parameters include; joint condition, spacing, orientation, RQD and type of rock mass. As the characteristics of the blasting pattern have very little effect on the amount of overbreak, the smooth blasting technique was chosen for the future operations where the current ground condition is going to be dealt with for about 500 meters of length, based on the data acquired from the Alborz Exploratory Tunnel. Results of this investigation helped to solve disputes between contractors and clients over the issue of permissible overbreak.

INTRODUCTION

Overbreak is the result of damage to surrounding rock mass, which can be quantified as the extra cost involved in additional removal of muckpile and the application of extra support. Overbreak either occurs immediately after blasting or within time durations, which are dynamic and quasi-static type respectively (Mandal and Singh, 2009).

As an undesirable phenomenon in underground construction practices, overbreak can occur due to the effect of the ground conditions and the nature of excavation operations (Ibarra *et al*., 1996). However, the factors influencing the smoothness and softness of the perimeter can be classified into four categories namely: drilling accuracy, perimeter hole spacing and loading (charging), treatment of first-row-in holes and geology (McKown, 1984). A summary of factors affecting overbreak is depicted in Figure 1. The occurrence of excessive overbreak can incur an additional cost for controlling the percent of overbreak, which is crucially important in any underground excavation project. Thus, during this investigation, smooth and presplitting methods of blasting were carried out to minimize the overbreak percentage in the Alborz Tunnel of Iran. The nature of overbreak after carrying these different blasting patterns was analyzed and decisions made towards the causes of dynamic overbreak.

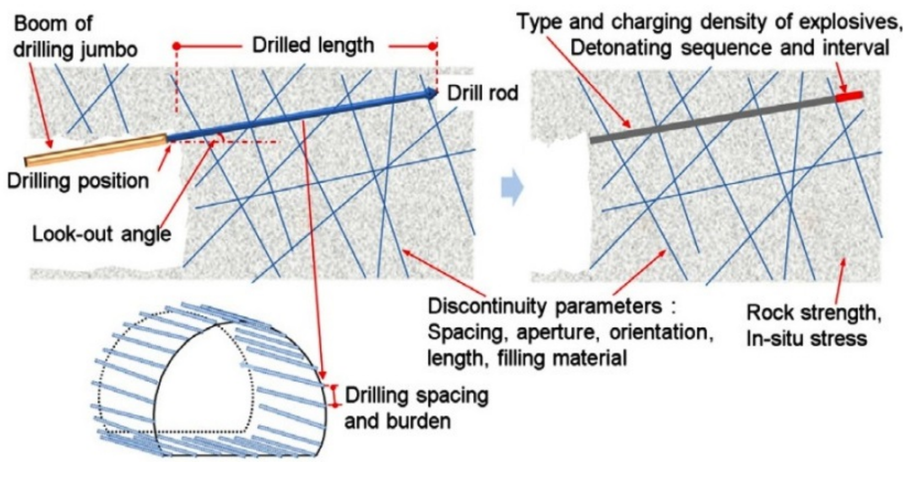

Figure 1: Summary of the causes of overbreak (Kim and Moon, 2013)

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Case study

The Albroz Tunnel is the largest one with an approximate length of 6400 to be excavated along the Tehran-Shomal freeway in Iran. The rock mass type blasted during this study was Tuff. A combination of black and grey Tuffs comprise the face of the excavation, where the uniaxial compressive strength of rock material for both types varies from 70 to 120 MPa. The thickness of alternative Tuff layers differs from 60 to 600 mm and the orientation of these layers with regard to the tunnel axis is fair as reported by Wickham *et al.,* (1972). Three different joint sets exist in addition to bedding surfaces. The characteristics of these discontinuity sets are presented in Table 1. The geomechanical evaluation of Tuffs of the Alborz region of Iran is reported by Yassaghi *et al*., (2005). A schematic view of the alternation of black and grey Tuffs is displayed in Figure 2.

Table 1: Properties and condition of discontinuities of the rock mass under investigation

System	Type	dip/dip direction	Roughness		Spacing (cm)
I	Bedding	15/244	Smooth	undulating	6 - 50
II	Joint	65/090-086	Smooth	planar	35 - 45
III	Joint	78/140	Slightly Rough	planar	20 - 25
IV	Joint	84/183	Slightly Rough	planar	15 - 18

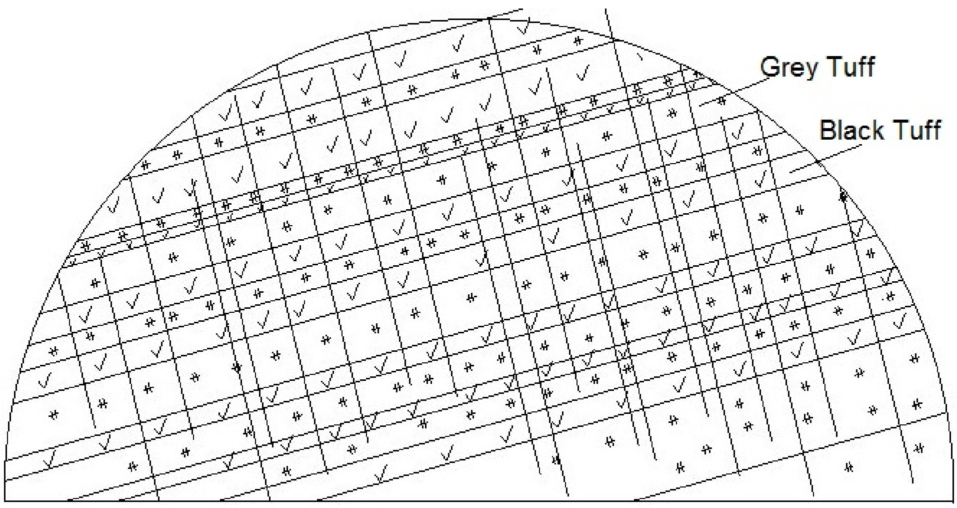

Figure 2: bedding condition in the face of excavation (schematic view)

Blasting practices in the alborz tunnel

As the characteristics of contour holes have a great influence on the results of blasting with respect to overbreak and underbreak, the presplitting and smooth blasting methods of controlled blasting were carried out in the Alborz Tunnel to acquire the intended tunnel profile with minimum possible overbreak. The characteristics of contour holes in the blasting patterns for both presplitting and smooth blasting are presented in Table 2. The implementation of these blasting patterns was strictly supervised in both drilling and charging stages ensure the accurate execution of designed patterns for 21 blasting rounds. However, the results of blasting did not cause any noticeable changes in the amount and nature of the overbreak due to the orientation of bedding with the tunnel axis. The acquired tunnel profile after each blasting round (either by pre-splitting or by smooth blasting) was as depicted in Figure 3, obtained via electronic surveying. Figure 4 shows the charging process and post blast profile of the tunnel. The dominancy of ground condition over the blasting pattern condition was concluded as a result of performing different controlled blasting methods. Therefore, it should be noticed in the definition of permissible overbreak for this section of the Alborz Tunnel, to consider the right values of constants to represent the ground condition, as suggested by Ibbara *et al.,* (1972). The difference in the amount of overbreak in right and left sections of the tunnel profile shows the effect and dominancy of ground condition over blasting pattern characteristics. The mechanism of overbreak in right section is due to sliding whereas it is due to block failure in left part. Due to the dominancy of ground condition on the overbreak the smooth blasting method is preferred compared to pre-splitting as it needs less drilling holes.

Table 2: Characteristics of contour zone in presplitting and smooth blasting methods performed in the Alborz Tunnel

Blasting method	Spacing (cm)	Charge density in drill holes (kg/m)	Hole diameter (mm)	Charge diameter (mm)	Powder factor of contour zone (kg/m^3)
Presplitting	50	0.24	51	27	0.44
Smooth blasting	70	0.2	51	27	0.28

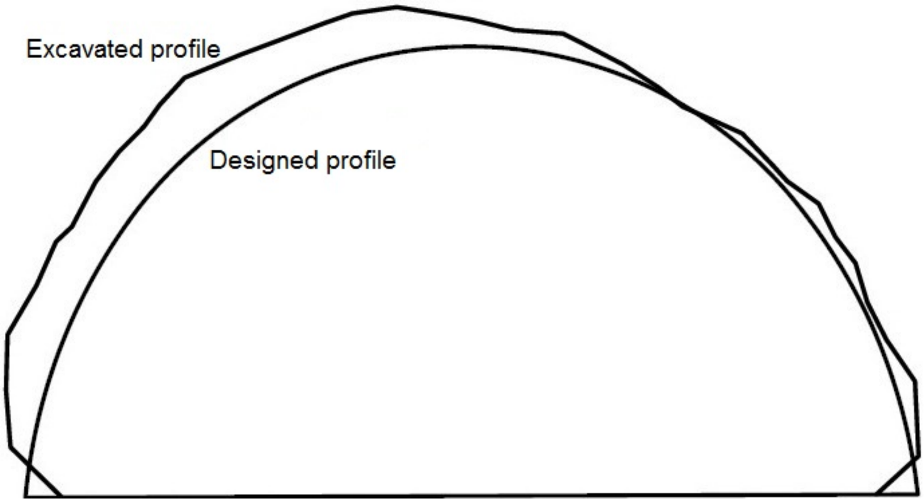

Figure 3: Overbreak of blasting rounds in the Alborz Tunnel

Geological causes of overbreak

The results of the presplitting and smooth blasting techniques revealed the dominancy of geological conditions over blasting patterns on overbreak occurrence in the study area. Therefore, a further study was carried out to determine specific causes of overbreak related to geological conditions which can be of great importance in future uses of presplitting and smooth blasting techniques in the Alborz Tunnel as well as any other tunneling cases.

Figure 4: Charging process and resulted profile after blasting

A wide range of research has been carried out to obtain a reliable method for determination of the amount of damage and overbreak on the surrounding rock mass caused as a result of blasting. Almost all parameters, used for determination of damage level to surrounding rock mass, are related to ground condition, showing the importance of geological features as the main cause of overbreak. Some of these parameters include Peak Particle Velocity (PPV), rock density, P-wave velocity, dynamic tensile strength of rock, site quality constant, Young's modulus, uniaxial tensile strength of rock, joint orientation and rock mass strength (Langefors and Kihlström, 1967; Holmberg and Persson, 1979; McKenzie, 1994; Yu and Vongpaisals, 1996; Innaurato *et al*., 1998; Johansen and Mathiesen, 2000). Jointing is the most critical aspect of stability and damage level to the surrounding rock mass and thus the stability of underground structure should be considered in terms of joint condition, spacing and orientation (Cunningham and Goetzsche, 1990). The following are some likely results of some investigations on the causes of overbreak in underground blasting, in cases with ground condition similar to the Albroz Tunnel.

- Excessive overbreak can occur where open joints containing gouge are encountered (Cunningham and Goetzsche, 1990).Filled open joints are present in parts of the Alborz Tunnel under investigation.
- Noticeable overbreak even in case of low values of powder factor and high advance per blast can occur in weak and fair rocks (Chakraborty *et al.,* 1994). The rock mass under this investigation is categorized as fair rock mass.
- The surrounding rock mass will be prone to excessive overbreak as the result of blasting if the Rock Quality Designation (RQD) index of rock mass is lower than 70% (Cunningham and Goetzsche, 1990). The RQD of the surrounding rock mass in this study is 60%.
- The excavation profile can be controlled by joint orientation to such a degree that it can be worthwhile to either change the design profile, or alter the position or orientation of the excavation. This would be of great importance if the plane runs diagonally across the tunnel and parallel to it (Cunningham and Goetzsche, 1990). Almost the same situation is present in the area covered by this study.
- Joint orientation of 60^o to 90^o, preserving the intended shape of the tunnel would be very difficult. The situation probably will be beyond blasting control for joint angles less than 15^o (Cunningham and Goetzsche, 1990). Joint angle is less than 15^o in the area under this investigation.
- Perimeter problems can be expected in the jointed rock mass, where the drilling pattern is wider than the joint spacing (Cunningham and Goetzsche, 1990). Due to very small spacing of the beddings and joint sets, the drilling pattern was wider than the joint spacing in the area of this study.

The quality of surrounding rock mass is therefore determined as the most dominant affecting parameter on the percent of overbreak in the study area. The same condition of surrounding rock mass in the Alborz Tunnel is going to be dealt with for about another 500 m based on the geological maps obtained from the Alborz Exploratory Tunnel. Thus, the obtained results from this research can be very helpful in dealing with blasting pattern design, overbreak considerations and disputes between the contractor and client over the issue of permissible overbreak.

RESULTS AND CONCLUSIONS

Different causes affecting overbreak were analyzed in the Alborz Tunnel using controlled methods of presplitting and smooth blasting. Two blasting methods were carried out for 21 rounds of blasting (10 rounds of presplitting and 11 rounds of smooth blasting) the results of which are as follows:

- The excavated profile after each blasting round was almost the same as other rounds of blasting for both presplitting and smooth blasting methods showing that the nature of blasting patterns have very little influence on the percent of overbreak due to dominancy of the ground condition.
- The differences between the nature of overbreak in the right and left parts of the cross section occurred as aconsequence of bedding orientation with regard to tunnel axis. These states of overbreak also proved the dominancy of ground condition over the blasting pattern characteristics.

- As there is no considerable change in the percent of overbreak, the smooth blasting method was chosen to be carried out in the blasting patterns due to its lower drilling requirements compared to presplitting method.
- Joint condition, orientation, spacing, RQD and rock mass type, as the factors defining ground condition, were determined to be the most important factors influencing the results of blasting as follows:

1. Joint condition: Open joint sets were encountered.
2. Joint orientation: The angle of discontinuity sets with regard to tunnel axis was less than 15^{o}
3. Joint spacing: Very small joint spacing led to a condition where the drilling patterns were wider than joint spacing.
4. RQD: was less than 70 %
5. Rock mass type: the strip surrounding rock mass caused noticeable overbreak even with low values of powder factor.

As the current condition of ground is going to be dealt with for about another 500 m of length, the results of this investigation will be very helpful in determination of permissible overbreak and solution of disputes between the contractor and the client.

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