



# Safety risk assessment of Iran's dimension stone quarries (Exploited by diamond wire cutting method)



Reza Yarahmadi\*, Raheb Bagherpour, Amir Khademian

Department of Mining Engineering, Isfahan University of Technology, Isfahan, Iran

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## ABSTRACT

Mining is among the most hazardous activities all around the world, being always accompanied with different incidents, injuries, loss of lives, and property damages. Dimension stone quarrying constitutes a big portion of mining activities in Iran owing to 1379 different quarries with twenty thousand employees. Therefore, risk assessment is an important consideration in these mines and it should be accompanied with adjustment approaches. During this study, Judging from filled out questionnaire by relevant experts, dangerous incidents of quarries were recognized and safety risk of them has been assessed. Incidents risk ranking showed that traffic accidents, cutting wire rupture and rock fall were in order of magnitude the greatest risk sources or reasons, respectively. To manage the risks, some regulations were followed to adjust safety risks. Machinery or man fall from bench crest and rock fall were the most influential incidents due to these regulations. The average safety risk of quarrying has calculated as 31.8 and 11.7 out of 100 before and after adjustment. This amount of total risk reduction (63.3%) showed the importance of risk management.

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## 1. Introduction

Mining is a substantial economic sector in many countries in terms of both producing needed raw materials of other industries and its great role in the economy. At the other hand, dealing with many uncontrollable parameters during handling natural and intense materials makes mining one of the most hazardous part of the industry. These hazards threat men and machinery which leads to limitations in production and economy of the mine. Quarries are no exception to this rule so this study aims to perform safety risk assessment of diamond wire cutting process in Iran's dimension stone quarries as well as employing some adjustment approaches to reduce these risks.

Among different kind of mining including underground, surface and quarry, the former is notorious for its high accident rates especially in coal mining (Saleh and Amy, 2011). Therefore coal mines safety has been discussed in literature more than any kind of mine. Latest researches in this area are those done by Paul and Maiti (2007), Margolis (2011), Khanzode et al. (2011), Kinilakodi and Grayson, 2011, Qun and Hong (2013) and Bahn (2013) who tried to evaluate hazardous underground mining activities.

Surface mines have their especial incidents too which have been investigated by many researchers. Ural and Demirkol

(2008) assessed working incidents and injuries in Turkey surface mines. Results showed that nearly 10% of employees were injured during activity. Another different effort in this area was by Groves et al. (2007) and Yenchek and Sammarco (2010) who worked on the influence of electricity and lack of lighting on incident and casualties in USA mines.

Dimension stone quarrying is a hazardous branch of the mining activity insofar as it has been reported that coal mines and quarries possessed the highest rates of incidents as compared to others (Yenchek and Sammarco, 2010). There are serious incident both during cutting rock from bedrock and transporting and handling it in quarries. The high frequency of these incidents is due to high weight and intense nature of dimension stones alongside necessity of exploiting them in blocks. Besides, Dimension stone quarrying constitutes a big portion of mining activities in Iran owing to 1379 different quarries with twenty thousand employees. According to Statistical Center of Iran's annual report in 2011, 189 incidents occurred in Iran's dimension stone quarries which left 186 injuries and fatality (SCI report, 2011). Therefore, reduction in hazards is an important consideration in these mines as it can lead to the development of production and subsequently, improvement of country's economy.

Joy (2004), Robson and Bigelow (2010), Onder et al. (2011) carried out some investigations on past incidents in dimension stone quarries. Gumus and Akkyun (2006) worked on occupational accidents of marble quarries in Turkey's Diyarbakir province. According to the results, 42.9% of incidents were due to cutting

\* Corresponding author. Tel.: +98 03113915118.

E-mail address: [r.yarahmadi@mi.iut.ac.ir](mailto:r.yarahmadi@mi.iut.ac.ir) (R. Yarahmadi).

wire rupture, 17.8% due to blasting and 3.6% were because of fall from bench. 10.7% of these incidents resulted in death. They also reported that there was a higher rate of injuries in illiterate workers compared to engineers.

Ersoy (2013) worked on occupational safety evaluation in marble quarries of Turkey. In his study, 10 quarries have been examined in terms of job safety, according to the occupational accident statistics of the quarries for 10 years and some safety measures are also introduced for each incident. He concluded that 40% of incidents in these mines were so dangerous for workers.

These studyings implemented different investigation approaches toward hazards and incidents in mines. Most of them, by considering number of incident in a special period of time, performed a safety performance evaluation procedure. Focusing on occupational incidents frequency and neglecting their corresponding consequences is the weakness of such approaches which is frequently used in today's mining organizations. Some cases implemented risk in their work indirectly like some researches in coal mining which imply risk concept by assessment of severity of occupational injuries. The number of days lost as a result of an injurious incident was the proxy measure of injury severity in their study (Hull et al., 1996; Komljenovic et al., 2008). There are some other cases especially in Australian mining which directly focuses on risk management approaches through some risk matrixes (Joy, 2004).

This study aims to offer a different approach by examining safety risk through risk assessment, rather than a safety performance evaluation. It seems that evaluation of incidents' probability of occurrence and their damages, followed by calculation of safety risk by available mathematical formulas, provide us with a more accurate understanding of occupational safety risks. Therefore, this study intends to assess safety risk of diamond wire cutting process in Iran's dimension stone quarries by employing this approach. This paper also demonstrates how the assessment of risk can be used to inform risk adjustments, thus making a significant contribution toward risk reduction and improved safety measurement in quarries.

## 2. Exploitation by diamond wire cutting method

Dimension stone is a natural stone selected or fabricated (i.e., cut, trimmed or others) to specific shape and size like blocks and slabs (Thrush et al., 1968). Dimension stones, which are widely used in building industry, can be divided into two major sections of calcareous and granites in Iran. Calcareous group includes sedimentary stones such as travertine and marble while all of igneous stones go to granites group. Because of numerous benefits of natural stone against artificial materials like mosaics, ceramics and artificial stones, their consumption had an increasing growth in the world. Total world dimension stone production in 2010 reached 115 million tons in 30 producer countries. 73% of this amount belonged to 5 major producer countries (ordered by production level: China, Turkey, India, Iran and Italy). If the average price of dimension stone could be assumed to be about 189 \$ per each ton, the value of this world market could be estimated to be as much as 21.8 billion dollars (Dolley, 2012). Known reserves of Iran's dimension stones reaches 3.7 Milliard tons, 3.3 billion of which has already been proved and the rest is likely.

The use of method and technology play an important role in safety and economic efficiency of dimension stone quarries. Removing major blocks from the ground and cutting them to smaller blocks are the main objectives of dimension stone exploitation. In the past, different exploitation methods including handy exploitation, plugs and wedges, cutter disks and blasting were used in quarries. A very low efficiency, high operating costs and lots of

safety risks are among the disadvantages of these methods. Nowadays most dimension stone quarries, especially calcareous ones, employ diamond wire cutting and in some cases, chain saw machine in Iran and all around the world. The important point on the efficient usage of diamond wire cutting is to produce blocks at minimum cost by adjusting the effective cutting parameters adequately (Özçelik, 2005). Fig. 1 shows a dimension stone quarry exploited by diamond wire cutting method.

Diamond wire cutting machines have been used in marble industry since 1985. They have affected the production rate and efficiency considerably (Özçelik et al., 2002). Today, they are widely used in more than 90% of the natural stone quarries (Yilmazkaya, 2007). In diamond wire cutting machines, cutting process takes place through some abrasive diamond wires. The diamond wire is simply a steel cable on which small beads bonded with diamond abrasive are mounted at regular intervals with spacing material being placed between the beads (Özçelik and Kulaksız, 2000). The diameter of diamond wire and steel cable is 10–12 mm and 5 mm, respectively. Number of beads varies between 30 and 35 per meter of the wire, making intervals between 25 and 32 mm. An automatic control panel controls cutting machine parameters such as rotation, tension force and speed. The power of cutting machine is supplied by an electrical engine that makes a drive wheel to rotate the diamond wire. The whole cutting machine is mounted on a rail that enables it to move back and forward. A schematic view of diamond wire cutting method and cutting wire can be seen in Fig. 2.

## 3. Quarries safety risk assessment

Calculation of incidents' occurrence probability is not sufficient during safety evaluation of mines and incidents consequences ought to be considered as well. Both of these parameters are involved in risk management. Risk is the uncertainty and lack of awareness about the consequences of an action or incident. This consequence can lead to loss or benefit. This study evaluated the safety risk in quarries so consequences would be from harmful kinds. Risk assessment counts an important stage in every economical or industrial activity. Since mining activities are always accompanied with incidents and hazards for men and machines, assessment and prevention of likely incidents for safety risk assessment are inevitable. Safety risk, which is defined as the amount and importance of the hazard, can be calculated by means of probability of incident occurrence and the amount of consequences. The overall amount of risk can be measured by Eq. (1):

$$R_i = P_i C_i, \quad R_x = \sum_{i=1}^n P_i C_i \quad (1)$$



Fig. 1. An active dimension stone quarry in Iran (Joshagan marble quarry).

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