

FACTORS INFLUENCING THE OCCURRENCE OF FLYROCK PHENOMENA ON SURFACE MINES – CASE STUDY

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Abstract

Drilling and blasting, which involve the application of explosive energy to fragment the rock mass, represent one of the most employed methods of extracting mineral raw materials in surface mines. However, blasting activities can generate potential hazards, the occurrence of which is influenced by various factors. These factors can be categorised into three primary groups: natural factors (mining-geological conditions in the deposit), technical-technological factors (depending on the rock mass extraction technology) and the human factor (related to operator expertise and procedural adherence). The consequences of such events may lead to significant material damage, including harm to mining machinery, surrounding infrastructure, and even pose risks to human health and safety. On the example of the "O2" quarry, the factors that influenced material being propelled outside the safety zone defined by verified mining documentation were observed. A comprehensive risk assessment was subsequently performed to identify the underlying causes of these deviations, highlight procedural deficiencies, and prevent further incident events, i.e., for risk mitigation.

Keywords: flyrock phenomena, blasting, safety, risk assessment, risk mitigation

1. INTRODUCTION

Explosive energy is one of the most employed methods for extracting mineral resources in quarries. Blasting activities, however, can pose potential hazards, most notably flyrock phenomena, air shock waves, and seismic effects, i.e., ground vibrations like earthquakes. Several factors, including natural conditions, technical-technological parameters, and human factors, can impact the results of a blast and increase the likelihood of associated hazards. The consequences of these events can have a significant impact, potentially causing damage not only to mining equipment and nearby structures but also posing a serious risk to human health.

Various authors have studied accidents related to the causes of hazardous incidents during blasting operations [1,2]. Furthermore, before conducting a blast, it is possible to analyse all relevant factors that may influence flyrock phenomena, thereby reducing the potential for damage [3,4,5].

In this study, through the analysis of the "O2" quarry, the previously mentioned factors influencing flyrock phenomena beyond the designated safety zone were analysed to determine which had the greatest impact. The goal was to identify the primary contributors to flyrock phenomena to prevent future incidents and reduce overall risk.

The "O2" quarry is in the northwestern part of Croatia (Figure 1a) is covering a total area of 30 ha. The analysed blast site is situated in the south-west part of the quarry, at an elevation of +440 meters above sea level (Figure 1b).

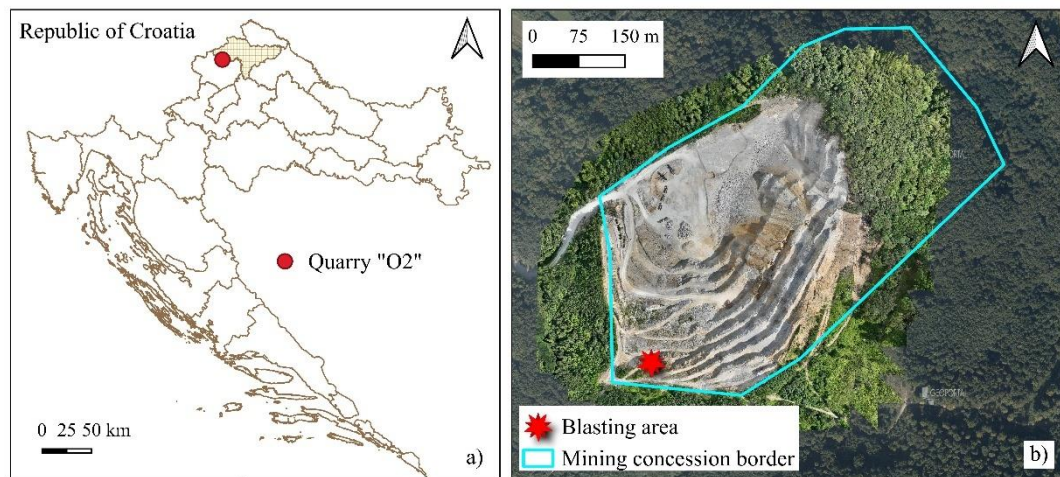


Figure 1. Site location of "O2" quarry and blasting area

2. METHODOLOGY

To minimise the occurrence of incidents related to blasting activities, the factors contributing to flyrock phenomena in the quarry were analysed. The negative effects of blasting operations are influenced by several key factors [6,7]: natural factors, such as the mining and geological conditions of the deposit; technical-technological factors, which involve the blasting technologies and operational procedures; and individual (personal) factors. The presence of any one of these factors can increase the likelihood of hazardous outcomes during blasting operations.

2.1 Potential Hazard Occurrences – Defining Safety Zones

Clearly defined safety zones for all potential blasting-related hazards are essential to protect people, buildings and machinery in and around the quarry. Safety zones are established based on mining design [8]. Accordingly, the safety zone for air shock waves is defined as 85 meters, while the safety zone for flyrock extends to 353 meters. Seismic effects of blasting were assessed through ground vibration velocity measurements, which confirmed that the recorded particle velocities at observation points did not exceed 5 mm/s [8].

2.2 Influential Factors

Mining and Geological Factors

The rock mass extracted from "O2" quarry consists of late diagenetic dolomites from Anisian (Middle Triassic), light grey in colour, massive, and of homogeneous texture. The "O2" quarry also contains clastic rock deposits from the Lower Triassic, Ladinian (Middle Triassic), and the Lower Miocene.

The primary discontinuity is defined by bedding with a general strike direction from E-W to SE-NW and a dip towards the S to SW at angles ranging from 30° to 40°. The bedding is often not well-defined due to numerous secondary discontinuities, which have caused the rock mass in the surface weathering zone to fragment into pieces approximately 5 cm in size. The engineering-geological characteristics of the rock mass in the quarry, along with experience from the nearby closed quarry, indicate that unstable slopes and block detachment can be expected. The stability of the slopes is further influenced by increased infiltration of rainfall due to the intersection of gullies, along which surface water, before the development of quarry benches, drained into a stream located north of the mine [9].

Technical-technological factors

Technical-technological factors and factors related to the working environment influence the execution of a specific task, in this case, the drilling of blast holes, their outfitting, and the activation of the blasting field. Technical and technological factors include the location of the worksite, the equipment layout, and the accessibility and visibility of the equipment used, while working environment factors encompass the physical and chemical parameters of the surroundings [7]. Since the work is carried out outdoors, the prevailing conditions are often very unfavourable, affecting human labour and behaviour, specifically regarding safety and the potential for accidents.

Individual Factors

Personal (individual) factors are human factors in the strictest sense, as they stem from the basic characteristics of each person (e.g., age, gender, health status, expertise). Individual factors contribute to accidents, as they often represent a lack of certain abilities, insufficient knowledge to perform a task, fatigue, stress while working, etc. [7]. Given the demanding working conditions during drilling and blasting operations, it is assumed that the likelihood of an accidental situation arising during blasting is the same regardless of who is performing the task.

3. RESULTS AND DISCUSSION

As a result of blasting in the southern part of the "O2" quarry, rock material was projected beyond the defined safety zone at over 500 meters. This caused damage to a residential building and a parked vehicle (Figure 2).



Figure 2. Damage caused by flyrock: a) damaged vehicle in an employee parking lot (525 m), b) damaged roof of residential building 10

Figure 3 shows the location of the analysed blast site, the geology of the immediate area of the surface mine, the defined safety zones and surrounding structures.

The occurrence of flyrock (shown by yellow arrows in Figure 3) was largely influenced by the drilling parameters of the blast holes. Due to the drilling operator's limited experience, the holes were connected at the bottom of the bench. The first row of holes was drilled at a 70° angle, and the second row at a 60° angle. Additional influence came from the geological setting, as the blast site is located at the boundary between massive grey dolomites and the weathered zone (Figure 3), resulting in lithological heterogeneity within the blasting area and variable explosive performance. Furthermore, the terrain configuration favoured the extended range of the flyrock. The blast site is positioned at +440 m above sea level, whereas the damaged structures are located at +250 m above sea level. The analysis indicates that all contributing factors, to varying degrees, played a role in the occurrence of flyrock.

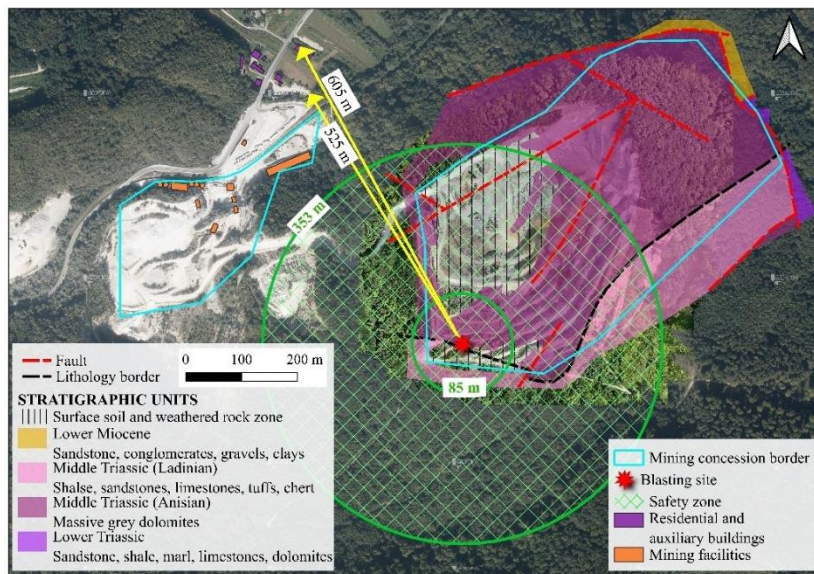


Figure 3. Safety zones, in conjunction with the geological map [9] and the presence of flyrock

4. CONCLUSION

In the case of the "O2" quarry, mining-geological, technical-technological, and individual factors were analysed, all of which influenced the occurrence of flyrock during blasting. Each of these factors contributed to the potential hazards and damage to varying extents; specifically, in the analysed case, this resulted in damage to a residential building and a vehicle. Analysing each factor individually and its mutual effects is essential to prevent similar incidents in the future blasting operations.

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