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Overview: Health and Safety in the Italian dimension stone quarrying industry

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When it comes to human health and safety, the extractive industry represents one of the most hazardous activities. When accidents occur in mines, quarries or processing plants, consequences are usually very serious. A description of Italy's state of the art is made herein, with a special focus on occupational injuries occurred during the 2012-2019 period of time as well as fatal injuries of the last eight years. The mining and quarrying economic activity had been intensely scrutinised and its outcome was further applied to the 5 economic division as per NACE classification. A further investigation was lead on the quarrying of stone, sand and clay, which is the most affected division with regard to occupational safety. The causes of fatal accidents of the past six years, were analysed and reported in this treatise. Based on the outlined data, the study aims to assess the main safety risks linked with the mining and quarrying industry with a focus on the Dimension Stone sector. It also analyses the diamond wire sawing process in more detail. Suggestions and ideas are offered to mitigate risks.

Keywords: *extractive industry, occupational health and safety, risk assessment, diamond wire, occupational injuries.*

1. Introduction

The extractive industry is a very strategic sector of the global economy. The 2019 global mine production (non-fuel minerals) has been estimated to an amount of more than 60 billions metric tons (USGS, 2020). Italy is a state of the art Country with regard to mining and quarrying technologies, and it has been reported to have the world's finest extractable and processing plants technologies (Montani, 2019).

According to the data published by the National Institute for Insurance Against Industrial Injuries, the number of employees involved in the mining and quarrying sector is about 50,000 units in Italy, a data which raises questions and concerns about occupational health and safety (last procurable year 2018, INAIL, 2020). Even if fatality is a very limited risk – due to a widespread culture which continues to regard the wellbeing and safety of workers as top priority – efforts should be made to reduce that risk to zero.

One of the industry characteristics is the safety risk which is directly linked to operations (Saleh and al., 2011). Unfortunately, Mining and Quarrying seems to be one of the most dangerous industries to work in.

As a matter of fact, the main damage suffered by the mining and quarrying workers exposed to occupational and safety risks include: death – fracture –amputation of an arm, hand, finger, thumb, leg, foot or toe – permanent loss of sight or reduction of sight – crush injuries leading to internal organ damage – serious burns (covering more than 10% of the body, or impairing the sight, respiratory system or other vital organs).

Table 1 shows the Accident Frequency Index (AFI is the statistic parameter that represents the number of indemnified injures/1,000 workers/year) for the construction, transportation and mining and quarrying sectors, and includes Permanent Disabilities and Fatalities (ANMIL, 2017). The data show that in the case of mining and quarrying sector the AFI for Permanent Disabilities is lower than the corresponding values of the construction and transportation sectors, while the AFI for Fatalities is the highest.

The AFI values demonstrate that even if the surface and underground mineral-extracting industries constitute an area of activity likely to expose workers to particularly high levels of risk, it is not the most hazardous one, despite the fact that the consequences of accidents are usually very serious.

With the objective to reduce the number of casualties to zero, it is fundamentally important to assess risk (MSHA, 2017). The productive chain must be analysed, different phases need to be specified, risks identified and safety measures applied to reduce such risks, in order to obtain a specific product, for instance rock blocks, with a level of efficiency that allows the maximum safety for workers (Joy, 2004; Ural and Demirkol, 2008).

In this study, the highest safety

Tab. 1 – Italian Accident Frequency Index of different industrial activities.

Accident frequency index		
Industry	**Permanent disability**	**Fatality**
Construction	3.78	0.10
Transportation	2.37	0.08
Mining and quarrying	1.87	0.11

risks during mining and quarrying activities are indicated and statistics data about work injuries which occurred in the past eight years in Italy are reported and evaluated. Fatal accidents causes occurred in the past six years were analysed in the division about the *quarrying of stone, sand and clay* in this treatise. Furthermore, the risk linked to the diamond wire sawing process is analysed more in detail and the potential cause of the accident identified and technical reduction solutions are examined.

2. General considerations

Accidents in Dimension Stone production quarries can be related to specific fields and causes (Ersoy and Yesilkaya, 2016); the main causes of accidents can be subdivided as follow:

- fall of workers to a level below the one they are working on;
- fall of workers in work areas with pedestrian circulation;
- hitting moving objects, getting caught on or between objects;
- falling off the edge of the excavation due to the work-face collapse, resulting in the crushing at the foot of the work-face;
- projection of fragments or parts, misuse of tools;
- direct or indirect electrical contacts;
- burns caused by hot machineries or utensils;
- explosions;
- thermal stress, exposure to extreme temperatures;
- noise;
- vibration;
- dusts, fumes or vapors.

Other problems could be related to occupational diseases caused by other physical agents, excessive efforts, physical and/or mental fatigue.

Other accidents can be related to road traffic in and out of quarries (Careddu and Siotto, 2011). In 2014, Espírito Santo State (Brazil) approved a series of decrees that set out rules for the dimension stone industry to monitor and control mining practices and safety criteria pertaining to the transportation of blocks, but accidents have continued (Macedo *et al.* 2018). University de Vigo and Politécnica de Madrid developed a software tool named Rock-fall risk assessment for quarries – ROFRAQ, that will help quarries to prevent accidents resulting from rocksfall (Alejano *et al.*, 2008).

An increasing number of companies have become more sensitive to issues related to productivity, training, health and safety, comfort level of employees and reduction of occupational accidents. Corporate responsibility towards this kind of issues has become more widespread (Pires and Amaral, 2014).

It should be noted that, "geological accidents" are likely to exist in the rock mass where the quarry is opened: although the studies on the rock mass may be in-depth, it is not possible to know it entirely, there will still be uncertainty. In this case, individuals could be not directly accountable for such accidents because it's possible that they are not caused by human responsibility or fault. On the contrary, the responsibility of all accidents which occur in stone-processing plants is only human.

Ersoy (2015) examined the causes of occupational accidents under the aspects of the environmental conditions, the machine-related factors, and the human behaviours.

Generally, the applications of measures to prevent occupational accidents vary depending on the legislation implemented in different countries. Worldwide mining laws must take into consideration health and safety issues (Careddu *et al.*, 2019b). The European Union has promulgated various directives, especially on safety and health protection of those working in the mineral extracting industries (European Communities, 1992), such as the Council Directive 92/91/EEC of 3 November 1992 concerning the minimum requirements for improving the safety and health protection of workers in the mineral-extracting industries through drilling and Council Directive 92/104/ EEC of 3 December 1992 on the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries.

2.1. Italian overview of mining and quarrying health and safety

European countries have all different mining laws, although each one has to follow the EU directives.

Based on the Council directives 92/91/EEC and 92/104/EEC, in 1996 Italy adopted the Italian legislative decree number 624 which deals with measures aimed at preventing the safety and health of the workers involved in the mineral-extraction activities in caves and mines, as per article 2 of the Royal Decree of 29 July 1927, nr. 1443 and subsequent amendments.

Other current specific rules are too dated: these are the above-mentioned Italian Royal Decree No. 1443 of 29 July 1927 and the Decree issued by the President of the Republic of Italy No. 128 of 9 April 1959.

Nowadays, Italy's reference directive on health and safety protection of employees in the workplace is the Legislative Decree nr. 81 dated 9 April 2008. This *Code* can be applied to all kinds of activities and risks, as well as to all workers. Unfortunately, it is still unclear which regulatory references apply to the mining and quarrying

safety. At this stage, significant interpretation problems emerge and it would be advisable to deepen, improve and unequivocally determine the roles, functions and competence of those who carry out specific tasks in the companies.

With regard to the economic activity coded B *Mining and Quarrying*, health and safety data is published by INAIL (Italy's National Institute for Insurance against Accidents at Work) as per last year procurable 2019. The data, which is classified by the Statistical Classification of Economic Activities in the European Community, has been elaborated for this treatise and an overview has been summarized hereinafter.

The European classification of Economic Activities divides the mining and quarrying economic activity into five divisions (NACE, 2008):

- *B.05 Mining of coal and lignite;*
- *B.06 Extraction of crude petroleum and natural gas;*
- *B.07 Mining of metal ores;*
- *B.08 Other mining and quarrying;*
- *B.09 Mining support service activities*.

Focusing on this classification, the data were developed and returned in two diagrams; the first concerning with the work-related injuries per years (Fig. 1) and the second with the fatal work-related injuries per years (Fig. 2). The sub-economic activities are indicated with different colours and all data are investigated in a period of eight years (2012-2019).

The occupational injuries per type of economic activity coded B is calculated at 646, a figure which refers to the mean value in the past 8 years (2012-2019), of which the average of fatalities is identified in 6.

As highlighted in the histograms of Fig. 1 and Fig. 2, the most implicated sector is *Other Mining and Quarrying*. This division includes extraction from a mine or quarry, but also dredging of alluvial deposits, rock crushing and the use of salt marshes. The products are used most notably in construction (e.g. sands, stones etc.), manufacture of materials (e.g. clay, gypsum, calcium etc.), manufacture of chemicals etc.

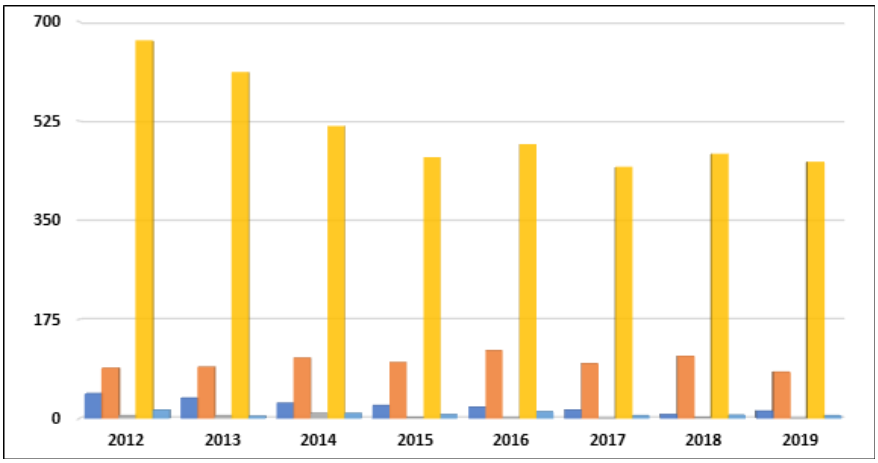

Fig. 1 – Work-related injuries per years.

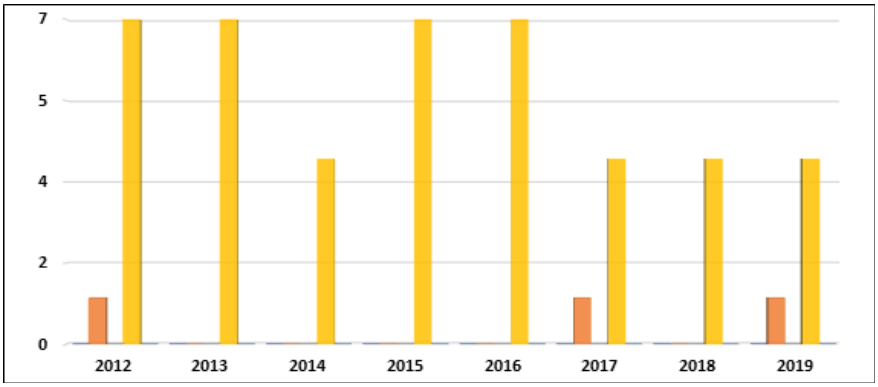

Fig. 2 – Fatal work-related injuries per years.

The Other Mining and Quarrying division is split into B.08.1 *Quarrying of stone, sand and clay* and 08.9 *Mining and quarrying n.e.c.* The division B.08.01 is further separated into *Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate* (coded B.08.11) and *Operation of gravel and sand pits; mining of clays and kaolin* (coded B.08.12).

The B.08.11 class includes:

- quarrying, rough trimming and sawing of monumental and building stone such as marble, granite, sandstone etc.
- breaking and crushing of ornamental and building stone
- quarrying, crushing and breaking of limestone
- mining of gypsum and anhydrite
- mining of chalk and uncalcined dolomite

The B.08.12 class includes:

- extraction and dredging of industrial sand, sand for construction and gravel
- breaking and crushing of gravel
- quarrying of sand
- mining of clays, refractory clays and kaolin

The most affected sub-sector is the first one B.08.11 with a mean value of 222 for work related injuries and 3 for fatalities per year.

Table 2 and Table 3 report an Italian data's overview, about B.08.01 division, extracted by the INAIL BDS (INAIL statistic database, 2020) and explained here, respectively for Work Related and Fatal Work-related injuries.

It is interesting to underline that the trend of accidents is in sharp decline, starting from the first years investigated to the last one.

Tab. 2 – Overview of Work Related Injuries data extracted by INAIL BDS regarding B.08.01 class.

	Work related injuries							
Nace Classification	2012	2013	2014	2015	2016	2017	2018	2019
B.08.1	15	12	10	19	16	8	7	11
B.08.11	297	274	236	207	198	185	200	181
B.08.12	264	240	209	173	204	186	207	206
Total B.08.1	*576*	*526*	*455*	*399*	*418*	*379*	*414*	*398*

Tab. 3 – Overview of Fatal – Work Related Injuries data extracted by INAIL BDS regarding B.08.01 class.

	Fatal-Work related injuries							
Classification Nace	2012	2013	2014	2015	2016	2017	2018	2019
B.08.1	1	0	0	1	0	0	0	1
B.08.11	4	4	2	5	5	2	3	0
B.08.12	2	2	1	0	1	2	1	1
Total B.08.1	*7*	*6*	*3*	*6*	*6*	*4*	*4*	*2*

Tab. 4 – Fatal accidents causes concerning economic activity coded B.08.1 (Quarrying of stone, sand and clay) in the past six years.

Year	Date	Workplace accidents
2014	13 March	Fall of a person whilst working at a marble quarry. The person was busy with material handling machinery and hit his head in the fall.
2014	6 September	Death of a foreign truck driver who fell into a depression that was used as a landfill
2014	18 December	The employee of a mining company has lost control of his vehicle as he was completing his driving schedule for the day. Being unable to move out, he died inside the vehicle.
2015	25 February	The employee was unable to move out of the work area and was literally sucked in by a powerful ejector which produces gravel out of material that is extracted from the river.
2015	4 June	A person fell from a bed rock into a quarry during activities, after a 50-meter-plunge.
2015	29 August	Quarryman died after falling from above while detaching a block from a bank. The person died after a 12-meter-plunge.
2015	14 September	Death of a quarryman following a fall in which he suffered several injuries six days earlier. The quarryman fell from a truck dock which was loading material.
2015	23 November	Quarryman died after hitting his head on a diamond bead chain whilst sawing in a marble quarry.
2015	11 December	The worker in charge of the marble stocking area was apparently crushed against a number of marble slabs during loading.
2016	5 February	A young employee has lost his life after being flattened and crushed by a heavy slab of marble which collapsed from a moving forklift.
2016	11 April	Two quarrymen died after being hit and dragged down into a marble landslide of over 2000 tons of marble which collapsed for 30 meters.
2016	9 May	Worker is hit by a slab whilst he was loading a number of marble slabs on the lift truck with his team. He was crushed by some of the slabs and died.
2016	10 August	The quarry manager was hit on his abdomen by a marble slab which unhooked during unloading.
2016	28 November	A quarryman was flattened by a heavy slab (about 2 tons) which detached from a block during the production phase. The person had just finished sawing and was in the process of removing the scaffolding around the slab.
2017	23 February	A person died after being crushed by a block of granite of 50 tons during sawing.
2017	06 March	A person employed as electrician was found unconscious on the ground, with a deep wound on his head, inside the warehouse where marble is processed.
2017	06 June	A young employee died instantly after being crushed by a marble slab.
2017	04 July	An early report described the fall of a person from a 6-meter-height as he was carrying out the maintenance of a conveyer belt. He worked in a sand mine.
2018	22 January	A person slipped into an 11-meter-deep quarry.
2018	04 March	A person slipped into a quarry and was subsequently hit by a boulder. The injury resulted in a lethal internal bleeding.
2018	11 May	An employee was crushed under a wheel loader in a marble quarry.
2018	09 October	An employee died as he was working inside a quarry. The cause of the accident has not yet been established.
2019	03 March	A person was overwhelmed by a heap of sand and dirt whilst working in the quarry. The quarryman was at the drive of a excavator. The cause of the accident has yet to be identified.
2019	20 July	A man was crushed between two corves which had been loaded with stones. The corves were running via a rack railway.

An *excursus* of the Italian outlined occupational fatalities along with accident causes occurred in the past six years is listed in Tab. 4 (ANMIL, 2020a and 2020b), keeping in mind that the main causes of fatal accidents in the extractive industry can be reassumed in six major classifications: cutting wire rupture, traffic accident, machinery or men fall from bench crest, rock fall, electric shock due to worn out cables and blasting induced damage (Yarahmadi *et al.*, 2014).

Fig. 3 – Block sawing by diamond wire in an ornamental basalt quarry.

3. Diamond wire sawing: health and safety considerations

The diamond wire saw is one of the most important technologies adopted in dimension stone quarries. Due to the spread of this technology, the rate of potential accidents in quarries which utilise such technology has increased.

Ersoy (2013) found that, in the block excavation works, the main risks tied with the use of diamond wire are "placement the diamond wire through the holes", "wring and add the diamond wire", "displacement, fill and overturning the block", "transport, installations and dismantling the water and electricity equipment", "the cutting process of diamond wire machine" and "drilling operation".

Beside the risks associated with the system power units (whether Diesel or electric), the hazard part of the technology is blamed to the diamond wire moving in a closed loop, with a tangential speed that can easily reach 40 m/s in common applications in marble quarries (22-28 m/s in granite quarries (Cai *et al.*, 2007)), and subject to a traction that depends on the type of rock to be cut (normally in marble is about 1.5kN, Careddu and Mulas, 2003). The sudden rupture of the wire causes a whiplash and the projections of the free diamond beads both in the same plane of the cutting area (Castelli and Cai, 1989). Yarahmadi *et al.* (2014) observed that diamond wire rupture is one of the three greatest risk sources in Iranian dimension stone quarries.

The risk of such an event can be diminished by reducing hazard levels and/or any possible damage. In the first case, the chance of wire rupture should be decreased, for instance by improving the rope quality, by limiting the rope operative stress conditions, by controlling the effectiveness of junctions. In the second case, the damage caused should be minimized, for instance by protecting the wire with a belt with the purpose of mitigating the whiplash effect, with the use of a plastic coated diamond wire to secure the beads to the rope and avoid their projection.

The safety of the diamond wire can vary during its service life; in fact, the length of the tool may change throughout its service-life. During the quarrying works, accidents happen, e.g. entrapment, thread breakage at the junction, etc. Every time something unusual happens, the operator must stop sawing and re-join the wire, resulting in the loss of at least two beads. In addition, it may be necessary to saw small areas (of about 4 m^2), which means that the operator needs to cut the DW in two and use only one half. Subsequently, the two halves could be re-jointed to reproduce a longer DW (Careddu *et al.*, 2018).

The dangers relating to the use of diamond wire are widely-known, whether in the quarry or in the stoneyard, aside from accidental and careless moves of the operator (which in any case are common to all machines), they are associated essentially with cable breakage (Cai, 1998).

4. Result and discussion

As previously pointed out, the potential hazards during the quarrying works make them unique in the field of industrial safety and health. Safety risks can be controlled by applying a proper policy. In this perspective, the role of human behavioural factors on safety is decisive. Competence and observance of safety measures are equally important to prevent and minimi-

ze quarrying and mining accidents. A feasible solution to improve working conditions along with the implementation of adequate safety and preventive measures, seems to be leading towards the creation of a management system which can be certified (e.g.: BS-OHSAS 18001; ISO 14001). Moreover, it becomes necessary to identify an unambiguous regulation to prevent serious legal cases, such as the ones occurring in those Italian regional authorities where the administrative bodies in charge of the territory come up with different risk mitigation solutions. This kind of attitude results in unequal economic outcomes, with subsequent aggravations for companies which have to comply with more restrictive provisions.

In fact, a key aspect of a company's reputation (public or private), both as an employer and with the local community, is the health and safety of its staff. Assessments of hazards should be made so that high risk activities can be recognised and mitigated during all production line. Although problems at the exploration stage are less severe than during quarrying and stone-processing, serious accident could be occur. First aid training should also be provided.

Surely, the behaviour of the diamond wire machine operator is another key aspect: it should be underlined that in the production chain "wire manufacturer – machine manufacturer – user of both", the first is always liable for all the problems occurring during the sawing operations: this is wrong! A closer and honest cooperation between the involved parts is absolutely necessary; such cooperation will largely contribute to finding a solution of many problems that still undermine the importance of this new primary sawing technique (Careddu and Cai, 2014).

Moreover, all contractors and workers of external companies and satellite industries should behave in a similar way to company staff and safety record should be a significant factor in choosing contractors. Finally, some authors (Moon and Whateley, 2006) demonstrated that one of the major sources of serious accidents is road transport, especially in remote areas. For this reason, staff should be provided with training in driving on poor road surfaces.

5. Conclusion

Occupational health and safety is becoming a social responsibility. Corporate, local institutions and civic society need to be made aware of *safety and safety culture must be created*. It would be advisable to think about a new perspective of risk assessment, where risks can be identified and analysed from the very beginning so that safety measures can be applied to prevent or mitigate injuries. This could be achieved by providing a further Code of Best Practice and Recommendations. Further actions must be taken to prevent additional occupational injuries and fatalities.

The fluctuating accident trend, relating to fatal cases in the eight-year period, in any case induces to maintain a high level of attention to safety, and even if the rate of accidents has decreased in recent years, it would be desirable to lower the trend to zero.

It is necessary to guarantee the minimum requirements designed to reach a superior standard of safety and health for surface and underground mineral-extracting industries in order to safeguard the safety and health of employees.

Moreover, it is necessary to support Italy's leading technology and *know-how with* regard to the safety of the mining and quarrying industry as a top priority, and create the right environment to deal with occupational health and safety issues or concerns.

As explained in the Council Directive 92/104/EEC, the improvement of workers' safety, hygiene and health at work is an objective which should not be subordinated to purely economic considerations.

References

Alejano, L.R., Stockhausena, H.W., Alonsoa, E., Bastantea, F.G., Ramírez Oyanguren, P., 2008. ROFRAQ: A statistics-based empirical method for assessing accident risk from rockfalls in quarries. International Journal of Rock Mechanic's & Mining Sciences 45 (2008) 1252-1272.

ANMIL, 2017. Le attività estrattive e la normativa correlata alla luce del Testo Unico (D. Lgs. 81/08 e s.m.i.). Relazione presentata ad Ambiente Lavoro Convention, 14 September 2017, Modena Fiere, Italy (in Italian).

ANMIL, 2020a. Archivio Caduti e Gravi Incidenti dal 2008 al 2019. Link: https://www.anmil.it/storie-e-numeri/archivio-caduti-e-gravi-incidenti-dal-2008-al-2019/. Last accessed November 18th, 2020. In Italian.

ANMIL, 2020b. Caduti e gravi incidenti sul lavoro. Link: https://www.anmil.it/storie-e-numeri/caduti-e-incidenti-sul-lavoro-storie-di-vite-interrotte-non-numeri/. Last accessed November 18th, 2020. In Italian.

Cai, O., 1998. Notes and comments on the safety of cutting diamond wires. Diamante A&T, 12/1998, pp. 40-48

Cai, O., Careddu, N., Mereu, M., Mulas, I., 2007. The influence of operating parameters on the total productivity of diamond wire in cutting granite, IDR-Industrial Diamond Review 3/07 pagg. 25-32.

Careddu, N., Cai, O., 2014. Granite sawing by diamond wire: from Madrigali "bicycle" to modern multi-wires. Diamante – Applicazioni & Tecnologia, n. 79, Anno 20, Dicembre 2014, pp. 33-50.

Careddu, N., Cai, O., Perra, E.S., 2018.

Performance and issues of diamond wire in ornamental basalt quarries. Geoingegneria Ambientale e Mineraria, 155(3), dicembre 2018, 85-92

Careddu, N., Mulas, I. Diamond wire cutting equipment in granite quarries: safety and standards. In: Diamante – Applicazioni e Tecnologia, Anno 9, n. 35, December 2003, pagg. 97-109. Ed. G & M Associated Snc.

Careddu, N., Perra, E.S., Masala, O., 2019. Diamond wire sawing in ornamental basalt quarries: technical, economic and environmental considerations. Bull Eng Geol Environ (2019) 78:557-568.

Careddu, N., Siotto, G., 2011. Promoting ecological sustainable planning for natural stone quarrying. The case of the Orosei Marble Producing Area in Eastern Sardinia. Resources Policy 36:4 (2011) 304-314

Castelli, M., Cai, O., 1989. Safety in the use of diamond wire in quarrying. Marmomacchine n. 85 (1989), 94-103.

Decreto del Presidente della Repubblica 9 aprile 1959, n. 128 Norme di polizia delle miniere e delle cave. Pubblished in *Gazzetta Ufficiale* n. 87 del 11-04-1959, Suppl. Ordinario n. 870. In Italian.

Decreto Legislativo 25 novembre 1996, n. 624 "Attuazione della direttiva 92/91/CEE relativa alla sicurezza e salute dei lavoratori nelle industrie estrattive per trivellazione e della direttiva 92/104/CEE relativa alla sicurezza e salute dei lavoratori nelle industrie estrattive a cielo aperto o sotterranee". Pubblished in *Gazzetta Ufficiale* n. 293 del 14 dicembre 1996, Supplemento Ordinario n. 219. In Italian.

Decreto Legislativo 9 aprile 2008, n. 81 Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro. Pubblished in *Gazzetta Ufficiale* n. 101 del 30-04-2008, Suppl. Ordinario n. 108). In Italian.

Ersoy, M., The role of occupational safety measures on reducing accidents in marble quarries of Iscehisar region, Saf. Sci., 57, 293-302, 2013.

Ersoy, M., 2015. A Proposal on Occupational Accident Risk Analysis: A Case Study of a Marble Factory, Human and Ecological Risk Assessment: An International Journal, 21:8, 2099-2125.

Ersoy, M., Yesilkaya, L., 2016. Comparison of the occupational safety applications in marble quarries of Carrara (Italy) and Iscehisar (Turkey) by using Elmeri method, International Journal of Injury Control and Safety Promotion, 23:1, 29-63.

European Communities – Council Directive 92/91/EEC of 3 November 1992 "Minimum requirements for improving the safety and health protection of workers in the mineral-extracting industries through drilling".

European Communities – Council Directive 92/104/EEC of 3 December 1992 "Minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries".

INAIL, 2020. Banca Dati. Link: http://bancadaticsa.inail.it/bancadaticsa/login.asp. Last accessed October 6th, 2020. In Italian.

Joy, J., 2004. Occupational safety risk management in Australian mining. In: Occupational Medicine Volume 54, Issue 5, 1 August 2004, Pages 311-315.

Macedo, D., Mori Junior, R., Carvalho, L.S.L.S, Mizusaki, A.M.P., 2018. Sustainability certification scheme for the dimension stone industry in Brazil: A proposal for an initiative based on the northwest region of Espírito Santo State, Brazil. Journal of Cleaner Production 182 (2018) 896-909.

Montani, C. The world stone situation: a sector with great competitive resilience. In: Directory 2019, Confindustria Marmomacchine/Associazione Italiana Marmomacchine Pub., Milano, pp. 56-92.

Moon, C.J., Whateley, M.K.G., 2006. Reconnaissance exploration. In: Introduction to mineral exploration, 2nd ed., Moon, C.J., Whateley, M.K.G. and Evans, A.M. (eds.). Blackwell Publishing, 2006. ISBN-13: 978-1-4051-1317-5.

MSHA – Mine Safety and Health Administration's (MSHA). Link: https://www.msha.gov/. Last accessed November 18th, 2020.

NACE Rev. 2, Statistical Classification of Economic Activities in the European Community. European Communities, 2008. ISSN 1977-0375.

Pires, V., Amaral, P., 2014. The importance of technical specification for stone construction products – StonePT the Portuguese stone brand. In. Proc. Book V Global Stone Congress, 22-25 October, 2014, Antalya (Turkey). Tuğrul, A., Akdaş, H., Yavuz, A.B., Yılmaz, M. (Eds.)

Regio Decreto 29 luglio 1927, n. 1443 Norme di carattere legislativo per disciplinare la ricerca e la coltivazione delle miniere nel Regno. In Italian.

Saleh, J.H., Cummings, A.M., 2011. Safety in the mining industry and the unfinished legacy of mining accidents: Safety levers and defense-in-depth for addressing mining hazards. In: Safety Science, Volume 49, 764-777.

Ural, S., Demirkol, S., 2008. Evaluation of occupational safety and health in surface mines. In: Safety Science, Volume 46, Issue 6, July 2008, Pages 1016-1024.

USGS, 2020. Mineral Commodity Summaries 2020. US Geological Service. Link: https://pubs.er.usgs.gov/publication/mcs2020. Last accessed November 18th, 2020.

Yarahmadi, R., Bagherpour, R., Khademian, A., 2014. Safety risk assessment of Iran's dimension stone quarries (Exploited by diamond wire cutting method). Safety Science 63 (2014) 146-150.

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