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THE ROLE AND IMPORTANCE OF PREVENTIVE SAFETY MEASURES AT WORK DURING THE PRODUCTION AND PROCESSING OF TECHNICAL STONE AT THE QUARRY

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ABSTRACT
Quarries are surface mines where construction stone is exploatation and processed. Ensuring worker safety in quarries and preventing injuries are crucial for creating a safe working environment and maintaining a productive workplace. In this paper, the critical role and necessity of implementing preventive measures in the production and processing of technical stone in quarries are emphasized to enhance occupational safety measures. The identification of hazards and an accurate assessment of safety risks are fundamental to the success of any safety program. Based on identified potential hazards and risks, it is essential to define all necessary technical and organizational preventive measures. A key component in injury prevention and the mitigation of occupational illnesses is the education and training of workers to ensure safe and healthy work practices. Workers must be fully informed about all hazards and risks associated with their assigned tasks, as well as any potential dangers that may arise during movement and presence within the quarry. If training is limited to formal classroom instruction, workers may lack the ability to recognize all hazards and risks present in the quarry, both at their specific workplaces and within the broader operational environment.

1. INTRODUCTION

The Quarry is a mining facility where building stone is extracted. Generally, quarries are surface operations, except for high-value stone types that are mined in underground excavations [1]. Without the production and processing of engineered stone, there would literally be nothing around us. Currently, about 90% of the total production of stone aggregates in Europe comes from natural sources, such as quarries and gravel pits. The remaining 10% of European aggregate production comes from marine deposits, recycling industrial waste like slag and ash, and recycling construction waste [2].

The aggregate industry in Europe includes approximately 16,000 companies (small and medium-sized enterprises) operating in 24,000 quarries and gravel pits across Europe, directly and indirectly employing around 300,000 people. This makes the aggregate sector by far the largest in the mineral resource extraction and production industry [3].

Workers in quarries operate in high-risk environments filled with hazards that can cause injuries and increase the risk of developing health problems. They are exposed daily to potential dangers such as physical hazards, dust, noise, falls from heights, and the effects of explosions during excavation [4]. Each of these activities involves a certain degree of risk. The risks associated with quarry work must be eliminated or minimized as much as reasonably possible to protect workers and others from injury, which is achieved through the implementation of all occupational safety measures.

Occupational safety is a multidisciplinary field that deals with the identification, assessment, and control of risks to ensure the safety, health, and general well-being of workers during the performance of their duties. In general, occupational safety as a concept encompasses various aspects, including legal regulations, technological innovations, education, training, skill development, and the promotion of a safety culture in the workplace [5]. Each year, millions of people are injured at work or suffer serious health impairments on the job. According to reports from the World Health Organization (WHO), workplace injuries account for about 19 percent of annual fatalities [6].

The risks arising from the production and processing of engineered stone at quarries must be eliminated or minimized as much as reasonably possible to protect workers and others from injury. The implementation of preventive measures is the guiding principle of occupational safety and health legislation [7].

2. THE ROLE AND IMPORTANCE OF PREVENTIVE MEASURES

Prevention refers to any planned or implemented action at any stage of work by the employer, aimed at preventing or reducing the risk of adverse events [8]. In contrast to prevention, control describes mitigation activities where risks cannot be entirely avoided.

Every employer is obligated to implement preventive measures when organizing work and work processes to protect the lives and health of employees, as well as to provide the necessary resources for their application [8]. The principles of prevention and control strategies are embedded in several sections of the EU's health and safety (H&S) legislation. The Framework Directive on Occupational Safety and Health (89/391/EEC) holds fundamental importance. It serves as the cornerstone of occupational safety law, establishing general principles related to the prevention and protection of workers from workplace accidents and occupational diseases, and it sets a framework for managing health and safety at the workplace [9].

This Directive outlines the following general principles of prevention:

a) Avoiding risks;
b) Evaluating risks that cannot be avoided;
c) Eliminating risks at their source;

d) Adapting work and the workplace to the worker, particularly regarding the choice of work equipment, methods, and technological processes to avoid monotonous tasks and reduce their impact on workers' health;
e) Keeping up with technical progress;
f) Replacing hazardous technological processes or work methods with harmless or less hazardous alternatives;
g) Substituting dangerous substances with non-hazardous ones;
h) Developing a coherent overall prevention policy that includes the organization of work, working conditions, social relationships, and the influence of environmental factors;
i) Giving priority to collective protective measures over individual protective measures;
j) Providing appropriate training and information to workers.

Workers often fail to recognize many of the hazards present in their workplaces and tend to underestimate the safety risks associated with identified hazards [10]. To improve hazard recognition and accurate risk perception, employers implement a wide range of training programs. However, the prevalent use of ineffective and unengaging training methods has not significantly changed workplace accident statistics [11].
To interpret the importance of hazard recognition and safety risk perception, a simple conceptual model of the safety management process has been proposed, as illustrated in Figure 1.

Figure 1. Representation of the Conceptual Safety Management Process [12]

As presented by the model, hazard recognition is generally considered the first step in the safety management process. Successfully identifying all potential hazards in quarries requires considering all aspects and their interactions that may pose risks to the health and safety of workers, as well as other individuals who, for any reason, enter or remain on the quarry site. This involves analyzing all elements of the work environment, including physical, chemical, biological, ergonomic, and psychosocial factors, among others, with the aim of identifying potential sources of hazards, harm, or strain. Following this, a safety risk assessment is conducted, and effective control measures are adopted to prevent injuries. Therefore, when hazards are not recognized or when safety risks are not accurately perceived, workers may fail to implement effective safety measures to prevent injuries [13].

2.1. Risk Assessment and Management

Risk assessment is the systematic identification and evaluation of all factors in the work process that may cause injuries, illnesses, or health damage, as well as the determination of possibilities and methods for preventing, eliminating, or reducing risks [8]. Before starting any work in a quarry, quarry managers must conduct a comprehensive risk assessment for each workplace and worksite in the work environment to understand the specific risks present at the site. The risk assessment process is carried out concerning the organization of work and the work process in the quarry, the tools and equipment used, raw materials and materials

involved in the technical-technological and work processes, working conditions at the workplace and in the work environment, and other elements that may pose a risk of injuries, occupational diseases, or damage to workers [14]. If the risk assessment is poorly conducted or not conducted at all, it is unlikely that appropriate preventive measures will be implemented.

The basic steps in risk assessment are:

1. Identifying hazards and those at risk,
2. Assessing and prioritizing risks,
3. Deciding on preventive actions,
4. Taking action and
5. Monitoring and reviewing.

The employer must have a risk assessment in accordance with Article 9 of Directive 89/391/EEC [15]. The risk assessment must be updated, especially if there have been significant changes in the risks within the work process. A complete revision and update of the risk assessment are required after any collective workplace accident with fatal outcomes that occurs at the quarry worksite or if mandated by the relevant inspection authority.

Risk assessment requires a thorough understanding of the concepts of hazard and risk. The risk assessment is conducted by an organization with experience in occupational health and safety, which meets the qualification and legal standards for this type of work.

Once the risk is assessed, decisions must be made regarding new measures to reduce residual risks, considering what is regarded as good practice as a guideline. Based on the assessed risks at workplaces and worksites in the work environment, the risk assessment document defines the methods and measures to prevent, eliminate, or minimize risks as much as possible. The measures determined may include:

- Changes in the technical-technological work process by replacing hazardous segments with less dangerous ones,
- Maintaining tools and equipment in good condition and performing prescribed periodic inspections and tests,
- Conducting prescribed periodic inspections and tests of physical, chemical, and biological hazards and the microclimate,
- Reducing workers' exposure time to identified physical, chemical, and biological hazards and the negative effects of the microclimate,
- Eliminating harmful substances from use or replacing them with less harmful ones,
- Installing isolated cabins,
- Limiting parts of the technical-technological process or harmful impacts on the work environment by installing barriers, frames, etc.,
- Introducing mechanization to replace the physical presence of workers,
- Ensuring prescribed conditions for safe and healthy work in the work environment,
- Training workers for safe and healthy work,
- Periodic checks of workers’ theoretical and practical competence for safe and healthy work, especially for positions with increased risk, within set deadlines,
- Providing personal protective equipment and maintaining it in good condition, sending employees for pre-employment and periodic medical examinations,
- Ergonomic measures,
- Changes in work organization, and others.

It is crucial that wherever preventive measures are implemented, they should enhance the level of protection provided to workers regarding safety and health. Where possible, it is especially important that decisions of this kind are made during the design or procurement phases of new processes, plants, products, and procedures.

2.2. Occupational Health and Safety Management System

Risk assessment and all types of prevention and control measures are typically integrated into the management process or system. Occupational health and safety management systems stem from a comprehensive quality management approach, particularly those aligned with the ISO 9000 quality management standard.

The method is based on the *Deming Cycle*, which consists of a four-step iterative process known as *Plan, Do, Check, Act (PDCA)*. Involving top management in all steps of the process is crucial for an effective management system. Risk assessment is most important in the *Plan* phase. Preventive and corrective measures should be implemented with employee participation during the *Do* phase. The implementation of these measures, along with corrective and preventive actions, form the core of the *Check* phase. The *Act* phase focuses on management evaluation, considering the performance measures of occupational health and safety.

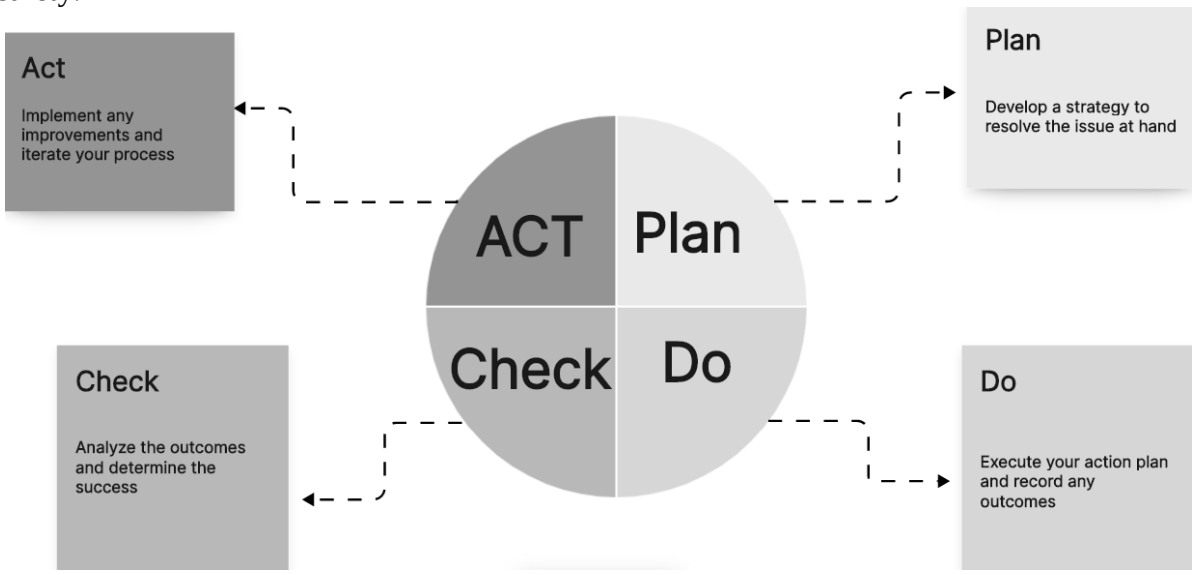

Figure 2. Quality Management System According to ISO 9000 Standard

The well-known standard for occupational health and safety management, **OHSAS 18001**, has been withdrawn and replaced by **ISO 45001**. The standard has a structure similar to other ISO management systems (e.g., **ISO 9001** Quality Management, **ISO 14001** Environmental Management), enabling companies to establish an integrated **OSH** management system.

2.3. Hierarchy of Preventive and Control Measures

Risks should be eliminated whenever possible; if not, they should be minimized by implementing preventive measures according to a priority sequence. This sequence is known as the hierarchy of control. Various institutions have developed different hierarchies of prevention and control measures. The most common hierarchy consists of five steps:

- Elimination
- Substitution
- Engineering Controls
- Administrative Controls
- Personal Protective Equipment (PPE)

Elimination:

Eliminating hazards involves completely removing the danger, thereby effectively preventing any identified potential accidents or health issues. The term *elimination* means reducing the

risk to zero without transferring it elsewhere. Elimination is the ideal goal in any risk management process [15].
Example: One of the hazards in quarries is the movement of passenger vehicles on the same transport routes used by dump trucks, which can lead to injuries and fatal accidents (Figure 3).

Figure 3. Collision of a dumper and a passenger car in a quarry [17]

If the transport routes for passenger, service, and other vehicles were physically separated from the transport routes for dump trucks during the development of the Main Mining Project, the potential danger to safety and health would be permanently eliminated (Figure 4).

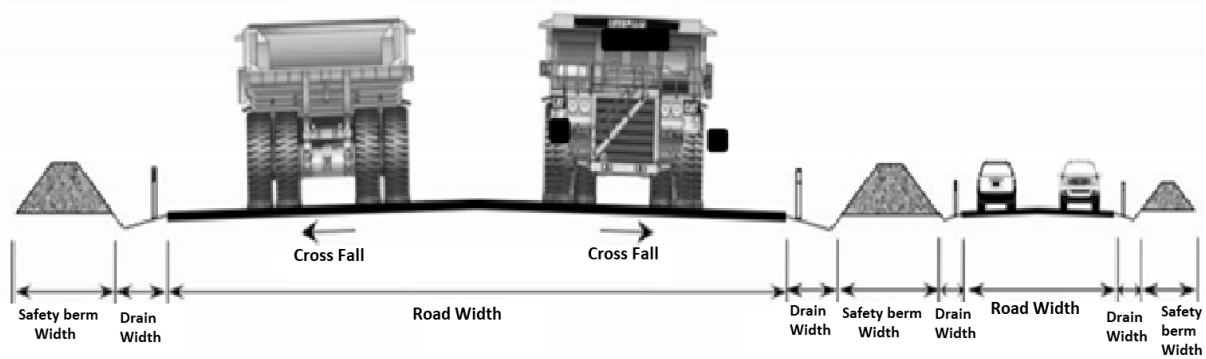

Figure 4. Transport routes in quarries with a physically separated roadway for passenger and service vehicles

This is a permanent solution and should be attempted in the first stage. If the danger is eliminated, all other control measures, such as monitoring and supervision of the workplace, training, safety audits, and record keeping will no longer be necessary.

Substitution: Substitution means replacing a hazard with one that presents a lower risk. Elimination is immediately combined with switching to something of much lower risk. Often or usually considered in the context of chemicals, the concept of 'replacing dangerous with non-dangerous or less dangerous' can be applied much more broadly; it is one of the core principles of a range of preventive measures contained in the 'Framework Directive' (Directive 89-391-EEC). In the case of chemicals, replacing with a safer form of the same

chemical, rather than replacing the chemical itself, can offer a more sustainable, safer option (e.g., pellets instead of powder).

Technical controls: Technical controls are physical means that limit the hazard. This includes structural changes to the work environment or processes, creating barriers to interrupt the transmission path between the worker and the hazard. Local exhaust ventilation to control dust or smoke risks is a common example, as is separating the hazard from the operator through methods such as enclosing or protecting dangerous parts of equipment (Figure 5.). Priority should be given to measures that protect the collective rather than individual measures.

Figure 5. Protection of all rotating and other hazardous parts in technical stone production and processing plants

Administrative controls: Also known as organizational measures, administrative controls reduce or eliminate exposure to hazards by adhering to procedures or instructions. Documentation should highlight all the steps to be taken and controls to be used for safely carrying out activities. Particularly concerning younger workers, social media is becoming increasingly important as a channel for spreading safety messages and other information related to occupational health and safety. Improving workers' resilience through measures such as promoting workplace health can also be a valuable aspect of a comprehensive approach to prevention and control.

Personal Protective Equipment (PPE): Personal protective equipment should be used only as a last resort, after all other control measures have been considered, or as a short-term emergency situation during maintenance or repair work, or as an additional protective measure. The success of this control depends on the proper selection of protective equipment, correct placement, wearing at all times, and proper maintenance. The reason why the use of personal protective equipment is at the bottom of the control hierarchy and actually a last resort is the higher likelihood (compared to controls higher up on the ladder) of failure to manage the hazard, as it relies so much on the individual’s success, whether it is about whether they actually use the PPE, how well they use it, or whether it truly fits them.

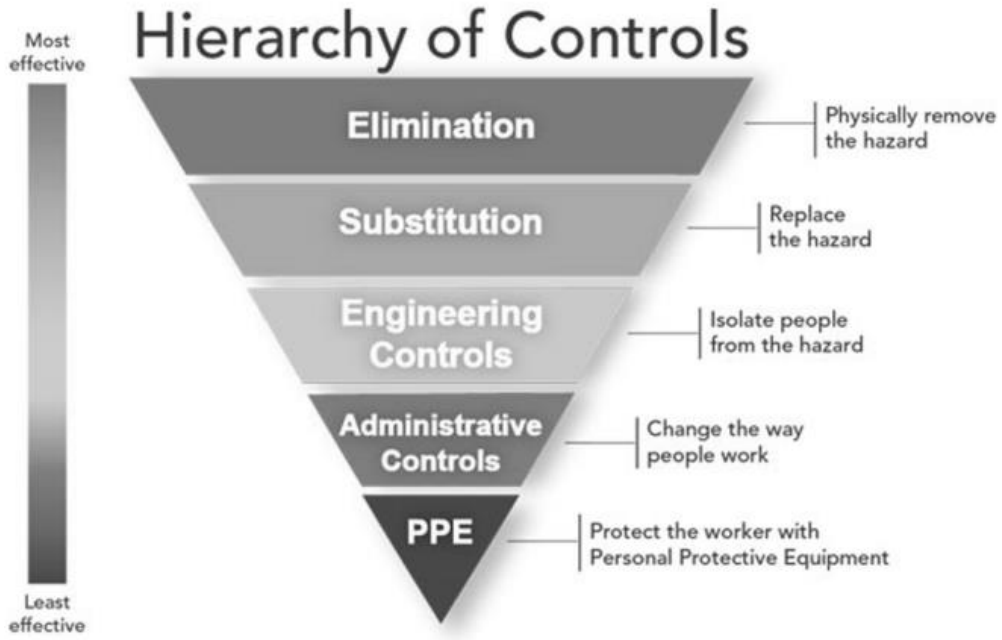

Figure 3. Hierarchy of controls [18]

The application of the hierarchy of preventive and control measures in quarries should be carried out in accordance with legal frameworks. In the context of prevention and control measures, the legal framework prioritizes avoiding and eliminating risks at the source, rather than reducing them.

Following European Union legislation, 'reducing hazards and risks' also has a dual implication, which, unfortunately, is not immediately visible at first glance in the aforementioned hierarchical system. If it is not possible to avoid risks or eliminate hazards, the next step must be to reduce (minimize) hazards and separate the remaining hazards from workers [19].

It should also be noted that as one moves down the list of options, controls become less reliable, more expensive, and require more effort to ensure their maintenance. In most situations, the actual method for controlling risk is a combination of options within the hierarchy. All quarry workers must be trained with basic knowledge of all potential hazards that may arise at the workplace, as well as within the quarry area, through safety training [20]. Designing safety training with workers aligns with Cooper's assertion that safety controls are not carried out on people, but with people [21]. Although safety systems can be designed and established by the employer, employee compliance with safety protocols can increase the effectiveness of the safety system. Therefore, the commitment and involvement of employers and employees in the safety system are fundamental to preventing workplace accidents and promoting a safer working environment. The lack of experience and awareness of the work operation among new workers usually leads to a higher risk factor compared to experienced workers [22]. A complex work environment hinders workers' awareness of workplace hazards; it is possible that multiple workplace hazards at the same time interfere with workers' application of safety knowledge and skills learned during safety training [23]. Due to the nature of their duties in the workplace, workers are more likely to have accidents when they are not under supervision and when left to their own judgment to make important safety-related decisions. As a result, workers must make independent decisions at the workplace using information obtained through education and training [24]. Safety program activities may include formal classroom training, safety inspections, peer training, and on-site demonstrations [25]. If training is limited to just formal classroom training, workers will not

be able to recognize all the hazards and risks that may arise in the quarry, both at their workplace and throughout the entire quarry area [18]. If a potential emergency scenario is identified as part of a risk assessment, then appropriate drills will also be part of the training and familiarizing workers with how to handle such a situation when it arises.
Worker training should be linked to all steps in the hierarchy of preventive and control measures, and as such, is fundamental in the prevention and control of all potential hazards that may arise in the workplace and its surroundings.

3. CONCLUSION

Occupational safety is a systematic approach to ensuring the safety, health, and general well-being of workers during the performance of their duties. Occupational safety includes adherence to legal regulations, standards, norms, and guidelines related to safety and health protection at work.
This paper primarily emphasizes the importance of identifying all hazards that could lead to workplace injuries, as well as the significance of preventive measures in all technological processes and operations in quarries. An important aspect of health and safety protection at work is promoting a safety culture in the workplace. Raising awareness among workers about the importance of safety and health protection at work, encouraging cooperation and communication between workers and employers, and adhering to regulations significantly reduce the risk of adverse consequences.
Due to the nature of their duties, workers are more likely to have accidents when they are not under supervision and when left to their own judgment to make important safety-related decisions. As a result, workers must independently make decisions in the workplace using information obtained through education and training. By designing safety programs that address both formal and informal ways of learning safety skills and knowledge, quarry managers can create a safer working environment for employees.
The principles of prevention and control support the management of health and safety risks in the workplace. These are well-established principles and are widely applicable. The focus of action and consideration should primarily be placed on the prevention of risks, particularly in terms of elimination at the source or substitution, for example, using less hazardous substances, instead of immediately considering risk control measures. Psychosocial issues and general health issues should also be considered alongside safety risks and health risks caused by physical, chemical, and biological agents.

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