Quarry Workers’ Hazard Identification, Interpretation, and Prevention Skills in Safety

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master’s in Science

In

Civil Engineering

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July 29th, 2019
Blacksburg, VA

Keywords: safety, quarry, hazard identification, severity interpretation, prevention
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ABSTRACT

The surface-mining worker fatalities are unacceptably high as compared to other private industries in United States such as construction, manufacturing, agriculture, forestry, fishing and hunting. Although many studies about generating a safe work environment and developing safety training through intervention modules have tried to reduce the number of worker fatalities by utilizing an administrative approach to the development of safety controls, a rigorous study about understanding craftworkers’ perceptions of a safe work environment is lacking. This study particularly investigated quarry workers’ safety behaviors regarding work hazards by adapting findings from construction safety research because construction and mining industries have similarities in work hazards and environment. Despite their similarities, the work fatality rate in the mining industry is greater than in the construction industry (BLS, 2018). To gain a greater understanding of how quarry workers identify and interpret work hazards and employ strategies to prevent accidents, this study explored quarry workers’ perceptions of work hazards (i.e., hazard identification, severity interpretation) and their preventive strategies to develop a safer working environment at the workplace. To accomplish this, a single descriptive case study was conducted with multiple sources of data such as interviews with photo elicitation, field notes, site photographs, and precursory meeting with safety managers. These sources of data were used to investigate quarry workers’ identification and interpretation skills and utilization of preventive strategies. This study will contribute to improve safety of workers by incorporating workers’ perceptions of work hazards and by exploring their experience to the development of safety training.
The surface-mining industry is one of the private industries with a high fatality rate in the United States. To reduce the number of accidents and help workers to perform safely in the workplace, previous studies have investigated different strategies to promote workers’ safety performance. These strategies include safety interventions such as safety training and safety inspections. However, a lack of study exists to understand workers’ behaviors and perceptions regarding safety and work hazards. To better explore workers’ behaviors and perceptions, this study adapted findings from construction safety research. Because the number of surface-mining safety research is relatively small and the work environment and types of work hazards in both the surface-mining and construction industries share similarities, the findings in construction safety research can be used to promote a safer workplace for surface-mine workers. By adapting findings in construction safety research, this study further investigated workers’ perceptions of work hazards, which is operationalized in two approaches: hazard identification and severity interpretation. This study also examines workers’ execution of strategies to prevent accidents. These observations were gathered through the utilization of a case study of quarry, which gave a guideline to the researcher to collect data from multiple sources (e.g., precursory meeting with safety managers, field notes, photographs, interviews) and analyze the findings by primarily using participants’ responses in the interviews with photo elicitation. This study will contribute to improve a safer workplace in the surface mining industry by incorporating workers’ perceptions and experience and by emphasizing workers’ involvement in tandem with company commitment to develop safety training.
ACKNOWLEDGEMENT

It is impossible to name everyone individually; and I hope those who prayed for me but do not appear in this short acknowledgment understand my appreciation, nonetheless.

First, I want to thank my advisors, Dr. Simmons, for her guidance and encouragement throughout this work. She was always available to answer my questions and discuss my ideas. I also thank Dr. Paige for his insightful comments and helpful suggestions and making his time available to serve as a co-advisor.

I also thank the members of my committee. I would like to thank Dr. Kleiner for his great ideas and suggestions about construction safety and leadership research. I would also like to thank Dr. McCall for her assistance and advice throughout my academic life as a graduate student.

I am also grateful for the assistance and support from my colleagues in the Simmons Research Lab. I could learn many strategies and develop my research skills.

Also, I would like to thank my fiancé, JeongAh Shin, for her love and motivation. Her support and love enriched my life and helped me complete this work.

Lastly, I thank my Korean students here in Virginia Tech for their friendship, trust, and love.

I dedicate my thesis to my family, SeongJoon Bae, Miyoung Jang, and Hwangeun Bae for their supports and love they provided along this journey.
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CHAPTER 1: INTRODUCTION

Introduction

Safety, along with cost, time, quality, and sustainability, is among the most significant measures that modern construction companies must consider when completing a project. In 2017, the construction industry had the highest number of fatalities among the private industry sectors in the United States (BLS, 2018). Despite the investments of construction projects and its contributions to national economy, 971 construction workers died in 2017 (BLS, 2018). Although the fatality trend in construction is decreasing, continuous efforts to protect workers from fatalities and injuries are needed. To reduce the number of accidents that occur at a construction site, current studies in organizational safety emphasize the importance of shared values and responsibility for promoting safe work environments (Cooper, 2018; Griffin & Hu, 2013). A safe work environment, or injury-free environment (IFE), can be achieved by the organizational belief that “safety must never be compromised for cost or schedule” (SKANSKA, 2017). This definition has a similar meaning with safety culture, which is defined as underlying values, attitudes, and perceptions shared by employees at all levels to represent organization’s safety and health (Misnan & Mohammed, 2007; Saunders et al., 2017). To empower workers with safety knowledge and skills, previous studies have developed safety management controls (e.g., safe behavior programs, risk assessment model) (Fleming & Lardner, 2002; Fung, Tam, Lo, & Lu, 2010) and safety training (Hasanzadeh, Esmaeili, & Dodd, 2017b; Namian, Albert, Zuluaga, & Behm, 2016) to improve workers’ ability to prevent accidents.

In particular, previous studies aiming to improve the effectiveness of safety training have emphasized workers’ visual recognition of work hazards and realization of the risks involved in such hazards (Hasanzadeh, Esmaeili, & Dodd, 2017a; Jeelani, Albert, Azevedo, & Jaselskis, 2017; Namian et al., 2016). This approach has been further operationalized by studies that have developed safety intervention modules and training programs to help construction workers understand work hazards within the work environment (Lyu, Chan, Javed, Wong, & Hon, 2016; Marin & Roelofs, 2017).
Also, some studies have found that encouraging workers’ proactive participation in creating a safer work environment is essential (Fang, Zhao, & Zhang, 2016; Hopkins, 2006; Lingard & Turner, 2017). This trend is evident in organizational leadership studies that emphasize the involvement of workers in achieving a zero-accident status in the workplace (Baker, 2007; Carsten, Uhl-Bien, West, Patera, & McGregor, 2010; Clarke, 2013). Therefore, rigorous research has been conducted to improve workers’ abilities to perceive work hazards appropriately and to encourage workers’ participation in safety.

However, few studies have examined how workers perceive hazards and their strategies to prevent accidents. As many studies have conflated this perspective with an administrative approach to managing and implementing new safety controls, little is known about how workers perceive safety and work hazards within their organization. Therefore, this study explores workers’ abilities to perceive work hazards and their strategies to prevent injuries.

In this chapter, the study’s conceptual framework will be overviewed, and key terms will be defined. Next, the problem statement, purpose of the study, and background information will be presented. This chapter will conclude with research questions and designs and a summary. First, to clarify the focus of this study, a conceptual framework is illustrated below.

**Conceptual Framework**

To better explore workers safety behaviors at the workplace, a conceptual framework is presented to frame the research focus of this study. Particularly, this conceptual framework provides an overview of the development of safe workplace by capturing procedures and variables from safety training to injury-free environment. Therefore, this conceptual framework provides how safety training influences workers’ safe behavior.

Safety training is one of the most significant factors in improving safety (Cohen, Colligan, Sinclair, Newman, & Schuler, 1998). To promote a safer work environment, prior research has investigated methods to help companies reduce the number of accidents by providing effective safety training. Safety training consists of two broad categories: hazard identification and risk perception (Albert & Hallowell, 2017; Hasanzadeh et al., 2017a; Namian et al., 2016). The definitions of these two categories are illustrated in following section. These two skills are
primary elements for workers to prevent accidents in the workplace. Additionally, an appropriate severity interpretation of work hazards is helpful for craftworkers who are exposed to a variety of work hazards and must make safety decisions if a safety supervisor is not present. To better equip workers with safety knowledge and skills to identify and interpret work hazards, previous studies have adopted advanced technologies (e.g., eye-tracking program) to improve their ability to appropriately identify and interpret work hazards (Hasanzadeh, Esmaeili, & Dodd, 2018; Jeelani et al., 2017). However, little research exists that examines how workers actually utilize and implement knowledge gained from safety training. While safety training contributes to workers’ awareness of work hazards, workers’ utilization of skills to identify and interpret work hazards needs more investigation. Further, their employment of prevention strategies should be studied to fully comprehend workers’ performance regarding work hazards. Therefore, this study will investigate workers’ abilities to identify and interpret work hazards and their employment of prevention strategies, as illustrated in the conceptual framework presented in Figure 1.

![Conceptual model](image)

**Figure 1. Conceptual model**

**Definitions**

Key terms are defined in this section to ground this study and articulate its aims and methodological approaches. These terms and definitions serve to bolster the reader’s
understanding of the terms situated within this study to conduct the research procedures and communicate the findings.

- **Safety** – is a promotion of health and well-being of employees and prevention of any accidents and injuries from hazards in the workplace, particularly within the contexts of environmental condition and human behavior (Maurice, Lavoie, Chapdelaine, Bélanger Bonneau, & Ellison, 1997; WHO, 1998).
- **Safety culture** – underlying values, attitudes, and perceptions shared by employees at all levels to represent an organization’s safety and health (Misnan & Mohammed, 2007; Saunders et al., 2017).
- **Safety climate** – the sum of workers’ perceptions of how safety management prioritizes safety in the workplace at a particular moment in time and is used to measure safety culture by examining worker’s attitudes, rules, and practices (Guldenmund, 2000; Saunders et al., 2017).
- **Safety training** – the “core activity” that brings other elements of safety and health programs together in which workers acquire new skills and knowledge and improve their attitudes concerning safety (Cohen et al., 1998). It is associated with higher levels of hazard recognition and risk perception (Namian et al., 2016).
- **Hazard identification** – workers’ ability to properly recognize work hazards (Hasanzadeh et al., 2017a; Jeelani et al., 2017)
- **Severity interpretation** – workers’ ability to properly estimate the degree of potential harm caused by work hazards (Hallowell, Alexander, & Gambatese, 2017)
- **Inductive data analysis** – a bottom-up approach to understanding the research context “by organizing the data into increasingly more abstract units of information” in order to draw conclusions from emergent themes (Creswell & Creswell, 2018, p. 181)
- **Photo elicitation** – “the use of photographs as prompts in a research interview” to elicit informants’ knowledge (Kaminsky, 2014, p. 1).

**Problem Statement**

Surface-mining is “a type of mining in which soil and rock overlying the mineral deposit (the overburden) are removed” (USLEGAL, 2019). Quarry workers in the surface-mining industry
excavate, cut, and break minerals or rock while experiencing potential hazards such as dust, noise, falls, and explosions in the process. These hazards can be classified into two categories: long-term and short-term (USLEGAL, 2019). Long-term hazards can be exemplified as exposure to dust that causes pneumoconiosis in workers. Short-term hazards, in contrast, include anything from a blast of fragments in an explosion to a fall from height. Due to their exposure to work hazards in the surface-mining industry, quarry workers are vulnerable to experience an accident in the workplace during their careers. Despite efforts to reduce occupational injuries in the surface-mining industry, the rate of fatalities increased from 10.0% to 15.5% per 100,000 workers in 2017 (BLS, 2018). In contrast, the fatality rate in construction decreased from 10.1% to 9.5% per 100,000 workers in 2017. Due to the contrasting statistical changes in these industries and relatively limited number of surface-mining safety research, this study adapted findings from construction safety research to better understand surface miners’ perceptions and prevention skills in the workplace.

**Significance of Study**

This study can improve a safer working environment by exploring quarry workers perception of work hazards and perspectives in safety. Although previous studies have investigated and developed safety management controls to enhance workers’ safe behavior by providing safety training, little is known how workers actualize the skills learned in the training. To explore their safe behaviors in the workplace, this study will help the practitioners to understand their process of hazard identification and interpretation, and their strategies to prevent accidents.

Furthermore, the current safety management controls can be improved by accommodating workers’ experience and perspectives gathered in this study. This study used an inductive qualitative research methodology to examine workers’ experience and perceptions of work hazards. Through this study, companies can incorporate workers’ opinions and thoughts by using methods used in this study (e.g., photo elicitation) to strengthen their safety management programs.

Particularly, this study conducted interviews with photo elicitation which can help researchers and practitioners to implement in their safety training and research design. Graphics
demonstrations can help researchers and practitioners to explore workers’ perceptions and experience because the photo elicitation encourages interviewee’s own interpretation. By utilizing the photo elicitation in safety training and research design, practitioners and researchers can grasp a rich understanding of workers’ perceptions and experience in the workplace.

Companies can also develop personalized safety training for workers. Each worker has different perceptions of work hazards (i.e., hazard identification and severity interpretation), and these perceptions affect their prevention strategies. Therefore, worker’s different perceptions of work hazards can be utilized to develop safety training that is personalized to improve their lagging skills to prevent accidents.

**Study Scope and Stakeholders**

This study draws from prior work in construction safety literature to improve worker safety in the surface-mining industry. Construction and surface-mining sites have similar work environments, including elements such as the operation of heavy machinery and working as a team, as well as comparable work hazards. For example, Donoghue (2004) proposed that the most common causes of fatalities in surface-mining are occurred by falls from a height, entrapment, electrocution, and mobile equipment accidents, while the “fatal four” in construction identified by OSHA include falls, being struck by objects, electrocution, and being caught between objects. In other words, falls, entrapments, electrocution are the leading causes of fatalities in both of the industries. Therefore, given the similarities of both industries, findings from construction safety research may be adapted to promote a safer work environment for surface miners.

To better understand workers’ perception of work hazards, this study emphasized the perspective of workers in safety. This approach is particularly important for companies to encourage the involvement and participation of workers in safety. While safety training enhances the workers’ abilities to identify and interpret work hazards, their perceptions (i.e., hazard identification, hazard interpretation) and implementation of this skill (i.e., prevention) may contribute significantly to developing a safer work environment. Therefore, quarry workers are key stakeholders, and their perceptions and behaviors should be the focus of research aiming to
develop safer work environments, thus prompting the companies and managers to improve safety programs within their workplace.

**Purpose of the Study**

Prior studies have aimed to develop safety training to improve workers’ hazard identification and risk perception skills. For example, Namian, Albert, and Feng (2018) found that workers’ inability to interpret the risks can lead to a greater exposure to hazards. While risk, a measurement of severity, exposure, and probability of accidents, gives useful mathematical estimation of accidents for a risk assessment plan (Jannadi & Almishari, 2003), it is complicated for workers who are imperative to make the safest decisions in a diverse, complex nature of construction workplace. Additionally, workers face difficulties in appropriately interpreting the risk because the work environment may hamper workers to get an accurate estimation of risk. To further explore workers’ safety abilities and injury-prevention strategies, an investigation of workers’ severity interpretation can be a more tangible approach to understand workers’ perceptions of hazards. Therefore, this study aimed to establish a greater understanding of quarry workers’ perceptions to identify work hazards and interpret severity, and their strategies to prevent accidents.

**Research Questions and Design**

To explore quarry workers’ perception of work hazards and their employment of prevention strategies, this study posed the following research questions:

- RQ1: How do quarry workers perceive hazards in their work environment?
  - RQ1a: How do quarry workers recognize hazards in their work environment?
  - RQ1b: How do quarry workers interpret hazards in their work environment?
- RQ2: What strategies do quarry workers employ to prevent work hazards in their work environment?

This study employed an inductive, qualitative methodology and conducted a descriptive, single case study of eight quarry workers at surface-mining organization of a corporate entity in the midatlantic region of the United States. The research collected data from various sources at the
quarry including field notes, a precursory meeting with safety managers, site photographs, and interview transcripts. Particularly, this study used employee interviews as its primary data source and incorporated data from other sources to support the emergent findings from the interview responses. The data collected in this study were inductively analyzed through the methods described in Chapter 3. Specifically, this study utilized the quarry as a case study to fully understand the research context through different sources of data, as previously described.

**Summary**

The purpose of this inductive qualitative case study was to gain a greater understanding of quarry workers’ abilities to identify and interpret work hazards and their strategies to prevent accidents. To accomplish this goal, this study posed three research questions, which were addressed by adapting findings from construction safety research because the fatality rate in the surface-mining industry increased while it decreased in construction in 2017. To better understand workers’ safe behavior, this study provided a conceptual framework to establish the research focus and found that appropriate hazard identification and severity interpretation in safety training are two primary elements for workers to prevent accidents. Therefore, this study posed research questions to explore workers’ perceptions of work hazards and their prevention strategies.

This study is divided into six chapters. Chapter 2 provides an overview of the current literature on safety, particularly within the contexts of construction and surface-mining. This chapter begins by discussing the difference between safety culture and climate. To explore the current approaches to develop a safety culture and climate within the workplace, safety management and management tasks are identified, and current challenges are illustrated. Finally, a brief background of quarry workers and their work environment is presented.

Chapter 3 provides a detailed explanation of each phase of the research design. It includes the research design, context, and description of participants. It also describes the researcher’s methods of data collection such as photo-taking, interview procedures, and supplementary data collection. In data analysis section, an inductive data analysis using Dedoose coding software is
described. Concluded with research quality, this chapter illustrates a rationale for using a case study research design as well as the data collection/analysis procedures.

Chapter 4 presents the study’s findings. Corresponding to each research question, each section of this chapter demonstrates the findings obtained through the methodological approaches described in Chapter 3. Workers’ abilities in identifying and interpreting work hazards are elucidated and their preventative strategies are described.

In Chapter 5, the findings are compared and contrasted with previous research in safety. This chapter includes comparison with findings from previous research to further understand the quarry workers’ perception of work hazards and to contribute to the growing body of safety research in the construction and surface-mining industries. Lastly, limitations of this study are described in this chapter.

Chapter 6 discusses the study’s implications and provides a summary of the results. This chapter concludes with implications for practitioners and researchers to further understand quarry workers’ perceptions of safety and thus reduce occupational injuries in the surface-mining industry.
CHAPTER 2: LITERATURE REVIEW

The purpose of this study is to gain a greater understanding of quarry workers’ perceptions of work hazards by exploring their abilities to identify and interpret work hazards and strategies to prevent accidents. In this chapter, previous studies in construction safety are reviewed to examine current practices of safety management and define challenges in the development of safe work environments. Further, the findings from construction safety research will be adapted to improve a safer working environment in the surface-mining industry because a lack of safety studies exists in the surface-mining industry. To promote a safer working environment in the surface-mining industry, this chapter draws from the findings in the construction safety research to explore quarry workers’ perspectives of work hazards in the surface-mining industry.

Introduction

The leading causes of construction worker fatalities are the “fatal four,” which include falls, being struck by objects, electrocution, and being caught between objects (OSHA, 2007). According to the United States Department of Labor, Bureau of Labor Statistics (BLS, 2018), the private construction industry recorded 971 (18.9%) of the 5,147 fatal work injuries occurred in the United States in 2017. Statistics show that the greatest number of fatalities is caused by falls (381 or 39.2%), followed by being struck by objects (80 or 8.2%), electrocution (71 or 7.3%), and being caught between objects (50 or 5.1%).

A primary reason for the high number of accidents and worker fatalities in construction is the various work hazards that are experienced throughout construction sites. There are gravitational (e.g., slips, trips, and falls), chemical (e.g., fires, explosions, and leakages), electrical (e.g., electrocutions, burns, and explosions), and mechanical (e.g., corrosions, misalignments, and overloads) hazards. These work hazards are not always apparent and can be difficult to identify. As a result, in most construction sites, workers are vulnerable to workplace hazards due to their lack of skills, unclear safety responsibility, and “boring and simple” safety activities or education (Mohammed & Tamrin, 2017).

At the same time, studies have found that work accidents are often caused by workers’ risk-taking behavior (Lehmann, Haight, & Michael, 2009; Rashid & Behzadan, 2018; Tixier,
Even if workers are equipped with knowledge and skills in their fields, they may still prioritize, or be pressured to prioritize, safety below advancing project progress and remaining on schedule (Hinze, 1997). That is, workers will take risks to achieve accomplishments such as meeting deadlines and production goals. To further convolute this issue, prior research has also demonstrated that program quality does not necessarily influence safety behaviors; workers will still take safety risks, even when comprehensive safety programs have been established (Howell, Ballard, Abdelhamid, & Mitropoulos, 2002). Therefore, it is important to consider individual workers’ perceptions and external factors that influence their behaviors.

**Challenges to the development of a safe workplace**

Construction projects involve different stakeholders. Each stakeholder has their own safety interests and they are difficult to integrate their safety expectations for a new project (Wu et al., 2016). These stakeholders are different at each stage (e.g., design, construction, maintenance) and include owner, general contractor, subcontractor, designers. Therefore, alignments and adjustments to their existing safety programs such as safety training and safety regulation require each stakeholders’ shared goal and mutual understanding to actualize an injury-free environment (IFE) for workers’ safety and well-being (Saunders et al., 2017).

However, efforts to create an IFE within their workplace often are discouraged by difficulties. These difficulties are sometimes created by complex work systems, long project durations, and temporal project partnerships that hamper development of systemic improvements for construction workers (Kleiner, 2006). Despite construction companies’ management-led strategies to improve workers’ safety and wellbeing, safety is frequently underprioritized compared to business-related aspects of construction projects including time, cost, quality, and sustainability, particularly when related to stakeholder needs (Sunindijo & Zou, 2012b).

**Other business-related measures to success over safety**

These considerations often take priority over safety in construction. For example, if a project is behind schedule or facing a budget shortfall, safety usually becomes a lesser priority, increasing the probability of accidents. In other words, to meet the stakeholders’ expectations, including
those of both clients and owners, safety is generally overshadowed by other business-related measures. As a result, social and organizational pressures are created within construction projects, mainly due to work overload, miscommunication, and production pressure (Tixier et al., 2014; Wang et al., 2018). Therefore, more studies must evaluate the experiences and perceptions of workers to enhance these approaches to workplace safety, thus achieving zero-accident construction workplaces.

**Broad scope of safety training**

Safety management supports managers in self-assessing safety activities and evaluations performed at the construction site from project conception to completion. Safety management serves to assess the safety of a work environment by quantifying some of the factors that can, directly and indirectly, promote a safer work environment. For example, a measurement of safety training effectiveness might provide individualized safety scores that indicate a worker’s strengths and weaknesses involving a certain type of work hazard (Jeelani et al., 2017). This finding suggested that the implementation of effective safety training interventions can improve safety performance by measuring and enhancing workers’ skills in hazard recognition and risk perception.

Workers’ safety behaviors are encouraged by safety training. Safety training is the core activity that strengthens the workers’ abilities to perform safely in the workplace (Cohen et al., 1998). In particular, the Conceptual Safety Management Process (CSMP) created by Namian et al. (2016) sought to improve workers’ hazard recognition skills through safety training engagement. Hazard recognition is workers’ ability to identify hazards, while safety-risk perception is defined as workers’ subjective judgment of the frequency and severity of harm associated with a hazard (Fung et al., 2010).

However, safety training can be too broad and vague (Cohen et al., 1998; Kirkpatrick & Kirkpatrick, 2006). Although OSHA inspects construction sites regularly, the materials they bring to a site will not always be helpful, as only a portion of the work hazards addressed in safety training may be identical to those faced in a particular workplace. Therefore, increased
emphasis on work hazards specific to each work environment could improve the effectiveness of safety training.

**Subjective safety evaluation and inspection**

While safety performance measurement allows safety managers to evaluate their safety goals at a single point in time, there has recently been increasing demand to facilitate knowledge transfer, particularly of safety performance, to other stakeholders. Awolusi and Marks (2017) developed the Safety Activity Analysis Tool (SAAT) to facilitate safety management using Microsoft Excel. SAAT enables users to proactively monitor safety performance, set goals for improvement, and share constructive feedback to foster a safer work environment at construction sites. This computer-based approach is promising in that all stakeholders can have direct access to unmanipulated worker safety data.

However, safety managers’ subjectivity is problematic because measurement highly relies on safety managers’ judgment. Kim, Ahn, and Yang (2017) examined workers’ bodily responses when encountering work hazards. Their study tested whether workers’ bodily responses were noticeable when facing a work hazard. They found that workers’ bodily responses were more irregularly demonstrated and distributed when encountering work hazards than they were in environments without hazards. Similarly, Yang, Ahn, Vuran, and Kim (2017) utilized workers’ irregular bodily responses to understand different hazards in various construction sites. However, safety management is still limited, and this does not intrinsically solve the most common barriers to workers’ abilities to recognize hazards and accurately perceive safety risks.

**Environmental barriers**

Environmental factors in the workplace hamper workers’ adequate understanding of work hazards because workers are constantly exposed to work hazards including excessive heat, noise, and chemicals (Mohammed & Tamrin, 2017) that distract them from employing appropriate safety knowledge and skills to prevent accidents. In other words, many factors affect workers’ unsafe behaviors in the workplace, though specialized safety training and tools may help improve their adoption of safety strategies (e.g., personalized safety training, safety training integrating virtual reality) (Hasanzadeh et al., 2017a; Jeelani et al., 2017). Thus, it is important to
understand what factors lead workers to perform unsafe behaviors and prevent safe construction practices in the field.

Further, construction workers must “exercise considerable independent judgment [on the job site] and usually receive an extensive period of training” (USLEGAL, 2016). Due to the nature of their duties on-the-job (e.g., hands-on activities, frontline tasks), workers experience a higher chance of accidents when not supervised and left to their own judgment and are responsible for making important decisions regarding safety. As a result, workers must address work hazards at the front lines, and their knowledge and skills in identifying and interpreting work hazards play significant roles in avoiding accidents and protecting individuals and their coworkers from injuries.

**Psychological barriers**

In particular, Wang, Wang, and Xia (2018), identified various factors that encourage or discourage workers from adopting safe construction practices. They identified safety-related stressors that impaired workers’ safety participation and found that psychological capital (PsyCap) serves to moderate the stressors. The most critical safety-related stressors were found to be role ambiguity, role conflict, and interpersonal safety conflict, and these stressors negatively influenced workers’ safety performance. These stressors hamper workers in maintaining workplace safety, but Wang et al. (2018) claimed that the four psychological factors may mitigate the negative impact of the stressors and consequently lead workers to follow safety procedures by promoting their commitment and engagement to safety.

Self-efficacy, confidence, resilience, and autonomy are also key psychological factors that were found to bolster workers’ proactive behavior to support safety (Conchie, Moon, & Duncan, 2013; Marín & Roelofs, 2017; Wu, Wang, Zou, & Fang, 2016). For example, Marín and Roelofs (2017) stated that self-efficacy and confidence equip workers with the capabilities to work successfully. That is, by applying safety knowledge to independently practice safe work procedures, workers acknowledge themselves as skilled and confident in what and how work is to be performed. Also, Conchie et al. (2013) suggested that autonomy could improve ownership, subjective competence, and relatedness among the workers, encouraging the completion of work
while maintaining safety practices. Along with self-efficacy, autonomy, and confidence, resilience has been shown to help workers maintain positive attitudes and self-commit to approaching problems as challenges to overcome (Conchie et al., 2013; Wu et al., 2016). With these psychological factors in mind, workers’ commitment and engagement can reduce occupational injuries. Overall, this prior work suggests that considering workers’ psychological factors with safety practices can better facilitate their involvement in safety and adoption of safe practices.

**Current approaches to develop safety culture**

To develop a safe work environment in the construction industry context, companies often use a variety of administrative approaches to management and controls (Awolusi & Marks, 2017; Fung et al., 2010; Haro & Kleiner, 2008). In the workplace, safety has been considered in two contexts: safety climate and safety culture (Byrom & Corbridge, 1997, September; M. D. Cooper & R. A. Phillips, 2004; Planeix Dumas, 2011; Trinh, Feng, & Jin, 2018). Safety culture is defined as underlying values, attitudes, and perceptions shared by employees at all levels to represent an organization’s safety and health (Misnan & Mohammed, 2007; Saunders et al., 2017). Within organizations, safety culture is generally established if all workers value and prioritize the safety of themselves and their coworkers. On the other hand, safety climate is the sum of workers’ perceptions of how safety management prioritizes safety in the workplace at a particular moment in time (Zohar, 1980). Safety climate is often used to measure safety culture by examining worker’s attitudes, rules, and practices (Guldenmund, 2000; Saunders et al., 2017). Empirically, Sunindijo and Zou (2012a) distinguished safety culture from safety climate through the source of safety practices (i.e., 37 management task, see Appendix A). While the safety climate is fostered by employees’ perceptions of safety, safety culture is established by upper management as they promote safety practices among the collective company. Therefore, while safety culture creates a positive perception of safety in the work environment, safety climate can be used as an indicator to diagnose and evaluate safety within an organization.

To create an effective safety culture in the context of a construction project, Dingsdag, Biggs, Sheahan, and Cipolla (2006) advised senior project managers and executives to use the Construction Safety Competency Framework (CSCF) to set safety standards within their
companies. Sunindijo and Zou (2012a) further tabulated 37 CSCF safety-management tasks, as shown in Appendix A, that can help promote safety culture among construction workers and encourage them to be more proactive in their behaviors and attitudes regarding safety. To further establish a safety culture and climate, previous studies have also stated that employers must provide construction workers with safety equipment and tools to improve workers’ perceptions of safety management, thus promoting a positive safety culture (Cohen et al., 1998; Kirkpatrick & Kirkpatrick, 2006; Lehmann et al., 2009).

However, it is generally accepted that organizational culture requires 5 years to develop (de Witte, 1986), which can be difficult for construction projects. As claimed by Dov (2008) that different safety climates can be observed in construction sites, building a safety culture is challenging. For example, construction companies often face the challenge of working and cooperating with subcontractors, requiring a new safety culture to be built. For this temporal nature of construction projects, Kleiner (2006) asserted that the projects can only have safety climates, stating that “culture can be differentiated from organizational climate. The former is much more permanent and pervasive, while the latter is the temporal reaction to critical incidents and events.” (p. 280) Therefore, project safety climate can be examined to improve workers’ safety before changing organizational culture for a project.

To effectively promote and evaluate safety climate, factors were developed for construction companies to adopt and utilize in their safety programs. Probst, Goldenhar, Byrd, and Betit (2019) specified eight safety climate factors, which include 1) demonstrating management commitment, 2) aligning and integrating safety as a value, 3) ensuring accountability at all levels, 4) improving site safety leadership, 5) empowering and involving workers, 6) improving communication, 7) training at all levels, and 8) encouraging owner/client involvement. These factors can be rigorously implemented at safety meetings to promote a shared understanding of and agreement to practice safety. However, research is scarce regarding how to integrate safety climate factors into an organization. While Probst et al. (2019) listed safety climate factors to measure organizational safety performance, information on how organizations can assess the implementation of safety climate factors is lacking, leading to confusion and a failure to incorporate these factors. Therefore, a detailed approach and actionable strategies are necessary to guide companies in translating the safety climate factors into reality.
To address the issue of building a safety climate and culture within complex and varied construction projects, Haro and Kleiner (2008) suggested implementing macroergonomic analysis of structure (MAS) and macroergonomic analysis and design (MEAD). MAS was developed by Hendrick (2004) to establish an effective structure for an organization's work system. Macroergonomics is a top-down approach to designing work systems such as human-job, human-machine, and human-software systems and employs three major sociotechnical system elements (i.e., technological subsystem, personnel subsystem, and relevant external environment). MAS enables construction projects to adapt and design organizational systems structures to mitigate safety-program discrepancies among contractors and subcontractors. MAS provides a more optimal work system by generating analysis of work operation including human factors, ergonomics, and needs for intervention/implementation. MEAD also supports users in evaluating how their existing safety programs could effectively comply with the characteristics of a new project work environment. Many previous studies, including those using MAS and MEAD, have sought to support managers by employing administrative approaches to improving workplace safety in construction in which safety supervisors can evaluate and promote workers’ safety behaviors.

**Overcoming challenges**

*Implementation of innovative technology*

The advancement of technology supports workers to recognize the safety hazards in their work environment. For example, a real-time safety assistance system to help workers to make informative decisions has been widely studied. Fang and Cho (2017) implemented a load-oriented lift-assistance system to support a crane operator in the process of hazard perception and recognition to assist in making safety decisions. This assistance system also supported the operator in visualizing their surroundings, as graphics information is more easily processed than words, and images can be interpreted faster than words if illustrated accurately.

Moreover, to better understand workers’ failure to accurately identify work hazards, Hasanzadeh et al. (2017b) employed eye-tracking methods and analyzed the gathered data through mathematical models. Under the premise that workers’ lack of hazard recognition is due to
inadequate visual attention to the hazards, the researchers developed a tool for companies and practitioners to assess workers’ abilities to identify work hazards and thus to provide adequate safety training to improve workers’ understanding of the safety knowledge they lacked. Similarly, Jeelani et al. (2017) found that participating workers, who were only able to identify 42% of hazards, were able to identify 77% of hazards in the intervention phase through personalized hazard-recognition safety training incorporating visual cues. Also, Albert, Hallowell, and Kleiner (2014) developed a high-fidelity augmented virtual environment [System for Augmented Virtuality Environment Safety (SAVES)] to help workers better identify hazards. They found that participants, on average, who identified 46% hazards prior to the intervention, could recognize 77% of hazards after the intervention. Therefore, it is evident that graphic demonstration of work hazards contextualized in the specific work environment and tailored to workers’ lacking hazard recognition skills improve workers’ safety performance and help them leverage their skills to prevent potential accidents.

Aside from using eye-tracking technology and graphic demonstration of work hazards to enhance workers’ abilities through personalized safety training, wearable mobile sensors have been suggested by Nath, Akhavian, and Behzadan (2017) and can be utilized to avoid subjective judgments by safety managers when observing workers’ behavior at a worksite. For example, safety managers potentially make inconsistent and ambiguous judgments when measuring workers’ safety performance. To combat this, smartphones can be used to measure workers’ trunk and shoulder flexion in a manner that is far more accurate than managers’ typical evaluations (Nath et al., 2017). As sensory technology and automation develop, it seems that engaging sensors attached to personal protective equipment may help inform safety managers without requiring them to devote too much energy to observing each individual worker.

**Significance of managers’ role in safety**

On top of these technological advancement in building a safe workplace, managers’ commitment to safety is necessary. Generally, an employer (i.e., general contractor) is responsible for employees’ safety and wellbeing. According to OSHA, the OSH Act’s General Duty Clause states that each employer “shall furnish to each of his employees employment and a place of
employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employee” (OSH Act of 1970).

However, we often underestimate the duty of employees, as the act further states, “each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct.” While an organization’s safety systems can be designed and established by an employer, employees’ compliance with safety protocols can increase safety-system effectiveness. Therefore, both employers’ and employees’ commitment to and involvement in safety are fundamental in preventing work accidents and promoting safer work environments.

**Significance of workers’ participation in safety**

A hierarchical power dynamic within a company between safety management (i.e., enforcing passive behavior) and workers (i.e., satisfying minimal requirements without active participation) still remains, and few studies have examined ways to encourage workers’ active safety behavior. Along with implementing safety management and providing advanced safety equipment, workers need further encouragement to practice safe behavior to effectively reshape their safety mindset when encountering work hazards. Thus, safety must be rigorously investigated from not only an administrative perspective, in which a manager or supervisor holds the sole responsibility for safety, but also from a worker’s perspective that every worker is motivated to promote safe work environments in which workers can trust management and their coworkers.

However, a few previous studies have established the need for shared safety responsibility in which the workers are empowered with the knowledge and authority to promote organizational development (Marín & Roelofs, 2017; Western, 2013). To bolster workers’ involvement, particularly in safety, organizational safety must be perceived as a priority and responsibility shared among all members of the workplace. Therefore, further research is needed to investigate how workers perceive work hazards and employ strategies to prevent accidents in the workplace, thus generating safe work environments.
Craftworkers in the quarry industry

Surface miners, like construction workers, are a population that faces a disproportionate number of work accidents. The fatality rate in the surface-mining industry increased from 10.0% to 15.5% per 100,000 workers, while the fatality rate in construction decreased from 10.1% to 9.5% per 100,000 workers between 2016 and 2017, respectively (BLS, 2018). As noted earlier, this trend might be apparent simply due to the relatively limited number studies addressing surface-mining safety compared to construction safety despite the similar safety hazards experienced in construction and surface-mining environments.

The surface-mining industry has a similar work environment to the construction industry. Surface miners experience an environment as complex and diverse as that in the construction industry. For example, surface miners operate heavy equipment, wear similar personal protective equipment (PPE), and encounter comparable types of accidents (e.g., slips, falls, and becoming stuck between objects). Because of these similarities, this study is informed by prior work in the construction industry to inform this study in better understanding quarry workers’ perceptions of workplace safety.

Also, the surface-mining industry has developed safer work environments in recent decades. To reduce the number of accidents in the surface-mining industry, previous studies have analyzed the different types of hazards that mine workers are most likely to experience at the workplace. Donoghue (2004) identified physical, chemical, biological, ergonomic, and psychological hazards to improve the precision of medical treatment for mine workers. Noting the unique risks of mining at altitude, Vearrier and Greenberg (2011) identified particular adverse health effects that such workers face, including occupational diseases (e.g., cardiovascular, pulmonary, and neurological effects). Previous studies investigated the types of work hazards and their negative effects on mine workers’ health to reduce occupational injuries in the surface-mining industry.

With these studies of work hazards, the mining industry is advancing its safety assessments and training workers in safety skills. To continue working toward risk-free and zero-accident work environments, commitment from mining companies and involvement from workers are necessary.
Additionally, many prior studies have utilized safety inspections and evaluations to develop safety protocols to mitigate work fatalities among quarry workers in the surface-mining industry. While these protocols are often enforced by the company and other governing agencies, such as the OSHA and the MSHA, little is known about how quarry workers perceive work hazards and employ safety knowledge during periods of unsupervised work. Therefore, more research is needed to explore quarry workers’ behaviors and safety performance while unattended by their safety supervisors.

One particular benefit of investigating quarry workers is that the surface-mining industry generally features an established organizational culture, which construction workers might not experience because construction is project-based, and it takes 5 years or more to form an organizational culture (de Witte, 1986). While construction projects often involve several subcontractors, the surface-mining industry is mostly self-performed. Unless workers must travel to different mines, they naturally become aware of their coworkers, and the company’s shared organizational values. Thus, as there is generally an adequate time to develop an organizational culture among quarrying organizations, these companies may be better able to engage everyone in a mutual vision for safety. Therefore, this research investigated quarry workers’ abilities in hazard identification and severity interpretation, and their preventative skills in mitigating the hazards to promote their safe behaviors in the workplace.

Summary

Previous studies in construction safety have expanded and the growing body of research on the relationship of organizational systems structure and safety management. For example, Haro and Kleiner (2008) developed MAS and MEAD to facilitate organizational systems structure and Sunindijo and Zou (2012a) suggested to implement 37 management tasks to improve safety management. These systematic approaches contributed to overcoming challenges in creating safety climate and culture within an organization.

However, challenges remain regarding the development of a safe work environment. Safety training provided by government agencies (i.e., OSHA, MSHA) can be perceived as too broad and vague for workers to relate to it and utilize it within their work environment (Cohen et al.,
1998; Kirkpatrick & Kirkpatrick, 2006). Also, the safety evaluations and inspections performed by safety managers rely too heavily on managers’ subjective judgment and perspective; thus, measurements might be biased. While technology advancement supports workers’ abilities to identify and interpret work hazards, more research is needed to enhance workers’ safety skills (e.g., hazard identification, severity interpretation).

In the surface-mining industry, few studies on safety have been conducted compared to the number in the construction industry, and the number of mining-industry fatalities was found to have actually increased in 2018 while a decreasing trend of fatalities is observed in the construction industry (BLS, 2018). As the surface-mining industry shares many similarities with the construction industry in terms of work environment and hazards, construction safety findings may help identify methods to improve mining safety. Therefore, the mining industry has tremendous potential to improve safety by adapting approaches from the construction industry.

Additionally, zero-accident status is yet to be accomplished. Based on a literature review, one strategy to achieve zero-accident status is to encourage workers’ involvement and participation in safety. To promote workers’ engagement in safety, future studies must elucidate workers’ perceptions of work hazards and identify their strategies to prevent accidents. Thus, a safe workplace could be better established with management commitment and workers’ involvement. Therefore, to further involve workers in safety management, it is imperative to understand how workers perceive work hazards and their implementation of prevention strategies. Findings from this work may then be expanded to better inform safety procedures and training in the surface mining industry to reduce occupational injuries and to promote an IFE.
CHAPTER 3: METHODS

The purpose of this study is to gain a greater understanding of quarry workers’ perceptions of work hazards and the strategies they use to prevent accidents. To accomplish this purpose, this research poses questions about workers’ perceptions of and mitigation strategies for work hazards. Specifically, this research investigated how workers recognize and interpret work hazards and proactively identify strategies for injury prevention in the absence of a safety supervisor. In this chapter, the methods and research protocols to achieve the purpose of this study are discussed, as guided by the research questions.

Research Design

To answer the research questions posed within this study, an inductive qualitative research design was utilized to gain breadth and depth of quarry workers’ perceptions, behaviors, and experience regarding safety in the workplace. This study employed a case study design (Yin, 2012) to collect data from multiple sources by using interviews, photo elicitation, precursory meetings with safety managers, field notes (see Figure 6), and site photographs (see Appendix J). Particularly, interviews and photo elicitation were primarily used for data analysis. A summary of the methodological approaches employed within this research study, along with their corresponding research questions, are presented in Figure 2.
While many previous studies have underscored the role of safety managers who are generally responsible for the safety and wellbeing of workers, the focus of this study emphasizes the importance of workers’ abilities to recognize and interpret hazards and appropriately identify preventative strategies to reduce the likelihood of work accidents. Thus, without posing any particular type of work hazards, the research questions were designed to investigate workers’ safety behavior against any work hazards they might experience. Therefore, the participants were generally tested on their ability to identify and interpret hazards. However, the most known hazards in the quarry work were discussed and identified with the safety managers in the precursory meeting to check the types of hazards in the photos provided to the participants, which will be discussed in following sections.
Case Study Research Design

This study employed a case study design to better understand the ways in which workers recognize and interpret work hazards as well as examine the preventative strategies employed by workers when a hazard is encountered. Case study research, according to Gillham (2000), is defined as a way of investigating a subject, either an individual or community, to answer a research question by seeking different types of evidence gathered from the case setting. Further, a case study is “a main method” (Gillham, 2000, p. 13) that is composed of subordinating methods such as interviews, observations, documentation, and so forth. While some researchers contend that only qualitative data and ethnographic studies can be used and benefited by case study (Miles, 1979), this qualitative approach effectively accommodates different types of data, including quantitative or qualitative, for analyzing observational outcomes with statistical analysis (i.e., biological lab results) or to understand the quantitative indicators with qualitative evidences (i.e., historical events). Because case study has a strength in investigating and gathering data from real-life context, the data can better represent the external factors (i.e., phenomenal influences) that traditional experiments cannot capture through a deliberate separation from its context.

Further, case study may be conducted in different modes to sufficiently satisfy the purpose of study. Among the other modes that Yin (2012) illustrates (i.e., exploratory, explanatory, evaluative), this study employs a descriptive case study which helps the researcher to investigate a single case to describe a phenomenon or behavioral strategies that people employ within a particular context. This study, in particular, investigated a single case of quarry workers’ perceptions of safety hazards and preventive strategies at their particular workplace (i.e., surface-mining organization of a corporate entity in the midatlantic region of the United States). Therefore, a single descriptive case study is utilized in which the researcher collects data in various ways within a single context (Yin, 2012).

This study also utilized a case study research design to strategically observe and explore contextual variables that may influence workers’ behavior when faced with a hazard on the worksite. Specifically, this study used a combination of interview and photo elicitation methods to collect data. This case study research approach enabled the researcher to thoroughly explore
the research context by accessing different types of data. Other forms of data in this study included photos, discussions with safety management, and site observation notes, which allowed the researcher to more thoroughly analyze and understand the research case. These data sources also provided insight into social norms and professional culture that exists within the workplace under study (i.e., characteristics that may influence the workers’ behaviors in safety). For example, while safety training and safety management/leadership were already practiced via established regulations and rules at the research site, workers’ day-to-day interactions and experiences of encountering hazards needed to be examined to further understand the their abilities to: 1) identify the hazards in workplace; 2) interpret these hazards and potential harms they may cause and; 3) employ preventive strategies to generate a safer working environment. Therefore, it became evident that this research context contained a variety of rich data sources that could be used to understand the contextual aspects of workers’ safety behavior. As such, case study did not only allow the researcher to gain insights into workers’ behavior as influenced by their own stance (i.e., experience and perspective), but also those shaped by contextual variables (i.e., work stressors, organizational norms).

**Research Context**

Data were collected from craftworkers employed at a surface-mining organization. This organization was chosen not only for ease of research access, but also due to the relatively limited amount of safety research conducted in the context of the surface-mining industry. For these reasons, this site attracted the researcher’s attention for expanding and adapting construction safety research to the surface-mine context.

This study examines a surface-mining organization of a corporate entity in the midatlantic region of the United States. This organization is an open-pit type of surface-mine which is also known as a quarry. The quarry which started its operation over 100 years ago is surrounded by a residential area. The quarry is about 40 acres large, and produces 25 to 50 tons of limestones per week for commercial use. The quarry provides limestone with a serene-color combination of pink, red, brown, gray and black. The quarry’s operation produces noise and dust.
The quarry’s operation requires workers to craft rocks into a marketable shape. The quarry primarily operates in three phases: excavation, cut and delivery. Excavation involves blasting and digging. Workers use black powder to blast stone from the earth and break rock slabs by using hydraulic excavator and pneumatic hand drill. After the excavation, quarry workers cut rocks by using hydraulic breakers and saws (i.e., blade saw, wire saw) to trim rocks into a rectangular shape ready to be delivered. The blocks of rock are stacked together on pallets and moved by a bobcat for delivery.

Particularly, the cutting phase requires the most workers. Three to six workers operate the breaker on different sides of the machine. One or two quarry workers control the lever/switch of the breaker which uses hydraulic pressure and a double-action wedge system chisel to split the rocks. The split-rock is then placed on a conveyor belt where two operators separate rocks from debris (i.e., trash rocks). The rocks are then stacked together on pallets for a bobcat to carry and arrange them to be delivered. Because the quarry’s operation requires workers to coordinate their efforts across the three operational phases, teamwork is essential for this operation.

The quarry is characterized by a traditional organizational structure where an employer manages and controls operationalization of the quarry. The quarry is operated by the associate vice president and chief facilities officer and managed by the site coordinator with the support of two field supervisors. The hierarchical organizational structure of the quarry management is illustrated in Figure 3.

As illustrated in Figure 3, the current organizational structure of the quarry is a hierarchical formation that employs a top-down approach to the management and supervision of the quarry workers. This figure provides an overview of the quarry’s operational controls. It also shows how quarry workers are managed by two field supervisors and supervised by a site coordinator. As shown in Figure 3, the safe performance of quarry workers is directed by two field supervisors and one site coordinator, though workers may make their own adjustments and decisions concerning operations when supervisors are not present.

At the quarry, a total of 14 to 16 workers were on site to fulfill a daily production goal. The quarry workers’ average working day was from 7:00 am to 3:00 pm during the weekdays. The
number of workers at this site varied throughout the duration of the study because the organization was hiring more workers to expand their workforce. Within the organization, three individuals were maintained the upper levels of the hierarchical organizational structure (see Figure 6) and had specific titles and roles. The site coordinator was the head of the quarry and in charge of managing and overseeing quarry operations. The site coordinator closely worked with quarry workers and middle management. The remaining members of middle management, who reported to the site coordinator, were two supervisors who assisted the site coordinator and supervised quarry workers during day-to-day operations. In particular, their role was to closely monitor and control the safety of the workers’ activities, allowing the site coordinator to share responsibility with them when he is offsite. With more than 19 years of experience at the quarry, the supervisors have enough knowledge to guide and instruct workers in their tasks, and notably, they have keys to lock the two saw rooms, which must be kept inaccessible and are prohibited to unauthorized personnel. Through these approaches, the supervisors could also contact each other through an emergency communication tool that enables users to alert one another in case of an emergency. The rest of the quarry workers had varying work experience ranging from 3 months to 25 years.
Quarry workers received a list of safety training programs to improve their knowledge in maintaining their safety and wellbeing in the workplace every year. For example, they received yearly safety training offered by their own organization. Safety managers, including the site coordinator and supervisors, ran the training for 8 hours in a classroom. The quarry workers often referred to this training as a “refresher course.” The quarry workers also received safety training provided by the Mine Safety and Health Administration (MSHA). While MSHA inspectors visited and examined the quarry at least twice a year, the most recent safety training by MSHA at this site was offered two years ago using a safety presentation comprised of photos and videos from other quarries to help workers gain awareness of related hazards that may occur in their workplace. Per MSHA requirement, new quarry workers must take an initial safety training within 60 days and another subsequent training within 90 days of employment. Additionally, the new hires were provided with field training where they observed and watched other experienced workers operate the machines. This apprentice-type training allowed enough
time (e.g., from a week to a month) for new workers to gain enough knowledge and confidence to run the machine on their own. Lastly, with the assistance of the supervisor, each quarry worker was required to take an individual computer-based safety training. In the event that the quarry worker experienced an accident, that worker was required to retake a full course on the encountered hazard.

Participants

To collect data and recruit participants, the researcher obtained Institutional Review Board (IRB) approval to conduct the study. Documents required to obtain approval by the IRB, with the exception of the Research Protocol are located in Appendices B through H. To gain an access to the participants, the researcher contacted the vice president of facilities department. In the process of gaining access and recruiting participants, the researcher had several meetings with the management team. In the first meeting with the quarry management, the researcher and managers, including the vice president, discussed the breadth and depth of the study as well as its outcomes. A second meeting was held with the human resource manager, quarry coordinator, safety coordinator, and associate director of buildings and grounds to further discuss project procedures such as conducting interviews and taking site photos (see Appendix I for full timeline of data collection).

Once the researcher gained an access to the participant at the quarry, they worked collaboratively with the site coordinator to recruit participants with a recruitment script (see Appendix F) and schedule for interviews after discussing with the site coordinator for worker’s safety issues. In this study, no monetary compensation was included for interview participants, but the researcher provided a bottle of water for the participants to drink during the interview.

Participants were purposefully selected for this research to “best help the researcher understand the problem and research questions,” as stated by Steele (2011, p. 185). According to Creswell and Creswell (2017), the number of participants in qualitative research on phenomenology and ethnography typically ranges from twenty to thirty. For a case study, Yin (2009) noted that the focus should be its case replications, stating “the typical criteria regarding sample size are irrelevant” (p. 262). Due to the fact that the total number of employees at the research site ranged
from 14 to 16, and the limited time slots for research access to employees, eight participants agreed to participate the study. Approximately, 50% of quarry workers at this site volunteered to participate in this study. Finally, to protect participants’ identities, the demographic information has not been revealed in this document.

Prior to the interview, the researcher obtained both verbal and signed consent from interview participants. Verbal consent was collected after the researcher’s reading the recruitment script (see Appendix F). Once the interview participant verbally agreed to participate the study, the site coordinator and researcher discussed to arrange interview schedules because interviews were going to be conducted during business hours. For safety purposes, the researcher was required to openly discuss workers’ availability for the interviews. Therefore, the site coordinator, obliged to know participants’ identities, agreed not to disclose the participants’ identities to unauthorized personnel such as individuals outside of the research team by signing Non-disclosure agreement (see Appendix H). A signed consent was gained immediately prior to the start of the interview, after reminding the participant of the project description and their right to withdraw from the study at any time without penalty. A copy of consent form and a business card of the researcher was provided to be taken by interview participants for their records. The complete, IRB-approved consent form is attached in Appendix E.

Data Collection

Photo-taking

Prior to taking the photos of the quarry, the researcher asked for guidance from scholars well-versed in photo elicitation methods (Albert et al., 2014). The researcher contacted the one of the scholars via email and scheduled a phone call to discuss the procedures and barriers encountered while taking the photos. To take the photos of the quarry, site visits were iteratively scheduled with quarry management to ensure the safety and health of quarry workers and to preserve the productivity and operationalization of the work. The researcher had to be very cautious as not to disrupt the productivity of the organization, particularly because the summer was the busiest time at the quarry when the researcher was on site to take photos. Therefore, the researcher had to thoroughly discuss the optimal times and dates for visiting the site to take the photos with the site
coordinator. Once the researcher and the site coordinator agreed on a date and time to meet, the researcher had to acquire Personal Protective Equipment (PPE) such as a pair of steel toe shoes, eye protection goggles, ear plugs, and safety vests due to safety regulations for visiting personnel. Additionally, the researcher was required to participate in a one-hour safety training prior to visiting the quarry to be aware of any hazards and likely accidents. Upon satisfying the safety requirements for entering the quarry, the site coordinator escorted and introduced the researcher to the quarry workers. The researcher talked with quarry workers to gain consent to take photos of the workers and their work environment while they were in operation. With the quarry workers approval, the researcher assured that their faces would not be shown in the photos and, in case their faces were on the photos, they would be blurred to protect their identities.

The photos were taken over the course of two days. On each day, the researcher took over 50 photos of the site and some scenes were taken several times in different angles to better illustrate the working environment. The researcher attempted to capture a variety of weather conditions; however due to weather patterns during site visits, only photos capturing sunny weather were acquired. A full description of timeline, including site visits, is demonstrated in Appendix H. Approximately, 50 site photographs were taken by the researcher and three photos were selected to illustrate three major operations at the quarry (e.g., breaking rocks by hydraulic excavator, cutting rocks by the saw, cutting rocks by the breaker). The photos were taken by the researchers’ personal cellphone camera (i.e., Iphone 6s). The photos were included in the interviews after examining the types of hazards with safety managers in the precursory meeting. These photos were distributed in the same order to participants in the interviews with a full 8.5” X 11” print.

**Interview Procedures**

The majority of data was collected using semi-structured interviews. Semi-structured interviewing is a widely used approach to data collection used in qualitative research. According to Hanington and Martin (2012), interviews are “a fundamental research method for direct contact with participants, to collect firsthand personal accounts of experience, opinions, attitudes, and perceptions” (p. 102). To explore quarry workers’ experience and attitudes toward safety
behaviors, semi-interviews allowed the researcher to collect rich data based on participants’
descriptions of their experience and attitudes without being constrained to the interview script.
This allows the researcher to grasp the full perspectives of participant not only by exploring an
exhaustive dimension of their lived experience in safety at the quarry but also by addressing the
research questions through research protocols in this study.

The interview protocol was initially designed with the research team to specifically answer the
research questions. To test and improve the interview protocol, a pilot study was conducted with
a graduate student at large, land-grant university in Southeastern United States. The researcher
took notes to develop on the interview protocol and had a chance to practice an interview.
Through the pilot study, the researcher could better prepare and improve the interview
environment to be calm and ready for participants. The pilot study allowed the researcher to
experience an interview setting and to lead conversation within the context of research topic.
Changes to the interview protocol were made, such as changing a word and phrase in the
interview questions.

The setting of absence of safety supervisor was established by conducting interviews with
participants in a private location on the worksite, as approved by the site coordinator. To help
build rapport between the participants and the researcher, the researcher tried to avoid creating
any sense that participants were being tested. Therefore, prior to the interview, the researcher
visited the quarry several times to chat with workers and instructed participants not to feel
obligated to answer in a certain way, as if there was a correct and incorrect answer, but rather to
freely discuss their thoughts and perceptions concerning safety.

Each interview was conducted in four consecutive phases: introductory interview, photo
elicitation, follow-up interview, and demographic survey. A summary of this interview process is
shown in Figure 4. All four phases of the interview were conducted in about sixty minutes and
completed in one sitting. Each phase was explained in full to participants prior to the start of the
interview. Participants were not required to complete all four phases of the interview and
allowed to quit at any time. In this study, all participants remained and completed all phases of
the interview.
Each of the four interview phases were developed to find answers to each research question by asking a series of questions to participants. RQ1a asked about quarry workers’ ability to identify work hazards, which was addressed using photo elicitation methods. RQ1b involved quarry workers’ ability to interpret the hazards and was addressed in the introductory interview and photo elicitation phases. The first three phases of the interview (i.e., introductory, photo elicitation, and follow-up) aimed to answer RQ2, which concerned quarry workers’ ability to employ preventative strategies to promote a safe work environment (see Figure 5 for detail). The demographic survey, gathered at the end of the interview, helped the researcher gain further insights into the relationship between safety behavior and personal traits and background. By obtaining background information about the participants, the researcher could grasp a better idea of how contextual factors affected participants’ experiences and attitudes toward safety, which are further described in the following sections.
Figure 5. Corresponding Interview Questions to Research Questions

**Introductory Interview**

In the introductory interview, participants were asked general questions about safety in the work environment. Such questions included, “What do you think is a safe working environment?”, and “What can you do to improve a safe working environment?” to gain a better idea of how the participant described a safe work environment from their own experiences. The complete interview protocol used in this study is attached in Appendix D. In preparation for the next phase of the interview, a handout about hazard and severity was also distributed to normalize
participants’ understanding of hazards and their risks and reviewed with the researcher. To improve and recall participants’ comprehension about hazards and risks, the definitions of hazard and risk were introduced verbally and on paper with respective examples. Once it was determined that participants understood the difference, a short exercise was given to ensure their adequate understanding of hazard and risk for the interview.

Photo Elicitation

The next phase of the interview process was photo elicitation. Photo elicitation is useful for capturing participants’ knowledge and experience through images. Kaminsky (2014) states that “images do not have a singular objective meaning.” An image can be interpreted differently by participants because of their culture and workplace climate; therefore, photo elicitation allows researchers to understand the perspectives of people by their explanation of a circumstance with a minimal use of words (Kaminsky, 2014). Although photo elicitation is not widely used in engineering research, it enables researchers to thoroughly explore participants’ experiences and attitudes.

In this study, photo elicitation was used to bolster communication between the researcher and the participant. For data collection using photo elicitation, images are typically developed in two ways: 1) a researcher can prepare a set of images that are contextualized for the study or 2) participants can take pictures by using a camera that captures their response to a particular prompt. The latter option enables participants to have more freedom to bring creativity about a particular topic through taking pictures unaffected by the researcher. Because photo elicitation was going to be used to bolster conversations between the researcher and participant, the former method was better suited for this study because it allowed the researcher to scope the content – and the topics – discussed during interviews. Thus, a set of images that were relevant to work hazards was prepared by the researcher and validated with site safety personnel. The photos used in this study are similar to those used by Albert et al. (2014), which illustrates comprehensive lists of construction hazards in sixteen photographs. In this study, the researcher took about 50 photos and 3 site photographs were selected by the researcher and safety managers to illustrate the major operations at the quarry. The photos are shown in Appendix J.
During the photo elicitation phase, images of a work site (shown in Appendix I) were distributed in the same order for each participant. Image order was chosen because the participants might be implicitly misguided by the order of images to seek for a specific number of hazards or a degree of severity of hazards, thus leading to unreliability in the data analysis. The researcher generally asked about the photos to avoid giving the impression that the participant was expected to find a work hazard as if they were taking a safety test. Thus, to ensure quality of interviews and promote the comfort of the participant, the researcher gave them ample time to discuss the photo by intentionally allowing for long pauses and photo review.

**Follow-Up Interview**

The next phase of the interview was the follow-up interview. This phase included asking questions specifically related to participants’ experiences and opinions about the images that were shown. In this phase, a participant was asked about their own ideas for preventing potential accidents that could result from the hazard in the photo. With a visual demonstration of the photo, participants were asked if they could interpret the severity of hazards. To establish a baseline-understanding of a participant’s knowledge regarding a specific hazard presented in the photo, the researcher asked the participant to identify and describe any observed hazards. Although scholarly works have investigated various scales to quantify and measure the severity of work hazards (Namian et al., 2018; Rashid & Behzadan, 2018), workers’ abilities to define and explain severity levels needs further research. Lastly, participants were asked if they could employ any strategies to prevent observed hazards and improve safety. After exploring participants’ perceptions of safety via photo elicitation, the researcher asked if they had any experience with work accidents or have witnessed someone getting injured in the past. The questions asked in this phase included, “What is the most memorable safety training you have received?”, and “Have you ever been involved or witnessed an accident in your workplace?” By asking such questions in the follow-up interviews, the researcher could gather a wider range of data from the participants without being influenced by safety-focused and -framed questions.
**Demographic Survey**

Lastly, the researcher distributed a fill-in demographics survey to participants at the end of the interviews. Steele (2011) states that the threat of stereotype conveyed by demographic survey can decrease participants’ ability and achievement for the given task. By putting the demographic survey at the end of the interview in this study, the participants could fully explain their experience in safety without fear of being judged based on demographic associations. The demographic questions included age, gender, ethnicity, duration of work experience in quarrying, and experience of safety training. Particularly, the duration of work experience and age helped in developing codes, categories and themes of participants’ experiences and attitudes in safety during analysis.

**Supplementary Data Collection**

Data was also collected from field notes and meeting with safety and site coordinators. This enabled the researcher to acquire detailed information about workers’ safety training and the organization’s perspectives of safety. A sample field note is provided in Figure 6.

![Figure 6. A sample of field note](image)

Once the different sources of data were collected, the interviews were audio recorded and transcribed for data analysis.
Data Analysis

Inductive qualitative approaches were used in this study to understand quarry workers’ perceptions of and behaviors toward safety (Creswell & Creswell, 2018; Thomas, 2006). Overall, this study used five stages to analyze the data and to improve the transferability and credibility of research findings, as shown in Figure 7.

![Figure 7. Five Stages of Data Analysis](image)

Emergent codes were inductively identified in participants’ responses during interviews. These responses were identified using interview transcript segments that were relevant in answering the posed research questions. These segments were grouped and categorized together to develop an emergent code. Code names were identified that captured the meaning of the participant responses using representative phrases or gerunds. For example, a participant responded that wearing earplugs, impact gloves, and safety glasses are important features to promote a safe workplace. This response was clustered with other responses and developed as a code-named *everyone wearing PPE*. Once codes were generated, the researcher grouped them into themes based on research questions and the meaning of participants’ responses. This approach allowed the researcher to explore participants’ experiences and attitudes without being constrained by bias and also without being constricted by an established framework (Creswell & Creswell, 2018; Gillham, 2000; Yin, 2012). Throughout the analysis process, the researcher utilized the qualitative data analysis software, Dedoose, to develop codes and themes, as shown in Figure 8. Dedoose helped the researcher to simultaneously find an excerpt and develop codes to generate emergent themes.
Figure 8. An example of codifying interview transcript

Once the researcher developed the codes by using Dedoose, these codes were grouped together to generate a theme. For example, participants’ responses on their perceived safe workplace (e.g., everyone wearing PPE, cleaning, everyone paying attention) were clustered together to generate a theme-named Perception of safe working environment. Although the researcher primarily used Dedoose to cluster codes to develop themes, Dedoose lacked a visual representation of comprehensive lists of clustered codes and themes. Therefore, the researcher used Microsoft Excel to organize the codes and establish themes to improve readability and comprehension of data. The total number of codes generated in this study was 56 developed from 170 page-long interview transcripts. A summary of emergent themes and definitions are illustrated in Table 1.

Table 1. Emergent themes and corresponding definitions

<table>
<thead>
<tr>
<th>Emergent Theme</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers’ perception of the current work environment</td>
<td>Quarry workers perceived and described the work environment at the quarry regarding with safety and operation</td>
</tr>
</tbody>
</table>
Table 1. Emergent themes and corresponding definitions, continued

<table>
<thead>
<tr>
<th>Theme</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-perception of workers</td>
<td>Quarry workers described their experience at the quarry as proud and satisfied</td>
</tr>
<tr>
<td>Perception of safe working environment</td>
<td>Quarry workers described a safe working environment as promoting a safe teamwork and following the safety guidelines</td>
</tr>
<tr>
<td>Workers' abilities to identify hazards</td>
<td>Quarry workers identified different hazards in each photo shared in the interview with photo elicitation and, sometimes, indicated additional hazards than those identified by safety managers</td>
</tr>
<tr>
<td>Workers' abilities to interpret the degree of severity</td>
<td>Quarry workers interpreted the degree of severity on different operations in the photos and used scenario and experience to estimate the severity</td>
</tr>
<tr>
<td>Preventative Strategy</td>
<td>Quarry workers unintentionally adopted the hierarchy of controls to prevent accidents</td>
</tr>
<tr>
<td>Barriers to practicing safe operation</td>
<td>Quarry workers identified barriers to practice safe operation at the quarry</td>
</tr>
<tr>
<td>Safety Intervention</td>
<td>Quarry workers utilized prior safety training and instructions to help themselves to recall and remind of work hazards</td>
</tr>
<tr>
<td>Workers' demands to improve safety</td>
<td>Quarry workers desired to improve safety by different strategies from their perspective</td>
</tr>
<tr>
<td>Critical acceptance</td>
<td>Quarry workers critically accepted unexpected hazards and indicated that they were frustrated for not having to prevent them from accidents</td>
</tr>
<tr>
<td>Moderators to safety behavior</td>
<td>Quarry workers improved safety to meet the needs of community and satisfy safety managers</td>
</tr>
</tbody>
</table>

Research Quality

In the preliminary phase of analysis, the researcher had to pose a naïve assumption because, *anything could mean anything*. Having a such assumption is particularly helpful because the researcher does not impose any meaning to the participants’ response until an emergent finding clusters together to represent a meaning. Qualitative study calls on credibility and transferability to improve research quality (Creswell & Creswell, 2018). Credibility is termed as determining the accuracy of research findings from the perspective of the researcher, participants, and readers (Creswell & Creswell, 2018). Transferability is similar to qualitative generalization which indicates the replication of research findings while acknowledging the particularity of research.
context (Creswell & Creswell, 2018). To ensure the credibility and transferability of findings and improve the quality of study, the researcher employed three strategies presented by Creswell and Creswell (2018): 1) triangulation of data, 2) peer debriefing, and 3) member checking.

Triangulation of data can be achieved by collecting data from a variety of resources to improve the validity of findings. In this study, the researcher was able to collect the data through multiple resources (i.e., site photos, precursory meeting with managers, interview transcripts, field notes) to attain triangulation of data. The researcher corroborated descriptions of the worksite with these data to check emergent findings in this study. For example, the researcher observed while taking a field note that only one quarry worker worn a respirator on the breaker even though they were recommended to use. This became clear when participants described discomfort by wearing the respirator in the interview. Peer debriefing can be achieved by assigning a third person to review coding strategies and emergent themes. This approach enables the researcher to gather feedback on the findings from a research mentor. Throughout the study, the researcher sought advice for and discussed interpretation of emergent findings with a second researcher to seek for a true meaning of data through meetings. Member checking can be achieved by reviewing the results with the participants. In this study, the site coordinator was contacted to verify the participants’ description and perception of work hazards. Overall, as stated by Borrego, Douglas, and Amelink (2009), the strengths of using inductive qualitative method by using descriptive case study helped to improve transferability of study by providing a thick description of research contexts for readers to adopt to their own situations, which quantitative approaches may lack.
CHAPTER 4: RESULTS

The purpose of this study is to gain a greater understanding of quarry workers’ perceptions of work hazards and their strategies to prevent accidents in the surface-mining industry. Specifically, this study explored quarry workers’ hazard identification and severity interpretation and corresponding safety behaviors. In this chapter, the results generated through the methodological protocols in Chapter 3 will be discussed.

Introduction

Significance of safety training

To better understand quarry workers’ perception of work hazards and preventative strategies, it is important to identify different types of safety training the quarry workers are required to take to improve their safety knowledge. The quarry workers must take initial safety training as required by MSHA within 60 days of employment, and subsequent safety training within 90 days of employment. Also, the quarry management provides field training for novice workers to be equipped with skills and confidence to operate the machines at the quarry. Along with field training, the quarry workers are required to take safety classes provided by Environmental, Health and Safety Services. These classes cover work hazards likely experienced by quarry workers and include electrical awareness, fall protection, hearing conversation, lockout-tagout authorized person, machine shop safety, PPE awareness, portable fire extinguishers, powered industrial truck observation, respiratory protection training, reverse signal operation safety, scaffold awareness, and silica awareness. On top of these classes, the site coordinator and field supervisors are required to take additional classes for first aid and cardiopulmonary resuscitation (CPR) treatments.

To help quarry workers remind of work hazards as they get used to the operations, the quarry management yearly provides “refresher” course. For an 8-hour course, this safety training particularly helped the quarry workers to recall their safety knowledge and to be watchful of work hazards. Additionally, MSHA inspected the quarry at least once in every year and provided a safety presentation to promote quarry workers hazard awareness. The last safety training
provided by MSHA on this site was 2 years ago. Overall, the quarry management offered a variety of safety training to improve workers’ safety knowledge and safe performance.

**Descriptions of participants**

A total of eight quarry workers volunteered to participate in this study. Participants had different duration of employment and distinct experiences of accidents. For example, participant 1 (P1) had 4 years of employment at the quarry and experienced a finger injury on the breaker. P2 worked for 25 years at the quarry and experienced a bruise on their head from a flying rock that broke away from the breaker. P3 was employed for 5 years and had not experienced an accident. P4 worked for 28 years and experienced accidents including a finger injury on the old breaker. P5 had 4 years of employment and bruised arm by the blast of air hose during excavation. P6 worked for 19 years and witnessed accidents including a finger smashed by the chisels on the breaker. P7 had 15 years of employment at the quarry and also witnessed accidents of fingers getting smashed, legs broken, back pains from the breaker. P8 worked for 3 months and had not experienced nor witnessed an accident at the quarry. This information is shown in Table 2.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Years of employment</th>
<th>Experience of accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>4</td>
<td>Finger injury on breaker</td>
</tr>
<tr>
<td>P2</td>
<td>25</td>
<td>Bruise on head from a flying rock that broke away from the breaker</td>
</tr>
<tr>
<td>P3</td>
<td>5</td>
<td>none</td>
</tr>
<tr>
<td>P4</td>
<td>28</td>
<td>Finger injury by conveyor belt on the old breaker</td>
</tr>
<tr>
<td>P5</td>
<td>4</td>
<td>Bruised arm by blast of air hose during excavation</td>
</tr>
<tr>
<td>P6</td>
<td>19</td>
<td>witnessed a finger smashed off by the chisels on the breaker</td>
</tr>
<tr>
<td>P7</td>
<td>15</td>
<td>witnessed smashed fingers, cut legs, back pains from the breaker</td>
</tr>
<tr>
<td>P8</td>
<td>0.3</td>
<td>none</td>
</tr>
</tbody>
</table>

Quarry workers took pride in their quarry and were satisfied with their work. According to Bontis, Crossan, and Hulland (2002), workers take pride in their organization if their work environment is safe. In this study, the interview participants stated that they particularly like
working at the quarry because, unlike other laborers, they perceived quarry workers to be professionals with unique skills: “I've done everything from drilling stone, blasting stone, sawing stone, specialty stone, production stone, heavy equipment.” One participant stated that “I wanted to do the manual labor and be active during the day and do all that, and it is interesting. I know people in the side shop that engrave those stones that I'm polishing, so I'm starting it and they're finishing over there. It's kinda [sic] interesting to be a part of it.” As shown in the interview excerpts, quarry workers were satisfied with their work at the quarry because they felt they were gaining expertise in their field and were fulfilled by participating in building a safe work environment at the quarry, which records one of the highest fatality rates among private industries in the United States (BLS, 2018).

As described by participants, quarry workers experienced the majority of accidents while working on the breaker. The breaker often involves three to five workers and uses hydraulic pressure to operate the chisels. The work operation included balancing and handling the rocks on the conveyor belt and the quarry workers spent the most time working on the breaker. Although they had more experience working on the breaker, they perceived that the breaker has the most work hazards existing at the quarry.

**Data collection and analysis**

This study is a single descriptive case study that was conducted to understand quarry workers’ perceptions of work hazards and their preventative strategies. Through this case study, the researcher obtained benefits in collecting and analyzing data. First, the researcher could expand the description of the quarry to fully explore the dynamics and environment of this organization. The use of case study helped the research to build relationship through data collection (e.g., precursory meeting with safety managers, site visits to take photographs) prior to the interview.

Also, the utilization of case study enabled the researcher to better communicate about their work experience during the interview. For example, the researcher could physically experience the work environment of the organization (e.g., work operations) and understand their work norm through site visits. Also, the researcher was required to take safety training to gain an access to the quarry. This safety training was a page-long instruction to inform about different hazards at
the quarry. The researcher could better be aware of their work experience and easily understand their stories at the workplace through case study.

To explore quarry workers’ perceptions of work hazards and their preventative strategies, this study collected data from different sources (e.g., fieldnotes, photographs, and a precursory meeting with safety managers). The researcher had iterative visits to the quarry to take site photographs and build rapport with the quarry workers. The researcher took approximately 50 site photographs and 3 photos were selected by the researcher to illustrate major types of operations at the quarry. These photos were checked by safety managers to identify the types of hazards in the precursory meeting.

To conduct interviews with participants, the researcher recruited the quarry workers by introducing the research to the quarry workers. This approach included reading the recruitment script as illustrated in Appendix F. All quarry workers who volunteered for the study were interviewed. Interviews were conducted in an office agreed upon by the site coordinator and researcher and lasted between 35 to 75 minutes. The researcher obtained verbal consent from participants whose interview exceeded 60 minutes. Interviews were audio recorded by the researcher’s recording instrument and saved in a password-protected file location as identified by the IRB. Interview transcripts were analyzed using the methodological approaches described in chapter 3, with the primary data coming from participants’ responses to the interviews with photo elicitation. The recorded interviews were then transcribed and analyzed using the Dedoose qualitative data analysis software.

Once the codes were developed based on research questions and meaning of participants’ responses, they were clustered to generate emergent themes. Themes were then grouped together based on characteristics in answering the research questions. For example, RQ1a addressed participants’ ability to identify work hazards. To answer this question, a theme was titled as “Workers' abilities to identify hazards,” and is defined as “Quarry workers identified different hazards in each photo shared in the interview with photo elicitation and, sometimes, indicated additional hazards than those identified by safety managers.” A detailed list of themes and codes are illustrated in Appendix K. For example, codes, such as everyone wearing PPE, cleaning, everyone paying attention, and looking for people/surroundings, were clustered together to
generate a theme-named perception of safety working environment. These emergent codes and themes were checked with a research mentor throughout the development of codebook.

Notably, a discrepant case was observed in this study. When participants described the degree of severity of work hazards in each operation, their responses were ambiguous and too broad to be measured in severity scale (e.g., negligible, marginal, critical, catastrophic). This result will be further discussed in research limitation in chapter 5.

**Transferability and credibility**

Transferability and credibility were achieved using three methods suggested by Creswell and Creswell (2018) to improve the validity and reliability of analysis results. First, data triangulation was achieved by accommodating and examining data collected from different sources. This study primarily analyzed data from interviews with participants, while fieldnotes, a preliminary meeting with safety managers, and site photographs supported the researcher’s understanding of the context and meaning of workers’ interview responses.

Second, peer debriefing was implemented by verifying the results with a second researcher. The researcher reviewed the data codes with a second researcher throughout the analysis process to improve transferability and credibility. The researcher verified the meaning of the codes by creating a codebook to improve clarity and by meeting with the second researcher. This process particularly helped the researcher avoid projecting meanings onto the interview responses and helped to clarify the participants’ intended meanings.

Lastly, member checking was conducted with the site coordinator after the data was analyzed. The researcher documented and shared a handout with a brief overview of the results with the site coordinator prior to a phone meeting. During the phone meeting, the researcher explained each hazard that the participants had described in each photo and confirmed the names of the hazards described in this study. For example, the site coordinator agreed with the findings concerning Photo 1 and explained that noise would not be identified by the participants because quarry workers, with the exceptions of the machine operator and assistant, work in another part at the quarry and may not experience hazardous noise levels.
Additionally, the researcher asked the site coordinator if he had any concerns or questions about the findings. The researcher explained that the participants interpreted hazard severity through simulating a scenario and drawing on their experience with the operation, while the safety managers utilized measurement and theories to understand the severity of hazards. Various parties’ strategies to prevent accidents were also discussed in the meeting. Although the site coordinator described the current controls and efforts to reduce exposure to hazards by the management, he acknowledged that workers would still recognize hazards as there was always the potential for injury at the quarry. Through member checking with the site coordinator, the researcher was able to verify participants’ perceptions and descriptions captured in the interviews were accurately presented in the emerging findings.

**Presentation of findings**

The findings will be presented according to the research questions. In RQ1, the researcher sought to understand how the quarry workers perceived hazards to examine their approach to making safety decisions. Quarry workers’ perceptions of work hazards were operationalized through hazard identification and severity interpretation. These sub-questions allowed the researcher to not only to explore quarry workers’ abilities to identify work hazards, but also to learn more about their abilities to interpret work hazards. For example, RQ1a sought to understand how the quarry workers identified work hazards, while RQ1b explored how they interpreted the severity of work hazards. In this chapter, RQ1a will be discussed by illustrating different types of hazards the participants identified (Finding 1) and how they identified different types of work hazards (Finding 2). Similarly, RQ1b will be discussed by presenting participants’ estimations of severity levels (Finding 1) and their processes of describing the severity (Findings 2 and 3). Finally, RQ2 sought to identify strategies that quarry workers employed to prevent accidents (Finding 1).

Table 3 provides a brief overview of the study’s emergent findings, which will be further discussed throughout this chapter.

**Table 3. Summary of RQs and corresponding findings**

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Hazard Identification</td>
<td>Types of Hazards</td>
<td>Safety Training</td>
<td></td>
</tr>
<tr>
<td>1b</td>
<td>Severity Interpretation</td>
<td>Description of Severity</td>
<td>Scenario-based</td>
<td>Experience-based</td>
</tr>
</tbody>
</table>
This chapter will explain participants’ description and interpretation of the types of hazards in the photographs of their worksite. Participants identified different types of hazards based on the type of equipment in the photograph (i.e., hydraulic excavator in Figure 1, blade saw in Figure 2, breaker in Figure 3) as shown in Appendix J, and estimated the degree of severity after identifying the hazards. Following sections will explain participants’ use of safety knowledge acquired from safety training and their simulations of accident scenarios related to work hazards and past experiences to describe severity. Next, participants’ preventative strategies will be discussed according to type, spanning from wearing PPE to monitoring coworkers’ safety.

**Research Question 1a: Hazard Identification**

Participants were asked to identify the work hazards in the photographs taken by the researcher and examined by the safety managers and site coordinator. These photographs were distributed to all participants as described in chapter 3 and were composed of different work operations in the following order: operating a hydraulic excavator (Photo 1), blade saw (Photo 2), and breaker (Photo 3), as described in Appendix J.

**Photo 1: Hydraulic Excavator**

Different types of hazards were identified in the precursory meeting with safety managers. Safety managers indicated four different hazards, including 1) a machine slipping, 2) dust, 3) noise, and 4) a fall from a ledge. The researcher used this information to guide the interview process.

Detailed information on types of hazards is presented in Table 4.

Table 3. Summary of RQs and corresponding findings, continued

<table>
<thead>
<tr>
<th></th>
<th>Preventative strategies</th>
<th>Types of strategies</th>
</tr>
</thead>
</table>

Each participant is represented by a random number. For example, participant 1 (P1) identified the machine slipping and the blast from an air hose in Photo 1. The number of hazards each participant identified is shown in the bottom row next to “Total.” The number of participants, five, who identified the machine slipping as a hazard is shown in the left column under “Total.”
In addition to the hazards identified in the precursory meeting, participants identified three more hazards in Photo 1. For example, seven participants recognized a blast from an air hose as a hazard, four identified a blast from hydraulic lines, and two noted tripping over pallets. These worker-identified hazards are marked with an asterisk (*) and shown in Table 4.

**Table 4. Types of hazards in Photo 1 identified by participants**

<table>
<thead>
<tr>
<th>Types of Hazards</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine slipping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Dust</td>
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<tr>
<td>Noise</td>
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<tr>
<td>Fall from a ledge</td>
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<tr>
<td>Blast from an air hose*</td>
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<tr>
<td>Blast from a hydraulic line*</td>
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<tr>
<td>Tripping over pallets*</td>
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<td><strong>Total</strong></td>
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<td>5</td>
<td>4</td>
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</tbody>
</table>

**Machine slipping.** Participants identified different hazards in Photo 1. Five participants stated that the excavator may roll downhill if it was not properly scotched. Some participants stated that a worker in the picture should move uphill rather than downhill of the excavator. Although the participants emphasized communicating with the operator in the excavator, they acknowledged the chance that the excavator could slip and lead to an accident.

**Dust.** Participants identified dust as a hazard that could potentially harm workers because quarry work largely involves cutting and breaking rocks. One participant in particular stated that “[dust is] probably one of the biggest things, because it is a hazard.” These participants perceived dust as a primary hazard in the quarry.

**Noise.** Participants did not identify noise as a hazard in Photo 1.

**Fall from a ledge.** Six participants identified falling as a hazard during the excavation. A participant appreciated the innovation of their equipment, which had evolved from using hand drills to incorporating a hydraulic excavator. This participant stated that with the “hand drill you
got to go start the two foot, then the four foot, then the six foot to get up to the proper step, [while] the hydraulic excavator was about one—saves some time and manpower.” However, participants still acknowledged fall hazards could potentially cause an accident if workers stood near the ledge during excavation.

**Blast from an air hose***. Seven participants identified a blast from an air hose as an emergent hazard that safety managers did not find. This hazard, and other identified by workers and not managers, were recognized through workers’ experience and emerged from operating the excavator. A participant shared an experience of getting hit by the air hose, stating that, “I’ve seen air hoses bust and I’ve actually been hit by air hoses that something fell on it and it busted. It will just beat you. You can't get away from it.” These participants indicated that a high-pressure blast could make the hose hazardous.

**Blast from a hydraulic line***. Similarly, four participants identified the hydraulic lines of excavator as a hazard. One participant referenced a case where an operator could be injured, stating that, “You've got hydraulic lines, stuff that could blow and be swept right back on the operator.” The participants explained about the potential harm caused of chemical components and compressed liquid if workers were too close to the hydraulic lines.

**Tripping over pallets***. Two participants noted the potential for workers to trip over pallets stacked near the doorway. They saw that the pallets were blocking the emergency evacuation path. Although not specifically related to excavation, participants identified trip hazards behind the pictured operation.

In addition to the hazards identified by the safety managers, participants shared their experiences related to Photo 1 and recognized three additional hazards. Although safety managers identified the machine itself as a hazard, participants’ detailed descriptions of these hazards were supported by their experiences in the field. Participants’ detailed descriptions of the hazards they identified are presented in Table 5.
### Table 5. Hazard identified in Photo 1 and interview excerpts

<table>
<thead>
<tr>
<th>Types of Hazards</th>
<th>Interview Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine slipping</td>
<td>&quot;[M]achine could roll or slide off the ledge and hit it.&quot; &quot;Honestly, the only other thing is, as a person, I wouldn't be near it. I wouldn't be down here, and I wouldn't be close to the piece of equipment, in case it slides.” &quot;It's possible that that excavator could slide.”</td>
</tr>
<tr>
<td>Dust</td>
<td>&quot;There's a lot of dust involved in that.&quot; &quot;That's probably one of the biggest things, because it is a hazard. Eventually it's going to get on the road, but it's... and it's one of those hard ones to get. You try everything, try all kinds of dust collectors and stuff like that, but probably one of the biggest one [sic] is just all the dust, the dust that you have.”</td>
</tr>
<tr>
<td>Fall from a ledge</td>
<td>&quot;Well, somebody could fall off the ledge right here.&quot; &quot;Well, also there's a potential for fall hazard. You know, I mean, if you walk too close to that edge, and we have barriers for that.” &quot;You could fall off the edge or this could give away. And there's usually nobody right here next to it, so if it does give away it'll just slide off, I guess.”</td>
</tr>
<tr>
<td>Blast from an air hose</td>
<td>&quot;An air hose... [because] it's about 120 pounds of pressure on that hose.&quot; &quot;Cause say it gets cut and it don't blow apart this time, maybe next time we use it we put all the air on it at one time, and it's so stressed it just blows apart. It could be worse on the next guy.” &quot;He could fall off or that air because this right here is actually air. This red hose right here, it's air. So, it could bust.”</td>
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<tr>
<td>Blast from hydraulic lines</td>
<td>&quot;If there was somebody standing out here pretty close it (hydraulic line) would bust. They could get you... (because) it gets pretty hot. It could burn you.” &quot;It's all hydraulics. If you have a hydraulic leak, and it goes to raise this up and you have no fluid or something, it can drop that whole piece down.” &quot;That hose could just shoot off there because it's all water or something like that, or they have clamps that can break off there. The hose can come off there, and all that pressure is still on that hose, so it's just flying around until you cut it off at the source.”</td>
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</tbody>
</table>
Photo 2: Blade saw

The blade saw in the quarry did not require operators to run it because it was automated with button controls. While the other two operations captured in the photographs (i.e., the hydraulic excavator and breaker) needed operators on site to run and control the machine, the blade saw was remotely operated from a secure saw room locked by authorized personnel, such as the site supervisors and coordinator. Because the quarry workers were restricted from entering the saw room, participants identified hazards they saw when they cleaned the saw room or had discussed with coworkers. Their description of hazards was supported by their observations (e.g., trail of a saw segment on the wall/rooftop) while cleaning the saw and the floor. A total of eight hazards were identified by participants in Photo 2, and there were no emergent hazards in addition to those identified by safety managers, as shown in Table 6.

Table 6. Types of hazards in Photo 2 identified by participants

<table>
<thead>
<tr>
<th>Types of Hazards</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
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<th>P6</th>
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<tbody>
<tr>
<td>Dust</td>
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<tr>
<td>Saw segment projectiles</td>
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<td>6</td>
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<tr>
<td>Slipping on the floor</td>
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<tr>
<td>Tripping over a water hose</td>
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<tr>
<td>Flyrocks</td>
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<td>3</td>
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<tr>
<td>Shock from an electric line</td>
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<td>Noise</td>
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<td>Weather</td>
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<td>Total</td>
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</table>
Dust. As was commonly discussed by and was a source of concern for the quarry workers, dust was identified as a hazard by three participants. Although the saw room was locked and quarry workers had limited access, they were aware of the dust hazards generated by the blade saw as an unwanted byproduct. Their identification of dust hazards was supported by their witnessing of dust filling up the saw room and having to open the back door to ventilate the room. Some participants were knowledgeable about the medical effect of dust, silicosis. Although they had water sprays and a dust collector to keep the dust down, it was still perceived as a hazard.

Saw segment projectiles. Six participants recognized that a saw segment could burst out and could damage the wall. One participant emphasized the possibility of getting injured by a projectile from the saw segment, stating that, “I mean, if it hits a rock wrong, if it hits a really hard spot and breaks, the wheels are not good on it, then there's a chance it can come off.” Participants expressed extraordinary caution when discussing these projectiles.

Slipping on the floor. The slick floor was also identified as a hazard by six participants. While a water spray helped to keep the dust down, it made the floor wet and slick, creating a slip hazard. Participants explained that they needed to be cautious when entering the saw room to clean the saw because, as one participant stated, “certain sections of concrete hold the water and make it more slick [sic] than it is.” Participants acknowledged that they exercised caution to avoid slipping on the floor made slick by the water spray.

Tripping over a water hose. Additionally, three participants identified trip hazards due to the water hose on the floor. Although there was minimal chance of encountering this trip hazard due to the safety tape fencing off the blade saw, participants still acknowledged that obstacles on the floor, such as the water hose, may cause harm.

Flyrocks. In addition to saw segment projectiles, participants were very cautious about other fragments in the saw room (e.g., saw segments, rock particles) becoming projectiles. Although workers’ limited accessibility to the saw room prevented them from potential injuries, participants reminded themselves to be careful when entering the saw room for cleaning. A
participant stated that small rock particles popped out and made a hole through the roof of the saw room when the blade saw was cutting a hard rock.

*Shock from an electric line.* Only one participant identified the electric line as a hazard. This participant simply noted that as the machine was powered by electricity, workers could be exposed to electrical shocks by the parts of the blade saw.

*Noise.* Four participants indicated the noise of the blade saw as a hazard, stating that it gets very loud for residents near the quarry. Participants noted that some residents complained and requested for the blade saw not to be operated after 7:00 pm. To comply with their request, the blade saw was not operated after 7:00 pm.

*Weather.* Three participants identified weather condition as a hazard because the floor of the saw room became slippery during winter. To keep the dust down in the saw room, water is sprayed while the saw is in operation. Participants described that, as a result of water on the floor, the floor became slick, and a fatal accident could occur if a worker slipped on the floor and hit the saw. Therefore, participants suggested that cold weather conditions were a hazard, as they generated a slick floor.

**Table 7. Hazards identified in Photo 2 and interview excerpts**

<table>
<thead>
<tr>
<th>Types of Hazards</th>
<th>Interview Excerpts</th>
</tr>
</thead>
</table>
| Dust                    | "It (the dust collector) sucks it (dust) up, and it (dust) goes out the top of the room they got working. It takes it out, because that's silica dust—it gets to your veins."
                          | “I would've cracked the door a little more in the back to let out the dust…. But there's still dust and sometimes getting filled up. It just completely fills up the room.” |
| Saw segment projectile  | "If it saws into something like metal, and that metal is able to move, it will knock all the segments off and fling them 100 mile an hour everywhere."
                          | “I mean if it hits a rock wrong, if it hits a really hard spot, and breaks, the wheels are not good on it, then there's a chance it can come off.”
<pre><code>                      | “I mean we've had, they've had them (saw segments) come off before. There's a chance. It ain't *[sic]* like an every week thing or every other month.” |
</code></pre>
<table>
<thead>
<tr>
<th>Hazard Identified</th>
<th>Interview Excerpts</th>
</tr>
</thead>
</table>
| Slipping on the floor | “Yeah, the slipping hazard was wet floor.”
But there is… there have been somewhere it's, maybe just smoother or something like that, and you get some of that water and dust combined. It can make it slick. But on this, this is rougher for that reason, so it's not slick.”
“I guess they're standing in water, but you have to sometimes [which may lead to a…slip hazard [because] certain sections of concrete hold the water and make it more slick than it is.” |
| Tripping over a water hose | "I mean, maybe talk about the water hose over here as a maybe trip hazard or something like that."
“That water hose shouldn't be in there. The water hose should be… there's a ledge right here. It should be back around the corner. That's where it hooks up back there, but it shouldn't be in the caution tape.” |
| Flyrocks | "You should be careful when its running because little pieces of rock can go flying around."
“Piece of rock can come off in the sling.”
“A lot of times what will happen is if a… the rock in there, you know, they're not square rock, they're on different kinda [sic] angles, or if it's all through so far, and if it breaks it could kick into the blade, there's some teeth that could come off. We've came in before, and every one of the teeth on the saw, it threw off. It happened at night when we were… weren't here to running the evenings like we need. There's a program in a little room.” |
| Blast from electric lines | “It's… running electrical [sic], definitely.” |
| Noise | "It (noise) could be one of those long-term hazards where exposure to that over time is gonna [sic] damage your hearing.”
“You have to have your ear plugs on when you're in there.” |
| Weather | "In the winter time when you're cleaning it, it's slick and it freezes up when you've got the doors up and you're in there trying to clean with water and stuff like that and it's 20 degrees outside and the wind blowing, it gets slick very quick.”
“Well, I mean, before in general, where it's got sludge in water, you take wintertime, and this situation plays out, so… But before this starts up, before they start the saw, we've got it all under—it's locked down. We've got it tagged up, and you're cleaning all this sludge from the previous rock sheets off. So, when you're in there, of course it's not in
Photo 3: Breaker

Photo 3 received the most attention from interview participants and motivated them to fully describe their lived experience with the breaker. One participant expressed particular excitement, describing Photo 3 as “the famous breaker.” In this phase of the interview, the researcher also observed that the majority of participants leaned towards the table and observed the photo, which might also indicate their familiarity with and greater knowledge of this operation. The breaker is operated by more than two workers and requires teamwork and cautiousness to safely break and cut rock. As the breaker requires direct manpower and hands-on activities, the quarry workers were highly exposed to a number of hazards, which are presented Table 8.

Table 7. Hazards identified in Photo 2 and interview excerpts, continued

<table>
<thead>
<tr>
<th>Types of Hazards</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
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<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>Total</th>
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<tbody>
<tr>
<td>Flyrocks</td>
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<tr>
<td>Repetitive posture</td>
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<tr>
<td>Shock from an electric line</td>
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<tr>
<td>Hydraulic line leak</td>
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<tr>
<td>Pinch by the breaker</td>
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<td>8</td>
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<tr>
<td>Full bucket of trash rocks*</td>
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<td>7</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>7</td>
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</tbody>
</table>

Table 8. Types of hazards in Photo 3 identified by participants
Like Photo 1, an additional emergent hazard was identified by eight participants and is marked with an asterisk (*) in Table 8.

**Flyrocks.** All participants identified flyrocks as a hazard in Photo 3. Participants emphasized that workers needed to pay extra attention to the rocks and their hands. For example, one participant stated that “When you would break that rock, if it was really hard stone, it might throw it. It would shoot it out there like it was shot out of a cannon or something.” They noticed that the rock fragments may burst out during cutting and possibly hit the operators.

**Repetitive posture.** Also, workers at the breaker had to repeatedly lift and balance rocks for the breaker to cut them properly, causing workers to experience sore backs and shoulders. Also, it became more difficult to control heavy rocks when they randomly bounced back and hit workers, which demanded extra attention. This ergonomic hazard was only identified by one participant.

**Dust.** Every participant identified dust as a hazard. Participants’ relatively greater awareness of this hazard might be due to their daily experience at the breaker. The breaker had a dust collection system on the top of the machine. Participants appreciated that management had revamped the dust collector to reduce dust during breaker operation. They described the effect of dust exposure as silicosis and explained that they could wear a respirator to breathe, which was optional but recommended.

**Noise.** Three participants noted that the breaker made a lot of noise, because the pump was implemented outside where workers operated the machine. A participant emphasized wearing PPE, stating that “you definitely need earplugs. It's about the loudest part of the quarry.” These participants perceived that the breaker generated noise, which they could mitigate by wearing earplugs.

**Shock from an electric line.** The breaker’s electric wires were described as hazards because they could become worn out or damaged during operation. One participant suggested that “the wires could probably be seen as a hazard. They get caught or broken.” Participants noted that the electric lines hanging behind the operators may shock them if not properly prevented.
**Hydraulic line leak.** Five participants indicated that the hydraulic lines may cause injuries to operators. For example, participants explained that the breaker is operated through hydraulic pressure, which pushes the chisel to break the rocks. According to a participant, a hydraulic line leak may cause chemical injuries to workers: “I guess some people could have an allergic reaction to that type of fluid. I've got it on my arm before, and it didn't bother me. It just smells awful.” These participants noted that hydraulic line leaks could cause breaker operation to fail and chemical injuries to workers.

**Pinch by the breaker.** All participants identified being pinched by the breaker as a hazard. If workers became fatigued and less attentive, they could be pinched by the breaker’s chisel and by the weight of a rock. The quarry workers experienced the pinch hazard in two contexts. First, participants explained that they could get pinched by the conveyor belt when they were lifting and balancing the rocks. Second, participants said that they needed to be very cautious if they put their hands in the chisel’s path to break the rocks. They also noted that they have impact gloves to protect their fingers from being crushed. Participants explained that many quarry workers had injured their hands during these operations.

**Full bucket of trash rocks.** All eight participants described the full bucket of trash rocks as a hazard, though the safety manager did not. Because cleaning and dumping the bucket was perceived as part of their operation of the breaker, the quarry workers frequently recognized the rock bucket as a potential trip hazard. While the safety managers did not identify the full bucket of trash rocks as a hazard, the participants said that they tried to clean the bucket and the floor to avoid trip accidents.

As the interview participants were particularly interested in talking about the hazards pictured in Photo 3, the greatest number of hazards was identified in this photograph. Including hydraulic line leaks and shocks from the electric lines, the quarry workers perceived hazards generated by the breaker itself, such as getting pinched by chisels or rocks. As a result of their exposure to different hazards in this operation, the quarry workers perceived the breaker as the most dangerous piece of equipment. One participant complained that “about 99% of your injuries down here is on the breaker. Back problems, smashed fingers, stuff like that.”
Additionally, human errors were identified in Photo 3, unlike in the other photographs, because the breaker requires intense worker involvement. Operators on each side of the breaker had to pay attention to each other’s behavior. As a result, the participants perceived the operator as a hazard due to potential human error. Interview excerpts describing the hazards identified by the participants in Photo 3 are presented in Table 9 below.

### Table 9. Hazards identified in Photo 3 and interview excerpts

<table>
<thead>
<tr>
<th>Types of Hazards</th>
<th>Interview Excerpts</th>
</tr>
</thead>
</table>
| Flyrocks         | “A lot of it is the rock, you can't control when it flips up. It's gonna [sic] do what it's gonna [sic] do.”  
                  | “They (operators) throw trash over here [and] it hits something and bounces over here on this person's standing here.”  
                  | “So, when you break it, it shoots the whole other rock back.”  
                  | “That was before we had solid sides. Before we used to break them, we didn't have nothing big, solid, or nothing. We just broke through the rock, and they had lots of places on the bottom. And they wouldn't sit real level, and that made a pressure out... there's more pressure. And it would kick it back, if it had a place on it. We don't have much trouble now as much, but back then we did. Yeah, there’s pieces some time, little pieces of rocks that breaks.” |
| Repetitive posture | “You can strain your back, too. Hurt yourself with your muscles and all that.” |
| Dust             | “They have actually put dust collectors, like suctions, on the operating side and the discharge sides of the breaker. Used to there was nothing down there and when you broke it, a cloud of dust would come up, and that's been between our safety office and MSHA. They do monitor, so our safety office does monitoring [sic], noise and dust monitoring, about every three to four months, and then MSHA comes in twice a year.”  
                  | “…just keeping a good distance between you and the initial dust aspect, because it comes out in a pretty good cloud.”  
                  | “So, it causes silicosis, that's why we have the dust collector. They redesigned this.” |
| Noise            | “You got noise issues with that pump in there too, running constantly. Cause if you notice out here on this breaker, the pump’s outside.”  
                  | “Because this is loud and when you're on this side, depending on the kind of rock, sometimes it does, sometimes it doesn't.” |
### Table 9. Hazards identified in Photo 3 and interview excerpts, continued

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Description</th>
</tr>
</thead>
</table>
| Shock from electric lines  | “The wires could probably be seen as a hazard. They get caught or broken.”
                              | “I mean, you've got electrical hazards. There's a lot of possibilities.”
                              | “Now, an electrical, not blocking it out if you're working on it. That could possibly cause death… So, if you're working on this, you want this head dropped all the way down, so that it can't, it can't creep off on you, and cut or squeeze you. You want the electrical cut off so that if you're touching anything that electric’s going to, you can't get electrocuted. You want to lock out all of your hazards. Or, block out all of your hazards as well. Like I said, if we work on this, we'll put a block on here so that it can't leak off any more than what it, what the size of that block is.” |
| Hydraulic line leaks       | “I guess some people could have an allergic reaction to that type of fluid. I've got it on my arm before, and it didn't bother me. It just smells awful.”
                              | “If all of that hydraulic leaks out, then nothing's holding the top teeth up.”
                              | “I mean the only other thing is, with all the machines, you've got these hydraulic lines, and we have had them bust and get on people.”
                              | “There are hoses, hydraulic hoses, that could bust. I've been unfortunate enough to be working on this breaker. We've worked on it for several hours, and a hose busted and that hot hydraulic fluid, it covers you.” |
| Pinch by the breaker        | "Probably shouldn't have his hands on the rollers, just in case he rolls that big eleven up there, and it pinches his fingers." |
                              | “You'll go get mashed fingers, you'll get pinched fingers. A lot of it is… it's natural. A lot of it is the rock, you can't control when it flips up. It's gonna [sic] do what it's gonna [sic] do. That's the reason we went with impact gloves.”
                              | “Yeah, you got pinch points here. That's why we got the guard over it, but you can see, you still can get your hand in the conveyor belt. Fingers. Right here, the chisels is a pinch point. If you're pushing rock in and you have your hand on the wrong side and somebody shoves it, it gets your finger. The top of the chisel, same thing. If you don't have them raised up to the appropriate height, you go to push them in, you can get your fingers.” |
Notably, the quarry workers could identify different types of hazards at different operations. They used their safety knowledge and work experience to perceive work hazards appropriately. More specifically, the quarry workers primarily utilized knowledge gained from safety training to identify work hazards while incorporating simulations and experience to judge the severity of hazards. These findings are illustrated in Figure 9 and will be discussed in the following sections.

![Figure 9. Approaches to perceiving work hazards by quarry workers](image-url)

| Full bucket of trash rocks* | "Well, if the bucket is real [sic] full and they throw trash over here, it hits something and bounces over here on this person's standing."
| | “You know, you get one pallet and you go through two buckets of trash, if you get… just making sure it keeps… once it starts looking like this, where it's not even fully in the bucket, it needs to be dumped. Plus, we just keep it good on that end. Just keeping it at a decent level, you know? Because it keeps getting higher and higher if you keep stacking it. And it doesn't hold, and when you back up, it still falls on the floor sometimes.”
| | “That bucket. There's no, that right there is uncalled for… cause you gotta [sic] get up in this bucket, and you could trip, whether you got an ax able, you can trip and fall in it. And the load in the basket. You know you put too much weight in it and you're taking it to dump it, you're going to be doing that. Those need dumped more. That's what we've found in there.”

Table 9. Hazards identified in Photo 3 and interview excerpts, continued
Hazard identification by recalling safety training

Quarry workers were required to take safety training. This training was geared toward workers’ safety when performing different tasks in the quarry. Quarry workers were required to undertake this training to improve their understanding of work hazards at the quarry. The quarry workers took online safety training provided by Environment, Health and Safety Services in the quarry. Among the quarry workers, two supervisors and the site coordinator received specialized training to provide first aid and CPR if an accident occurred. The quarry workers also received safety training from the site coordinator and safety managers. Particularly for novice workers, the site coordinator conducted field training which helped new workers to become acquainted with the operation of different types of machinery in the quarry. As a result of this comprehensive series of training, safety managers believed that the quarry workers had acquired the knowledge necessary to identify all workplace hazards.

Quarry workers used knowledge obtained in safety training to recognize work hazards. This training included those provided by MSHA and their own company. Quarry workers acknowledged the MSHA safety training for helping them to better prevent work hazards. In particular, one participant stated, “they (MSHA) come down here and inspect the site for any hazards and they let us know what's wrong and if there's nothing wrong, they let us know whether it's dense at other quarries and how to prevent those.” Additionally, the quarry provided an eight-hour safety course every year to refresh workers’ knowledge of certain types of hazards that they may encounter on the worksite.

As negligence and carelessness regarding hazards are common in the workplace, the quarry workers realized the importance of taking a refresher course every year. One participant said, “we all go up there, and they do it for eight hours and it's the refresher course. We do it every year or every two years. But it's pretty helpful.” Through these types of safety training, quarry workers became better aware of work hazards and their severity. A participant recalled a video from safety training and described how drastically it changed his perception of dust hazards, stating that, “The dust and stuff that we have up there, it actually opened my eyes, too. I didn't think it was nothing…” Then, the participant recalled a scene in the video, stating that “there was a bunch of people died from it because there wasn't any ventilation in the tunnels, they were
New hires were provided with additional field training before they could actually operate the machines at the quarry. A participant appreciated how the field training led him to better operate the machines and to be involved with the operation from different perspectives. For example, unlike with safety instructions and guidelines provided in text or video, new workers could experience the work environment face-to-face and learn by observing their coworkers. Their knowledge of safe breaker operation improved through the field training, as one participant stated, “you learn about the safety with how to move your fingers more and be aware of them. But you also are more aware of what's going on.” Through the participants’ descriptions, it was evident that the safety training helped the quarry workers to identify and remember work hazards they might otherwise have neglected or underestimated.

**Research Question 1b: Severity interpretation**

The researcher had a precursory meeting with safety managers and discussed the work hazards illustrated in the photographs and their severity. The safety managers could easily utilize theories to discuss their ideas about the photographs. For instance, they employed the hierarchy of controls to explain how they prevented accidents and described hazards’ degree of severity using four categories standard in the field: catastrophic (i.e., causing death or permanent total disability), critical (i.e., hospitalizations or temporary disability, major injury), marginal (i.e., recordable injury/illness, minor injury) and negligible (i.e., requiring first aid or minor medical treatment). Therefore, it was evident that the safety managers’ knowledge was largely theoretically informed and drew on administrative and managerial perspectives.

However, safety managers emphasized how a hazards’ degree of severity may vary in different scenarios. Safety managers analyzed the severity of hazards according to the probability of an accident. For example, safety managers inquired about the distance between the worker and the ledge in Photo 1 to analyze the severity of the hazard. Their estimation of severity was supported by measurement and specificity (e.g., worker distance from ledge). Also, they believed that work
hazards were largely mitigated by their safety controls. While safety managers understood the
degree of severity varied depending on circumstances, they often relied on measurements to fully
understand risk levels.

Unlike the safety managers’ and site coordinator’s descriptions, the quarry workers’ descriptions
of severity were broad and, in some cases, vague. For example, a participant described the
severity of a blasting air hose as, “it (rock particle) split and cut the air hose, then that could be
dangerous.” As shown in their responses, participants envisioned a scenario or shared their own
experiences to predict the likely harms of hazards rather than supporting their interpretation
through a theoretical or mathematical approach (e.g., distance between the worker and ledge).
While acknowledging the limitations of objectively measuring and quantifying severity levels,
the researcher analyzed participants’ responses to codify and categorize participants’ perceived
severity levels to understand their interpretation of work hazards. The degrees of severity
described by participants, with few exceptions of ambiguous responses (i.e., “dangerous”, “very
severe”), are illustrated in Table 10 below.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Identified hazard</th>
<th>Degree of severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Negligible</td>
</tr>
<tr>
<td>Excavator</td>
<td>Blast from an air hose</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Machine slipping</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fall from ledge</td>
<td></td>
</tr>
<tr>
<td>Saw</td>
<td>Dust</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Noise</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saw segment projectiles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slipping on the floor</td>
<td></td>
</tr>
<tr>
<td>Breaker</td>
<td>Fly-rock</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydraulic line leak</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pinch by the breaker</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shock from an electric line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dust</td>
<td></td>
</tr>
</tbody>
</table>
Severity interpretation through scenario simulation

When the participants were asked to describe the degree of severity of hazards identified in the photo, they put themselves in the photo and simulated what could possibly happen. One participant described the potential severity of a breaker-related hazard and used a scenario to explain the potential dangers, stating that “pushing the rock through and getting your hand caught can get a hand completely blown off with this breaker. It's (the breaker is) extremely powerful. Anything to cuts and bruises.” Also, when describing the severity of saw segment projectiles, a participant stated that “It could be real bad…as fast as that thing spins, it could throw one of their teeth right in you, I mean, plum through you probably.” While safety managers used theoretical knowledge to judge the severity of hazards, the quarry workers instead simulated a scenario to estimate potential harm.

Quarry workers primarily used scenarios to interpret the severity of hazards. The use of scenarios was more intuitive for quarry workers, who acknowledged the difference between safety in theory and in reality. Although the quarry workers perceived the safety training as helpful and important for refreshing their knowledge, some workers identified a gap between safety training and real-world situations. One participant stated that “it’s just hard to sit up there in the classroom, when they try to talk about safety down here,” because this participant realized that “not everything's gonna [sic] work how they say it's going to on a good day around here.” Moreover, another participant stated that the materials presented in safety training are somewhat irrelevant and antiquated, stating that “the videos are actually a little awful. They're outdated and everything in the videos that we watched don't all apply to us. They're just mines in general.” As a result, the quarry workers expressed a desire to improve safety training so that it better related to their actual work environment.

Severity interpretation through hazard-related experience

The researcher observed that the interview participants spent more time explaining and referencing the hazards around the breaker in Photo 3. This was because workers were more likely to have had experience operating the breaker and to have experienced a related work accident. While describing hazards around the other operations, their responses were not as rich
as their descriptions on the other operations because they spent the most time working on the breaker. Because of their greater experience with the breaker, they could better demonstrate the severity of hazards by describing accidents either witnessed or experienced.

During the interview, some participants explained hazards’ degree of severity by showing wounds. Participants referenced their experiences operating the breaker and willingly showed scars/bruises on their limbs to demonstrate the severity of hazards. For example, a participant stated, “I guess the most severe chop is when, well, I'll show you, when I cut my leg,” and showed a scar on his leg to help describe the severity of flyrocks. The participant was injured recently, and the scar was about six inches long. Participants often demonstrated the severity of work hazards to novice workers by showing them their scars to encourage novices to better be aware of work hazards.

Also, the quarry workers interpreted severity by referencing their hazard-related experiences. For example, a participant described a past experience at the excavator and stated, “I've slid on this ledge on the other side, and luckily, the guy was standing on the other side of me and if he had been standing there, he would have been dead.” Another participant shared an experience with the blade saw, stating that “those teeth are braised on, kind of like welding. Probably not a good idea to be in there, because we have had them thrown, throw the teeth off, and that can kill you as fast as that thing's spinning.” Additionally, a participant referenced a work experience with the breaker, saying “I've seen a few have their fingers smashed.” Overall, the quarry workers perceived the severity of hazards based on their past work experiences and thus made decisions to perform safely.

As mentioned previously, the quarry workers perceived work hazards differently from the managers and took different approaches to understanding hazards’ severity (i.e., simulation of scenarios and recalling personal experiences). While safety training helped the quarry workers to refresh their safety knowledge relevant to identifying work hazards, their interpretation of severity mainly depended on their abilities to adequately simulate the work environment and properly employ recalled work experiences. In summary, the quarry workers’ abilities to identify work hazards were developed through safety training while their abilities to interpret hazards’ severity was bolstered by simulation and experience.
Workers’ additional perceptions of work hazards and work environment

While the quarry workers employed the aforementioned approaches to perceive work hazards appropriately, these approaches were supported by an organizational commitment to making a safer work environment. Some quarry workers reluctantly admitted that some hazards could not be prevented and said that, “the safest person in the world can get hurt.” Although their awareness of unexpected accidents could have discouraged their continuous efforts to eliminate work hazards, the quarry workers sought to make a safer work environment due to the prevailing organizational culture.

On the other hand, the quarry workers identified concerns about their current work environment. In particular, some of these concerns included the carelessness of coworkers. Younger workers were typically perceived to be less careful. For example, one participant described an experience with a younger worker: “guys (younger workers) will tell you I fuss at them. They may hate me for it, but myself included, I've gotten hurt before. Everybody does. I don't care what you do or how long you're at a place of business, you get lackadaisical about stuff.” The participants further expressed a sense of frustration that coworkers did not care about safety and did not listen to advice.

Also, participants generally, though reluctantly, accepted that some hazards cannot be prevented. That is, the quarry workers believed that they could not be fully prepared for unpredictable hazards. For example, a participant stated that “you can't ever prepare yourself enough to actually know the rock, it'll do what it wants to do.” Some workers already accustomed to the quarry operations could not envision further improvements and innovations to make the environment safer. One participant stated, “There's really nothing they can do. Just keep a check on them, is best you can do.” Overall, despite their commitments to safety were partially discouraged by the perceptions of some coworkers who are less careful and negligent about safety, the quarry workers had a common commitment to fostering a safe work environment, and also shared the perception that they could not prevent all accidents. This means that the organizational culture promoted workers’ safe performance and empowered their teamwork through making sure to hold other workers accountable for maintaining safety procedures.
Research Question 2: Preventative Strategies

Once participants identified work hazards and estimated their severity, they were asked to envision preventative strategies to mitigate accidents. Although the quarry workers were not sufficiently knowledgeable of the hierarchy of controls to fully understand and adopt such preventative strategies, the researcher found that the workers utilized their own preventative skills to reduce the probability of accidents. Developed by the National Institute for Occupational Safety and Health (NIOSH), the hierarchy of controls is usually illustrated as an inverted pyramid, with the higher strata indicating greater effectiveness of control. The strata include PPE (i.e., wearing personal protective equipment), administrative controls (i.e., changing the way people work), engineering controls (i.e., isolating people from the hazard), substitution (i.e., replacing the hazard with less hazardous material), and elimination (i.e., physically removing the hazard), as shown in Figure 10.

![Hierarchy of controls by NIOSH](image)

**Figure 10. Hierarchy of controls by NIOSH**

Although the quarry workers did not necessarily cite the hierarchy of controls to prevent accidents, they unconsciously adopted the lower strata of the hierarchy of controls to reduce the probability of accidents. From PPE to engineering controls, the participants offered different
strategies that they thought would best address the work operation depicted in each photo. Further, some participants also tried to improve safety by cooperating with the other workers and emphasizing the significance of trust. As a result, the quarry workers employed different prevention strategies, from wearing PPE to suggesting engineering controls to the work operations, from the hierarchy of controls and from paying attention to others’ attitudes and behaviors during team operations.

**Personal Protective Equipment (PPE)**

Participants could easily employ the preventative strategy of wearing PPE. The quarry workers were provided with earplugs, eye protection, impact gloves, and respirators. In addition to what was provided by the quarry, they also were required to wear steel toe boots. The quarry workers could appropriately use PPE for protection from various hazards, such as wearing impact gloves to prevent cuts and bruises caused by the chisel on the breaker, wearing earplugs to block noise from the blade saw, and wearing a respirator to prevent dust inhalation. However, some participants felt the provided PPE was lacking. A participant mentioned that “they offer respirators here, but nobody likes them.” Also, the researcher observed that only one worker on the breaker was wearing a respirator during the site visit. Although the quarry workers were advised to wear a respirator, due to its discomfort, workers often did not wear one and desired to have their own. One participant said, “I wish I had mine,” expressing a desire for the company to offer personal PPE. For this reason, some PPE was not fully effective or useful.

**Administrative controls**

Quarry workers also employed administrative controls, the next level in the hierarchy of controls, to prevent accidents. Administrative controls were classified into two categories: following the controls and executing on-site prevention. For example, workers followed the guidelines and instructions provided by the site coordinator and supervisors to perform safely. This also included obtaining adequate safety training and thoroughly understanding equipment operation.

Additionally, the quarry workers made their own decisions to prevent accidents. For example, participants suggested locating the worker uphill in Photo 1 to mitigate the risk of being crushed
by the excavator. Further, they opened the door of the saw room to ventilate it and let the dust out. Also, they identified that potential harm on the breaker could be reduced by letting the rock slide off when it pops out of the breaker’s chisel. These strategies indicate that the quarry workers independently made safety adjustments to their work protocol to foster a safer work environment. Thus, the quarry workers decreased the probability of accidents by following management controls and making their own operative adjustments.

Engineering controls

Although the quarry workers lacked the ability to isolate themselves from all hazards, they wanted to implement innovative technological equipment to lessen their exposure to hazards. For example, participants expressed the desire to have a level-adjustable hydraulic table at the breaker to lessen the need for operators to handle rocks and transport them to a pallet where they were stacked to be delivered. Regarding the blade saw, a participant suggested installing safety ribbons to protect workers from coming into contact with it, stating, “it's blocked off with the rope, so that's good, so nobody walks into it.” Another participant discussed the benefits of incorporating a hydraulic excavator, because it lessened workers’ exposure to fall hazards and improved safety by reducing the use of pneumatic hand drills. As indicated by participants’ responses, the quarry workers practiced engineering controls by describing their desires to upgrade their equipment and referring to a current implementation of innovative technology.

Valuing safety and teamwork

Beyond their utilization of the hierarchy of controls, the quarry workers emphasized how their relationships and interactions created a safer workplace, as coworkers ensured they had “another eye on their back.” Participants described that watching each other’s operation was key to preventing accidents. Realizing the importance of safety and responsibility for others’ safety and wellbeing, a participant said, “it's part of my job, too, to make sure that they lock it (the saw room) out, make sure they lock the machine down.” Because the quarry workers understood that they make mistakes, they added another layer of protection for each other by assuring one another’s safety.
To increase novice workers’ valuation of safety, veteran workers shared their experiences and communicated about how much they cared about their safety. By expressing their concerns for them, the veteran workers encouraged the novice workers to become more cautious about hazards. For instance, a participant described a conversation with a novice worker: “I'll pull my hand out. I've got scars and stuff to show. I'll say, look I didn't care at one point in time.” The participant added, “It does show some of them, ‘Hey, I don't want to get cut, I don't want to get hurt.’” These types of interactions drew novice workers’ attention and encouraged them to be cautious of hazards they might have underestimated.

Most importantly, participants described the importance of being responsible for their safety roles in an operation. One participant particularly emphasized building trust among team members, stating that “most people just have to act as a team, and you don't have to be best buddies with everybody, but care about each other and not doing something that may hurt somebody else if they're not aware of what you're doing, or looking out for them if they're not seeing something come down.” Beyond this participant, another explained their concern for other workers. They cared about coworkers “not just because of this study, but it's seeing that these guys go out here with all their digits, and they go home to their families.” Therefore, the strong motivation to care and watch out for others strengthened workers’ perception of organizational safety and changed their perception of workers from mere colleagues to someone’s friend or family member. This perception of their coworkers enabled the quarry workers to work as a team and to feel safe at the quarry.

**Summary**

This chapter explained participants’ description and interpretation of the types of hazards in the photographs of their worksite. Participants identified different types of hazards based on the type of equipment in the photograph (i.e., hydraulic excavator, blade saw, breaker) and estimated the degree of severity after identifying the hazards. While participants primarily used knowledge acquired from safety training, they simulated accident scenarios related to work hazards and shared past experiences to describe severity. Participants’ preventative strategies were discussed according to type, spanning from wearing PPE to monitoring coworkers’ safety. Therefore,
workers prevented accidents and utilized safety strategies aligned with the lower strata of the hierarchy of controls.

In the following chapter, these findings will be compared and contrasted with previous safety literature in both the construction and surface-mining industries to extend knowledge in quarry workers’ perceptions of work hazards and their preventative strategies. Concluded with limitations of this study, the following chapter will guide future studies to consider the challenges addressed in this study.
CHAPTER 5: DISCUSSION

Introduction

This study aimed to gain a greater understanding of quarry workers’ perceptions of work hazards and their strategies to prevent accidents. Specifically, this study investigated quarry workers in the surface-mining industry, as few studies had examined safety in this field compared to the construction industry. To better understand quarry workers’ perceptions of work hazards and their preventative strategies, this study posed three research questions to specifically ask how quarry workers identified work hazards, interpreted their severity, and employed preventative strategies to foster a safer work environment.

In this chapter, the findings illustrated in chapter 4 will be compared with previous literature in both the surface mining and construction industries. Using the methods and procedures described in Chapter 3, Chapter 4 illustrated that safety training helped quarry workers identify work hazards. Workers judged the severity of hazards by recalling their experiences (e.g., work accidents) and by simulating scenarios. Based on participants’ interview responses, quarry workers unknowingly employed strategies from the lower strata of hierarchy of controls, spanning from wearing PPE to suggesting an engineering controls (e.g., sensory device) for the workplace as described in Chapter 4. To better understand how quarry workers’ safety performance is facilitated, this chapter begins by discussing how workers generally perceived safety training for hazard identification.

Hazard identification by Safety training

Significance of safety training

Safety training is the core activity that brings elements of safety and health programs together to promote a safer work environment (Cohen et al., 1998). To cultivate such environments, safety training is often required by agencies such as MSHA in which workers acquire new skills and knowledge and learn strategies to perform safely in the workplace.
However, in a study examining the relationship between safety training and risk tolerance, Lehmann et al. (2009) found that safety training alone was not an ultimate solution for preventing work accidents and fostering a safer work environment; simply implementing these programs are not enough and require proactive involvement of workers. While safety programs offered by OHSA and MSHA broaden workers’ perspectives and increase their awareness of work hazards, these safety programs typically address hazard types and accidents, key components of workplace safety, in a generalized manner. Because the materials discussed in generalized safety training are not heavily related to the types of hazards in their workplace, workers experience difficulties to adapt and utilized the safety knowledge gained in the training. Therefore, it is imperative that safety training intentionally encourage workers’ proactive participation to promote worker ownership of safety practices, thus improving the overall effectiveness of safety programs.

**Worker involvement and company commitment through safety training**

Findings revealed that study participants particularly appreciated safety training provided by their site coordinator. One participant stated, “Honestly, our annual safety meetings are really good. They just keep you knowledgeable,” and added reasons why he liked safety training: “I always think that's a real good one, because they show you in real life that it still could happen if you don't do that [safety performance], and it makes you definitely, you have it in the back of your mind all the time, that you want to do what you have to do, so that you can prevent that.” This sentiment was repeatedly expressed throughout the duration of the study; seven of the eight participants explained during their interviews that their company provided the most memorable safety training.

In the context of this study, quarry workers better comprehended material and information taught in the safety training provided by the company and utilized the knowledge they gained in their workplace. Their responses demonstrated that training from their safety managers using materials relevant to work hazards at the quarry was more memorable, and thus, this training possibly was an important and effective training for participants. Therefore, this observation aligns with existing literature that calls for more specialized safety training relevant to specific working environment (Maiti, Chatterjee, & Bangdiwala, 2004).
However, this change in behavior cannot be achieved without workers’ participation in and management’s commitment to safety. For example, changing employees’ safety behavior generally requires two components: 1) a proactive attitude among employees to improve and 2) a supportive work environment conducive to employees’ safety and wellbeing (Kirkpatrick & Kirkpatrick, 2006). That is, both the company and employees must share goals and values promoting safety to foster a safer work environment.

**Prevention strategies: proactive and passive safety behaviors**

Behavior-based safety programs are generally categorized among the lower strata of the hierarchy of controls, which provide the least effective accident prevention (Fleming & Lardner, 2002). These programs are primarily conducted through managers’ supervision of workers’ performance during an operation. In this approach, a manager’s role is to observe workers’ behavior to ensure their safety. In this study, however, quarry workers shared this role and strived to promote a safer work environment. Following sections will discuss quarry workers’ proactive and passive behaviors in the workplace.

**Proactive safety behaviors**

Based on participants’ interview responses, quarry workers shared the responsibility for safety amongst themselves. Workers’ assumed peer managerial and observational behaviors by carefully monitoring each other’s performances and behaviors. Quarry workers in this study shared the responsibility of encouraging safe performance by observing coworkers throughout the work process, even in the absence of a site coordinator and supervisor.

In this study, quarry workers identified hazards using knowledge from safety training and interpreted the degree of severity through their past experiences and by simulating potential scenarios. The quarry workers suggested a variety of preventative strategies reflecting the hierarchy of controls, from wearing PPE to implementing engineering controls. The participants emphasized watching out for each other during operations as one of the most important prevention strategies and strived to generate a safer work environment by developing trust among coworkers and thus enhancing team safety performance.
Quarry workers promoted safe work practices particularly through teamwork. Because workers performed tasks in different teams, teamwork at the quarry required workers’ collaborative efforts to develop a safe workplace. For example, they looked out for each other during operations. Participants emphasized that workers needed to pay special attention on the breaker, not only to the rocks but also to their coworkers. Because the quarry workers acknowledged the possibility of unexpected accidents, they wanted all workers to exercise caution while working, particularly on the breaker.

Also, veteran workers shared their experiences with novice workers to help coworkers become better aware of work hazards. While safety training helped quarry workers develop awareness of work hazards, older, professional workers shared their experiences of accidents with novice workers to encourage them to be watchful in the workplace. Sometimes, quarry workers showed their scars and bruises to novice workers to demonstrate the severity of work hazards.

Quarry workers also relied on their past experience to interpret the severity of work hazards and to employ preventative strategies. These strategies included sharing their experiences to promote a safe work environment and were often used to support workers’ accounts of accidents. As noted in Chapter 4, quarry workers interpreted the severity of hazards based on their lived experiences and communicated with coworkers to demonstrate the potential harm caused by misbehavior and carelessness. Notably, it was observed that workers who had experienced or witnessed an accident explained the degree of severity in more detail than did new workers at the quarry (i.e., scenario simulation).

While both the experienced and new quarry workers could identify hazards and interpret their severity (e.g., first aid, loss of work, fatality), new workers had a limited understanding of when and how such accidents could be prevented when encountered in the workplace. While new workers learned different types of hazards and safety practices in safety training, their limited experience at the workplace reduced adaptation and adjustment of safety practices. Due to their lower level of experience, novice quarry workers described work hazards broadly, as opposed to more experienced workers who could understand the potential of accidents in more descriptive manner from the experience (e.g., showing scars and bruises). According to the study by Alwasel, Abdel-Rahman, Haas, and Lee (2017), masonry workers with more than 5 years of
experience performed safer than apprentices with 1 to 3 years of experience. This study aligns with the finding that novice workers lacked prevention strategies which may result from their limited work experience.

However, novice quarry workers explained that a safer work environment could be promoted if they worked closely with the experienced workers in the quarry. Novice workers believed that experienced workers had more knowledge and strategies to prevent accidents and perceived experience in the field to be as important as safety training. Newer workers perceived that safety was improved when they worked around experienced, professional workers, emphasizing that “experience does help down here a whole lot. I mean, I still got all my digits.” Novice quarry workers highly regarded the knowledge passed down from their more-experienced counterparts and expressed that apprenticeships could also serve as a valuable source of safety training.

In contrast, experienced workers were more concerned about others’ safety and wellbeing. This finding was also observed in a study by Alwasel et al. (2017) who identified that novice workers tended to mimic experienced workers’ behavior and production levels. The findings from the present study further revealed that experienced workers were more proficient and cautious about ergonomic safety. They expressed frustration that younger workers were not as careful as they should be, stating, “[What] I would like is for some of our younger guys to take the safety aspect of it serious[ly]. They're not at a point where safety is a big deal to them. They think they're invincible. When you're 18 to 25 years old nothing can kill you.” Therefore, workers’ accumulated practical experience, possibly through an apprenticeship safety training program, may bolster a strong teamwork to maintaining their safety and wellbeing.

**Passive behaviors in safety**

In contrast to proactive behaviors, other aspects of safety were driven by quarry workers’ passive behaviors toward safety regulations as a means to satisfy site coordinator and safety manager expectations. While the quarry workers’ teamwork was illustrated by their proactive attitudes towards safety in this study, their passive adherence to safety regulations was also observed. For example, one participant stated that their site coordinator was not “happy” if they disregarded safety regulations and further explained a scenario concerning the breaker. During the site visit,
the researcher also observed that a number of quarry workers wore shorts rather than long pants that could protect them from hazards (e.g., flying rocks). Although the site coordinator acknowledged workers’ inadequate PPE, he also recognized the quarry workers’ discomfort when wearing long pants in hot weather, which may lead to a heat stroke. Except for their resistance to wearing proper attire, this study found that workers’ submissive behavior to safety protocols was encouraged by their desire to be seen as mindful of safety and to impress the site coordinator. Therefore, not only were quarry workers passively following safety regulations, but they also maintained a desire to satisfy the site coordinator. This observation indicates that the safety concerns (e.g., wearing shorts in hot weather) must be collaboratively communicated across workers and supervisors.

In his supervisory role, the site coordinator was perceived as a “policeman” by a few quarry workers, whose unsafe behavior he corrected. Hopkins (2006) suggested that managers should guard against chasing after a particular behavior rather than focusing on comprehensively understanding workers’ performance. Managers’ insistence on a particular behavior creates stress for workers and leads workers to be less responsible for their own safety. This study found that a few participants perceived their site coordinator as a “policeman;” however, they also acknowledged that the site coordinator is generally more concerned about workers’ safety as demonstrated in their employer-employee relationship.

From the perspectives of experienced workers, the relationship between experienced and new workers somewhat mirrored the relationship between workers and management. For example, veteran quarry workers identified concerns about younger workers’ failure to exercise caution around work hazards. Although the older, professional workers tried to warn and give advice to the younger workers, younger workers were perceived by veteran workers as inattentive and not heeding advice. Although such finding about the older workers’ perceptions of younger workers being less cautious was not found in literature, this study bolsters conversations that consider the informal management strategies of experienced workers.

Additionally, quarry workers stated special attempts to consider the safety of local residents near the quarry. For example, the blade saw was not operated after 7:00 pm because it created an uncomfortable noise for the quarry’s residential neighbors. As another example, workers noted
that children would sometimes come to play at the quarry after it was closed. Quarry workers
stated that they tried to lock all doors, particularly to the blade saw room, to keep unauthorized
individuals away from hazards and prevent accidents. Collectively, the quarry workers strived to
maintain a safe work environment for workers and community members, alike. With their
collective goal of building a safe workplace, the quarry workers described both proactive and
passive strategies for creating a safe work environment and community.

**Hierarchy of controls**

It was observed that quarry workers unintentionally adopted different strategies from the
hierarchy of controls to prevent work accidents. Among other safety controls, the hierarchy of
controls provides a comprehensive overview of different safety control solutions to potential
workplace hazards (NIOSH, 2015). These controls include PPE, administrative controls,
engineering controls, substitution, and elimination. Traditionally, the hierarchy of controls was
used by managers and employers to identify feasible strategies to avoid accidents in the
workplace. Safety managers often applied this theoretical perspective to design a safe work
environment for workers. While the hierarchy of controls is traditionally used by managers to
effectively implement safety controls, this study observed that workers also implemented the
hierarchy of controls to create a safer work environment.

However, this study found that quarry workers had the ability to employ preventative strategies
drawn from their own perspectives and experiences that nonetheless reflected the hierarchy of
controls, ranging from wearing PPE to suggesting engineering controls to prevent accidents.
Although quarry workers’ responses regarding preventative strategies varied, many of their
strategies concerned wearing PPE, which indicates as the least effective method of preventing
work accidents in the hierarchy of controls. For example, all participants described encountering
pinch hazards on the breaker and described mitigating the pinch hazards by wearing impact
gloves.

Beyond wearing PPE, the quarry workers also suggested implementing engineering controls to
work operation by adding a level-adjustable conveyor belt on the breaker and a sensory device in
the blade saw room. Their thoughts to the development of safe operation was illustrated by
engineering controls, which is defined as isolating people from hazard by implementing innovative designs and controls (NIOSH, 2015). Quarry workers developed a safe work environment both by protecting themselves from work hazards and by adjusting their work operation to lessen their exposure to hazards.

**Contributions and Implications**

This research assists practitioners and researchers in the surface-mining industry to effectively design safer workplaces and safety training. Incorporating workers’ perspectives and experiences in safety controls can help safety managers encourage workers’ safety behaviors, particularly in instances in which workers are unsupervised. As identified in this study, worker prevention strategies and teamwork can be leveraged to enhance the effectiveness of safety training and contribute to a positive safety culture at the workplace. Also, this study provides a guideline for researcher to develop and integrate visual demonstration of work hazards and environment in safety training and research. While photo elicitation is not widely used in safety research, this study contributes to the use of photo elicitation in future safety research. As these contributions and implications are described in following sections, this study underlines workers’ proactive involvement in and a company’s commitment to safety.

**The surface-mining industry: development of safety culture**

The surface-mining industry can better develop a safety culture by improving workers’ perceptions and behaviors. This study found quarry workers perceptions of work hazards and how they would execute different strategies to prevent accidents. These findings about workers’ safety perceptions and behaviors may particularly contribute to studies about safety culture in the surface-mining industry. While safety culture is widely used and investigated in construction safety research, a limited number of studies in the surface-mining context has been conducted. This study contributes as a conversation starter to facilitate an establishment of safety culture which future surface-mining safety research can be conducted to further develop a safe workplace.

Safety culture involves workers’ values, perceptions, and beliefs concerning safety and can be indicated by a safety climate. Safety climate, as described by Fang, Chen, and Wong (2006), is a
“snapshot” of safety culture captured through workers’ perceptions and behaviors regarding safety. In other words, safety climate consists of workers’ perceptions of how management prioritizes safety in the workplace at any given time (Zohar, 1980). As such, an organization’s safety climate can be examined in different ways in the surface-mining industry. For example, management’s attitudes towards safety, the frequency of safety communication, the frequency and extent of safety training, and the adequacy of safety systems can be evaluated to examine safety culture. The results from an evaluation of the safety climate can further be used to effect changes in workers’ safety performance and behaviors (Barbaranelli, Petitta, & Probst, 2015; M. D. Cooper & R. A. Phillips, 2004). Therefore, this study contributes to the change in workers’ safety performance that can be better incorporated by management commitment in tandem with worker involvement (e.g., exploring workers’ perceptions and behaviors) in developing safety programs, thus generating a safer workplace.

**Safety managers**

This study also found that safety managers have a significant role in developing a safe workplace with workers. By incorporating workers’ field experience and maintaining dialogue between the company and its workers, workplace safety can be enhanced through workers’ feedback on safety controls. Fleming and Lardner (2002) emphasized the importance of incorporating management behaviors into safety programs. This scholar further explains that positive management behaviors include meeting with employees frequently to discuss safety issues and responding quickly to safety suggestions and concerns raised by employees. These practices accommodate workers’ perspectives and thus motivates workers to change their behavior. Additionally, Demirkesen and Arditi (2015) stated that supporting individual thinking, holding group discussions, exchanging ideas, comparing training notes, and organizing roundtable discussions increases workers’ reflection on past work experience and encourages changes in their behavior. This study observed that their yearly “refresher” safety training allowed the quarry workers to be involved in group discussion and presentation. This could imply that their involvement in safety programs and group discussion encouraged their proactive participation in safety training.
Aligning with this finding, this study further noted that managers can improve a safety programs with workers’ task experience. As claimed by Niza, Silva, and Lima (2008), a safer work environment can be accomplished through workers’ task experience. In this study, some participants stated their desire to implement improved technology to help breaker operators stack rocks before they are delivered to the client. Specifically, one participant expressed an expectation that the management should implement improved safety procedures by stating that, “they (managers) figure out a different way for these pile ups.” Because workers encountered difficulties in moving furnished rocks from the conveyor belt on the breaker and manually stacking the rocks on the pallets, they desired the management to implement an innovative way to substitute manpower in this operation. Also, another participant mentioned a second challenge of breaker operation involving flying rocks created by the chisel. This participant simulated an accident and stated that “I’ve seen it, because it just had rollers four foot long…as soon as it would break, boom, it would shoot out.” Regarding this instance, another participant suggested to leave the rock when it pops out from the chisel because holding and resisting the flying rock could harm workers. Workers’ ideas about adopting technologies and overcoming difficulties in operating machinery could be usefully incorporated by management in their engineering controls. As shown in these responses, a safer work environment could be realized through collaboration and integration of workers’ task experience into safety training.

Further, workers’ adoption of the hierarchy of controls indicates a positive sign to collaboratively create a safe workplace that includes both managers and workers. Through quarry workers’ unintentional adoption of the hierarchy of controls, a technique typically used by management, the safety of the work environment was enhanced from the bottom up (i.e., the worker level). For example, one participant suggested implementing a sensor in the blade saw room in addition to the ribbon fencing off the blade saw. The participant shared an experience of expecting the blade saw to shut down when someone crossed the ribbon and suggested that the ribbon should incorporate a sensor to shut down the saw. This demonstrated how the quarry workers employed their perspectives and field experience to combat hazards. Listening to quarry workers’ concerns may further help identify applicable solutions to practical challenges in building safe workplaces. To bolster workers’ application of safety knowledge and their employment of preventative strategies, safety training should be designed to help quarry workers cultivate ownership by
sharing a responsibility for safety. As a result, safety training incorporating worker input may maximize workers’ abilities to control workplace hazards and thus minimize the probability of accidents.

Additionally, the exploration of workers’ perception of work hazards can assist practitioners in examining their organization’s safety protocols. Unlike the top-down approach that stems from management controls to evaluate workers’ safety performance, the approach used in this study can bolster safety systems by investigating workers’ abilities to identify and interpret work hazards and their strategies to prevent accidents. Awareness of these abilities can help practitioners evaluate their current safety protocols to develop safety systems and management utilizing workers’ perceptions of work hazards.

**Practitioners/workers**

In this study, workers’ leadership was observed as an emergent finding regarding the quarry workers’ preventative strategies. Quarry workers shared their past experiences and emphasized watching out for each other in the workplace to encourage coworkers to perform safely. While leadership is commonly perceived as an individual who effectively manages and administers from atop an organizational hierarchy, the quarry workers naturally executed a form of leadership among their teams to perform safely and to promote the safety of coworkers. To further investigate quarry workers’ leadership, the following sections discuss different types of leadership within the realm of occupational safety as described in previous research.

A safer work environment in the surface-mining industry can be achieved by workers’ execution of leadership. Cooper (2015, p. 49) defined *safety leadership* as “the process of defining the desired state, setting up the team to succeed, and engaging in the discretionary efforts that drive the safety value.” He further investigated the importance of safety partnership. In a safety partnership, employees and management should share the responsibility of maintaining a safe environment. The key to sustaining a safety partnership is sharing, rather than demanding, responsibility with employees. That is, safety control should be done *with*, not *at*, people.

Similarly, in this study, the quarry workers acted as safety partners who perceived safety as their own responsibility. For example, the quarry workers executed different kinds of leadership to be
responsible for others’ safety and wellbeing and strived to prevent accidents not only for themselves but also for others. For example, participants frequently mentioned monitoring coworkers’ operations and behavior to ensure their safety. One participant said, “If I'm doing something dumb, I expect these guys to tell me the same thing. I don't care if folks haven’t been here 20 years.” This participant emphasized that it is important to listen to coworkers’ warnings concerning work hazards, and continued, “You gotta get warned about. Nobody wants to get hurt.” Quarry workers’ teamwork resulted in additional eyes (beyond the managers’) being available to monitor others’ behavior.

As a result of their shared responsibility for their own and their coworkers’ safety, the quarry workers expressed self-leadership influenced by super-leadership. Super-leadership generates effective teamwork by encouraging self-leadership (Manz & Sims Jr., 1991). Under super-leadership, no single individual exercises sole responsibility. Instead, super-leadership encourages self-leadership among “followers” by fostering their authorship and ownership of their work, thus promoting shared visions and goals for organizational success. Thus, super-leadership emphasizes followers’ responsibility and motivation by empowering followers as self-leaders.

In this study, not only the site coordinator and supervisors promoted a safe work environment. Quarry workers also perceived safety as their responsibility and cared about coworkers’ safety. One participant stated that he tells coworkers to “watch your fingers and watch everybody else's mainly. Ya know, we want you to watch each other down there.” Additionally, as a preventative strategy, participants shared their past experiences to encourage awareness of work hazards among new employees. By communicating their own experienced work hazards and accidents, experienced quarry workers motivated new employees to maintain an awareness of and responsibility for safety. Therefore, it was evident that the quarry workers executed super-leadership by communicating safety and past accidents to encourage self-leadership among new hires.

However, this study does not constrain quarry workers’ leadership to the categories of super-leadership and self-leadership. Empowerment and shared ownership of work characterize many different forms of leadership. “Shared leadership,” as defined by Pierce and Conger (2003),
enables team members to dynamically and interactively influence each other to achieve an organizational goal. The success of shared leadership requires all team members to motivate and encourage each other through upward and downward hierarchical influences. Beyond shared leadership, “eco-leadership” is defined as a leadership style which links all members of an organization via an interconnected, living network (Simmons, Clegorne, & Woods-Wells, 2017; Western, 2013). These studies perceive leadership not as the task of a single authority figure, but as the empowerment of all team members. Therefore, these types of leadership (i.e., shared leadership, eco-leadership) also characterize the quarry workers’ proactive participation in safety. This observation needs to be further examined using leadership framework in future studies.

**Safety research in the surface-mining industry**

The use of photo elicitation can offer an enlightening method of conducting engineering research in safety. Though qualitative research has been widely used in engineering research, a variety of qualitative research methods have not been rigorously implemented within these contexts. Through the implementation of photo elicitation to collect data from participants, this study can provide a guideline to assist researchers in the engineering field wishing to conduct interviews that employ discussion about photographs to capture participants’ perceptions during this process. This study can further guide researchers in exploring various contexts and activities through participants’ motivation to share their stories about photographs.

**Research Limitations**

This study encountered some limitations due to the methodological procedures employed. For example, relatively few participants identified noise as hazardous in the photographs. It is likely that such results occurred due to the visual medium of a photograph, which would not explicitly represent hazardous sounds. Therefore, research incorporating virtual reality (VR) may overcome this limitation.

Another limitation of this study included an insufficient definition of severity when asking participants to describe the degree of severity during the interviews. Although a definition of risk was included in the handout to improve participants understanding of a hazard, the definition of
severity and severity scale were not provided for participants. While it was the researcher’s intention to fully explore participants’ descriptions of severity without constraining their explanation in a predetermined scale, this limitation emerged from participants’ broad descriptions of severity such as, “that could be severe,” and “it can be real dangerous.” These responses were drawn by not sufficiently giving necessary information to participants.

The last limitation identified in this study is the Hawthorne effect. The Hawthorne effect, described as a tendency of participants’ change in behavior during an intervention of an investigation or inspection (Adair, 1984), may have influenced interview responses. For example, some study participants expressed concern about sharing their thoughts on improving the safety of their current work environment. On the other hand, some participants were very satisfied with their work environment and perceived it as ideal. Thus, the participants who offered no complaints did not necessarily perceive their current work environment to be perfect, but may have wanted to impress upon the researcher that they continually managed and maintained safety. Such behaviors were observed at the beginning of the interviews when the researcher asked, “What do you think is the most important thing in your workplace?” The participants were already aware of the study and could have already generated a predetermined response of “safety” to be perceived as conscientious employees by the researcher. However, some participants tried to be open and share their opinions about improving safety at their workplace after ensuring that their identities would remain confidential. Field notes further captured this behavior. At the beginning of the interview, the participants sat back as though observing the researcher to understand the study’s purpose and outcomes, even though these had been introduced during the recruitment phase. Later, in the photo elicitation phase, the participants may have reminded themselves to be more attentive than usual in identifying work hazards. As a result, this study may validate workers’ knowledge about and abilities to identifying hazards, but only if workers maintain mindfulness. Thus, a follow-up to this study might investigate worker’s mindfulness of hazards, which serves as a step in establishing and propagating safety perceptions a culture of safety amongst the workers, as addressed by RQ2.
Future work

While this study introduces new emergent findings about quarry workers’ perceptions of work hazards and their prevention strategies, it is imperative for future studies to expand and articulate the findings through different case study research. In this section, a guideline will be proposed for future work to better explore workers’ perceptions of work hazards and their safety behaviors in the workplace.

First, workers’ behavior does not only reflect their experiences of accidents; their caution concerning work hazards can also be impacted by their personal family values. Another motivation for workers’ cautiousness was illustrated in research by Lehmann et al. (2009), which found that workers with dependents are less likely to take risks than those without dependents. Therefore, quarry workers with family members might have performed differently in the workplace, a phenomenon this study did not investigate within the interviews.

Also, future research needs to investigate workers’ level of involvement or belongingness to the organization. Belongingness to an organization can be another factor that influences workers’ safety performance at the workplace because workers’ perceptions of their safety management and safety programs can change workers’ safety practices. To encourage workers’ participation in safety, future research can examine workers’ perceptions of organizational belongingness and their safety performance.

Lastly, future work would include photo elicitation methods integrated with sound. While photo elicitation has its strengths on exploring workers’ experience and perspectives about the photos, sound could not be delivered through the graphic medium. This study also found that the noise hazard present in each photo was not recognized as frequently as the other work hazards that could be represented visually. To better demonstrate the worksite and its hazards, future work may consider recording the sound in tandem with taking photographs. Future study may examine if a photo with sound makes a difference in participants’ perceptions of work hazards.
Summary

In this chapter, quarry workers’ perceptions of safety training were discussed along with the role of safety culture and climate in encouraging workers’ safety participation. As a part of improving an organizational safety culture, proactive and passive participation was required from quarry workers to effectively implement safety controls. Quarry workers’ proactive participation in safety was demonstrated through their leadership and teamwork in protecting themselves and coworkers from work hazards. Their passive safety participation was demonstrated in their compliance to safety regulations to satisfy the site coordinator. This active and passive safety participation emphasizes the importance of incorporating workers’ perspectives to develop a safe work environment. The combination of company commitment and worker participation in safety was found to be highly effective in generating a safe workplace, as demonstrated by the workers’ unintentional adoption of the hierarchy of controls to prevent accidents. In particular, workplace safety could be better promoted through workers’ field experience, as the issues workers encounter during an operation could be shared and utilized to enhance safety training.
CHAPTER 6: CONCLUSION

Conclusion

This study aimed to gain a greater understanding of quarry workers’ abilities to identify and interpret work hazards and workers’ strategies to prevent accidents. To explore quarry workers’ perceptions of work hazards and their prevention strategies in the workplace, this study posed the research questions to understand worker’s hazard identification (RQ1a), severity interpretation (RQ1b), and prevention strategies (RQ2). To accomplish this objective and answer the research questions, this study employed an inductive qualitative approach to explore quarry workers’ perceptions of work hazards. Specifically, this study employed a descriptive case study to better understand the research context and the processes of quarry operation by collecting data from various sources. This study’s data were mainly collected through interviews with photo elicitation and analyzed using the qualitative data analysis software Dedoose. The interview transcripts were codified and categorized to generate themes to support the emergent findings described in Chapter 4.

The researcher found that quarry workers identified the majority of work hazards that the safety managers did. Quarry workers also identified additional hazards by recalling their safety training and experiences with the operation depicted in each photo. While quarry workers’ hazard identification abilities were primarily developed during safety training, workers also simulated scenarios and drew on their experience to interpret the severity of work hazards. Quarry workers unintentionally utilized strategies adopted from the hierarchy of controls. These preventative strategies ranged from wearing PPE to implementing engineering controls to reduce the probability of accident.

Quarry workers perceptions of work hazards and their employment of preventative strategies were investigated to better understand of workers’ occupational safety. While future study is warranted to further explore workers’ perceptions and behavior regarding work hazards and to foster safer work environments, this study observed that quarry workers utilized super- and self-leadership to bolster teamwork and trust, thus generating a safer work environment. Additionally, workers’ proactive participation in safety was motivated by the company’s
commitment to safety, which served to encourage both workers’ proactive and passive engagement in creating a safer workplace. Quarry workers perceived experience as their primary lens through which to interpret work hazards and shared their experiences to foster awareness of hazards among new workers.

Overall, this study contributes to the growing body of safety research. While previous studies investigated the administrative approach to manage and implement safety systems (e.g., 37 management tasks, Macroergonomics), lack of study was conducted to examine how workers perceive work hazards and actualize safety knowledge to prevent accidents. In the context of the surface-mining industry, this study observed quarry workers’ perceptions and experience in the workplace. To further understand quarry workers’ perceptions of work hazards, future research should explore external variables that may influence workers’ safety performance in the workplace (e.g., more cautious behavior among workers with a dependent). Considering different external variables that may affect workers’ behavior could lead to more robust findings regarding workers’ perceptions of work hazards and their utilization of prevention strategies.
REFERENCES


The OSH Act General Duty Clause.


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Appendix B. IRB Approval Letter

MEMORANDUM

DATE: August 24, 2018
TO: Cassandra J Groen, Hwangbo Bae, Denise R. Simmons
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)
PROTOCOL TITLE: Enhancing Quarry and Stone workers’ Skills in Safety
IRB NUMBER: 18-638

Effective August 24, 2018, the Virginia Tech Institution Review Board (IRB) approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:
http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:
Approved As: Expedited, under 45 CFR 46.110 category(ies) 5,6,7
Protocol Approval Date: August 24, 2018
Protocol Expiration Date: August 23, 2019
Continuing Review Due Date*: August 9, 2019

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution
<table>
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<th>Date*</th>
<th>OSP Number</th>
<th>Sponsor</th>
<th>Grant Comparison Conducted?</th>
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* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt. edu) immediately.
Appendix C. Project Description to Site Managers

Project Description

Investigator(s): Hwangbo Bae, Denise Simmons, and Cassandra Groen

- **Section 1. Project Title and Overview**
  - Title: Quarry and Stone Workers’ skills in safety
  - Overview:
    This study will use qualitative research methods, including interview and photo elicitation, to investigate craftworkers’ abilities to recognize and interpret potential worksite hazards and employ hazard prevention strategies.

- **Section 2. Purpose**
  - The purpose of this study is:
    - To investigate quarry and stone workers’ ability to recognize safety hazards;
    - To investigate quarry and stone workers’ ability to interpret the severity of safety hazards;
    - To investigate quarry and stone workers’ ability to employ strategies to prevent accidents due to safety hazards;
    - And finally, to find significant factors that can improve quarry and stone workers’ skills in safety.

- **Section 3. Benefits and Costs**
  - As a result of participating in this study, a summary of findings will be provided to the Virginia Tech Facilities Department and used to enhance current safety training and safety assessments to generate a safer working environment.
  - There is no cost nor risk associated with workers’ participation in this study.

- **Section 4. Implementation Method**
  - Participant interviews will be divided into four phases: introductory interview, photo elicitation, follow-up interview, and a demographic survey. It is anticipated that all participants will take part in all phases of the interview; however, they are free to withdraw from the interview and/or study at any phase without penalty. The interview, in its entirety, will be conducted in about 60 minutes and completed in one setting at a location agreed upon by the research team (Bae, Simmons, and Groen) and participant supervisor (Johnston). The researcher will explain each phase to participants prior to the start of the interview.
  - Overview of Interview Phases:
    - Phase 1: Introductory Interview
      1) General information
      2) Workers’ definition of a safe working environment
    - Phase 2: Photo Elicitation
1) Workers’ hazards recognition ability
2) Workers’ hazards interpretation ability
3) Workers’ employment of prevention strategies in unsafe working environment
   - Phase 3: Follow-up Interview
   - Workers’ experiences with and perspectives of safety
   - Phase 4: Demographic Survey

- Section 5. Project Timeline
  o The table shown below (Table 1) illustrates a tentative schedule for the proposed project. The Virginia Tech Institutional Review Board (IRB) must approve the study protocol to ensure safety of human subjects serving as study participants. This phase includes obtaining approval for all research procedures including the interview protocol as well as processes and materials associated with photo elicitation methods. After obtaining approval, the primary researcher will recruit study participants and conduct interviews.

<table>
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<tr>
<th>List</th>
<th>2018 Months</th>
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<tr>
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<td>Project Proposed</td>
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<tr>
<td>Data Collection (interview)</td>
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<td>Data analysis</td>
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<td>Thesis Write-up</td>
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<td>Thesis Submission</td>
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o Once participant data has been collected, interviews will be transcribed and analyzed during the fall academic semester. The final project report will be completed by the end of the 2019 Spring Academic Semester.

- Section 6. Participant Requirements
  o The study participants must
    1. be at least 18 years of age or older;
    2. currently employed as a quarry worker or stone worker; and
    3. speak English to talk about their experiences.

- Section 7. Anticipated Contributions
  o This research project will contribute to practice and study of safety in the construction industry by gaining a deeper understanding of workers’ abilities to recognize, interpret, and mitigate safety hazards encountered in the construction workforce.

If you have any question, please contact Hwangbo Bae at beabo92@vt.edu or (540) 449-7012.
Appendix D. Interview Guide

Materials: Introductory Interview (Section I), Photo Elicitation (Section II), Follow-up Interview (Section III)

Description: Upon obtaining consent from interview participants, the following semi-structured interview protocol will be used to guide the interview processes for interviewees. The questions below represent the content that will be explored during the interview; however, the exact language and question order may vary based on the flow of conversation and as the rapport between interviewer and the participants maintains.

Section I. Introductory Interview

[Start Interview]

Introduction:

First of all, I would like to thank you for taking your time to come and speak with me today. In this study, we are interested in learning about how quarry and stone workers perceive and perform safety in their work environments. The information that you provide in this study will be used to inform the development of mining companies’ safety training for quarry and stone workers and improve the implementation of safety assessments so that fatal accidents in quarry can be reduced and prevented. Keep in mind that there are no right or wrong answers; this interview is about understanding you and your experiences. If you have any questions at any time, please do not hesitate to ask.

General Information:

1. First, tell me about your experience working as a quarry/stone worker.
   a. How did you get to seek your employment?
   b. How long have you been working as a quarry/stone worker?
   c. What is the most important thing in your workplace?

Workers’ definition of a safe working environment

2. Please describe a safe working environment.
3. What can you do to improve a safe working environment?
a. Are there any particular strategies that you use to prevent accidents from happening at your job?

Section II. Photo Elicitation

Now, I will show you an example to help you understand the difference between risks and hazards. As illustrated in the handout that I gave you, Hazard is anything that can cause harm and risk is any action that increases the exposure to hazard. The first set of photos is an example of using an oven. You want to wear a pair of oven mitts to prevent getting burned by the heat. In this case, the risk is an action of touching a sheet pan without a pair of oven mitts while the hazard is the heat.

For the next example, I would like you to figure out what a hazard is in the photo. The risk in this photo is an action of operating electronics with wet hands.

What do you think is the hazard? The answer can be more than one.

Please note that there are short- and long-term hazards. Short-term hazards can cause immediate injuries like touching a hot oven sheet pan without an oven mitt. Long-term hazards can cause your back pains due to repetitive work posture and motion and lung diseases due to consistent exposure to chemicals.

Now, I would like to show you photos of a workplace. There are three photos that will be shown, one at a time. Some photos may contain different hazards/dangers.

Workers’ Hazards Recognition Ability

4. Describe any potential hazard that you see in the image of the quarry site and please mark on the photo.
   a. Tell me what type of hazard/danger exist in the photo.
      i. Why do you think this is a hazard?
      ii. What characteristics or items do you see in this photo that present a potential hazard?

Workers’ Hazards Interpretation Ability

5. What do you think the hazard/danger can cause, if not properly taken care of?
6. How severe, do you think, is the hazard/danger in the photo?
   a. What makes you think that this hazard is severe?
   b. What makes you think that this hazard is minor?

Workers’ Employing Prevention Strategies to Unsafe Environment

7. What would you do to reduce or eliminate the hazard depicted in the photo?
8. What strategies would you use to make a safer working environment in the photo?
(the same questions will be asked for remaining photos of the three)

Section III. Follow-up Interview

Now I would like to shift gears a little bit and ask about your experience and perspectives in safety.

Workers’ Experience and Perspectives in Safety

9. What is the most memorable safety training you have received?
10. Have you ever been involved or witnessed an accident in your workplace?
   c. If so, please describe the accident.
11. Are there any recommendations that you have for your team for helping to improve safety at your site?
   d. If so, what would those recommendations be?
   e. If not, can you explain why you think so?

[End Interview]
Appendix E. Consent Form

Consent form for participant interview and survey

Title of Study: Enhancing Quarry and Stone Workers’ Skills in Safety

Investigator(s): Hwangbo Bae, Denise Simmons, and Cassandra Groen

I. Purpose of this Study

The purpose of this research study is to explore quarry and stone workers’ experiences with and behaviors when safety hazards are encountered in the workplace. In particular, this study will examine workers’ abilities to identify hazards that may cause and strategies for mitigating potentially-fatal accidents or other injuries on construction-type worksites. The data collected for this study will be analyzed, and the results will be used to developed safety training and assessments tailored to the site under study and grounded within workers’ perspectives. Overall, the findings of this study will be used to promote and sustain safer working environments and disseminated in academic papers and journals.

II. Procedure

As a voluntary participant in this study, you will be expected to participate in an interview lasting a maximum of one hour. As part of the interview, you also agree to complete a short demographic survey. The interview will be audio-recorded and will involve sharing your experiences and opinions of safety conduct when encountering hazards on the work site. The interview will take place in a private setting near the work site.

III. Risks

The risks associated with participating in this study are considered to be minimal.

IV. Benefits

No promise or guarantee of direct benefits has been made to encourage you to participate in this study. However, findings from this study will be submitted to the company so that safety assessments, training, and regulations can be improved for current and future employees.

V. Extent of Anonymity and Confidentiality

The data collected from you during the above-mentioned interview may include information that could potentially identify you such as your name, your company name, job title, age, or gender. Your identity, and that of any other person whom you mention, will be kept confidential at all times and will be known only to the research team. The audio recording of the interview will be transcribed, and false names (i.e., pseudonyms) will be used in place of your name and for the names of any other individuals or organizations you mention. Any other information in the recording that could potentially identify you or anyone you mention will also be altered during the transcription process to protect your identity. Signed consent forms, audio-recordings, and all paper and electronic copies of the interview transcript will be stored on a secure password-protected system approved by the Virginia Tech Institutional Review Board (IRB). Only the research team will have access to collected data and signed consent forms. All consent forms and collected data will be erased or otherwise destroyed promptly per Virginia Tech IRB guidelines upon study and publication completion.

Virginia Tech Institutional Review Board Project No. 18-638
Approved August 24, 2018 to August 23, 2019
The Virginia Tech (VT) IRB may view this study’s data for auditing purposes. The IRB is responsible for overseeing the protection of human participants in research.

VI. Compensation

You understand that you will not receive any monetary form of compensation for participating in this study. As this study is occurring in the summer months, participants will receive a bottle of water to drink during the interview.

VII. Freedom to Withdraw

It is important for you to know that your participation in this study is entirely voluntary and that you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled. Also, your refusal to participate in this study will result in no penalty or loss of benefits to which you are otherwise entitled. If you choose to withdraw from the study, any information about you, and any data that you have provided, will be destroyed. You are also free to choose to not answer any question or to not respond to what is being asked of you, and this choice will result in no penalty or loss of benefits to which you are otherwise entitled. Further, any portion of your interview may be removed from analysis upon request without penalty.

VIII. Questions or Concerns

If you have any questions or concerns about this study, you can contact any member of the research team, whose contact information is included at the end of this consent form.

If you have any questions or concerns about how this study is conducted or about your rights as a participant, or if you need to report a research-related injury or event, you can contact the Virginia Tech Institutional Review Board via email at irb@vt.edu or by phone at (540) 231-3732.

IMPORTANT NOTE TO THE PARTICIPANT:

If you have any questions or concerns related to this consent form or to any other aspect of the study, please contact any member of the research team, listed below. Thank you for agreeing to participate in this study!
Hwangbo Bae, Graduate Student: beabo92@vt.edu or (540) 449-7012 / Cassandra Groen, PhD: cgroen@vt.edu or (605) 890-1464 / Denise R. Simmons, PhD: densimms@vt.edu or (540) 553-6013

IX. Participant’s Consent

I have read the Consent Form and meet the requirements associated of the study listed below and verify that:

☐ I am over 18 years old.

I verify that all of my questions answered. I hereby acknowledge the above and give my voluntary consent to participate in this study:

Printed Name / Signature of Participant

Date

Virginia Tech Institutional Review Board Project No. 18-638
Approved August 24, 2018 to August 23, 2019

Page 2 of 2
Appendix F. Recruitment Script

Recruitment Script

Good [morning/afternoon/evening],

My name is Hwangbo Bae, and I am a graduate student in the Civil Engineering Department at Virginia Tech. As part of my master’s thesis work, I am conducting a research study to further develop and promote safer working environments in construction. Because of your experience and expertise as a [quarry worker/stone worker], I am here today to invite you to participate in this study and advance our understanding of workers’ perspectives of safety in the field. The findings from this study will be used to develop, modify, and implement safety training and assessments for companies throughout the construction industry.

As a participant in this study, you will be expected to conduct an interview with me, Hwangbo Bae, that will last less than an hour. Individuals eligible to participate in this study must 1) be at least 18 years or older; 2) be currently employed as a quarry worker or a stone worker within the Virginia Tech Facilities Department; and 3) understand and speak English as means to talk about your experience with safety. Your participation in this study will is completely voluntary, and you are free to withdraw at any time without penalty. Your contributions to this study will be reported out anonymously to protect your identity. If you have any questions or would like to sign up, please contact me, Hwangbo Bae at 540) 449-7012 or heabo92@vt.edu.
Appendix G. Handout for Interview

Handout for Interview:
Hazards vs. Risks

This document is to help participant understand the difference between hazards and risks. The difference is essential knowledge for participant in the semi-structured interview.

Definitions:  Hazard: Anything that can cause harm
              Risk: Any action that increases the exposure to hazard

Example 1. Using an Oven

Risk: Touching a sheet pan without wearing an oven mitt

Hazard: Heat
Example 2. Using Electronics

Risk: Operating electronics with wet hands

?  

Hazard: [Participant’s answer]

*Please remember that hazard is anything that can cause harm.
Appendix H. Non-Disclosure Agreement

Title of Research Project: Enhancing Quarry and Stone Workers’ Skills in Safety

Investigator(s): Hwangbo Bae, Dr. Cassandra Groen, and Dr. Denise R. Simmons

This Non-Disclosure Agreement is made effective as of [Effective Date, and year], by and between Dr. Denise R. Simmons, Dr. Cassandra Groen, and Hwangbo Bae (the “research team”) and [Name of the Site Coordinator] (the “recipient”).

By request of the research team, the recipient agrees that they will protect the confidentiality of all study materials and information which may be disclosed between the research team and the recipient. Therefore, the parties agree as follows:

The recipient understands that they may have access to confidential information about study sites and participants. By signing this statement, the recipient indicates their understanding of their responsibilities to maintain confidentiality and agree to the following:

- I understand that names and any other identifying information about study sites and participants are completely confidential.

- I agree not to divulge, publish, or otherwise make known to unauthorized persons or to the public any information obtained during the course of this research project that could identify the persons who participated in the study.

- I understand that all information about study sites or participants obtained or accessed by me during the course of my work is confidential. I agree not to divulge or otherwise make known to unauthorized persons any of this information, unless specifically authorized to do so upon approval by the Virginia Tech Institutional Review Board and the research team acting in response to applicable law or court order or public health or clinical need.

- I agree to immediately notify a member of the research team should I become aware of a breach of confidentiality or a situation which could potentially result in a breach, whether this be on my part or on the part of another person.

_________________________  ___________________________  ___________________________
Signature                  Date                               Printed name

_________________________  ___________________________  ___________________________
Signature of Research Team Member  Date                               Printed name

_________________________  ___________________________  ___________________________
Signature of Research Team Member  Date                               Printed name

_________________________  ___________________________  ___________________________
Signature of Research Team Member  Date                               Printed name
Appendix I. Data Collection Timeline

a. June 1\textsuperscript{st}
   i. Meeting with Administrative Manager
      1. Introduced the study
      2. Demonstrated possible contributions to the company
      3. Discussed about workers availability
      4. Discussed that there is going to be no compensation for participation

b. June 13\textsuperscript{th}
   ii. Meeting with safety coordinator, Human Resource manager, associate director of buildings and grounds, and quarry manager

c. June 22\textsuperscript{nd}
   iii. 1\textsuperscript{st} Site Tour
   iv. Received a safety training (very simple)

d. July 12\textsuperscript{th}
   v. Trial 1: First photo-taking
      1. Cancelled due to MSHA inspection (visitation without notice)

e. July 19\textsuperscript{th}
   vi. Trial 2: First photo-taking
      1. Took 50+ photos, some of them were taken in different angles

f. July 24\textsuperscript{th}
   vii. Second photo taking in different weather
      1. Taking photos in rainy days did not succeed because the weather could not be precisely estimated and the it usually rained afternoon when the quarry workers were almost ready to be dismissed.
      2. **Although taking photos in rainy condition could have helped demonstrating the weather condition in the photo, the researcher was able to find that participants were able to bring their experiences in different weather conditions to conversation from the depicted photo.

g. August 1\textsuperscript{st}
   viii. Photo analysis with managerial-level individuals
      1. Hazard identification, interpretation, preventive strategies
         a. Chose three photos and analyzed each photo based on the safety protocol based on the managerial perspective and expectation on their workers.
      2. Discussed the safety trainings the workers have to take

h. August 16\textsuperscript{th}
   ix. Interview quality test with a colleague

i. Sept 3\textsuperscript{rd}
   x. Recruitment
      1. Read recruitment script to workers (8/14 agreed to participate)
      2. gathered a group of people or a personnel to an office room and introduced the study
      3. gathered the names participants
      4. scheduled for the interview

j. Sept 21\textsuperscript{st}
   xi. First interview was conducted
      1. Two interviews were conducted in a row and with a break of 30 min in between
      2. All the other interviews were conducted once per day for a week.

k. Sept 28\textsuperscript{th}
   xii. Last interview was conducted
      1. Two interviews were conducted just as the first interviews.
Appendix J. Photos taken at the quarry (photo credit: Hwangbo Bae)

Figure 11. Hydraulic drill at the Quarry
Figure 12. Blade Saw
Figure 13. Hydraulic Breaker
## Appendix K. Codebook

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<th>Themes with Codes</th>
<th>Definition</th>
<th>Example excerpts</th>
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| Workers' perception of the current work environment    | Quarry workers perceived and described the work environment at the quarry regarding with safety and operation | "It used to be these have 30 some people here, ... but ...I think, 15 are here maybe. Maybe, 16, or 17"  
"So you can shift around 'cause that's how they used to do it. Now a lot of times, a lot of people stay in a particular spot just 'cause the people that are available are limited. I know there's three guys that are usually always on this breaker. " |
| Decreased number of workers at the quarry              | Quarry workers perceived an increased amount of workload against the decreased number of employees | "If it's still raining, we'll try to get it done the day before..." |
| Efforts to manage the workload against weather         | Quarry worker try to maintain the productivity and safety against weather condition | "I mean more than likely it's not going to get pinched because that's really the only way we can do it right now because the drill's a piece of crap and the air..." |
| Failure of using innovative technology in the field     | Quarry workers noticed failure of implementation of                        |                                                                                                                                                  |
| Improved working environment in safety | Quarry workers perceived their working environment has improved compared to the past | "I think we're getting better here as far as PPE. I know before, like I said, we've, years ago it wasn't, we weren't told as much, you weren't harped on as much. Hey, wear your stuff and be safe. You knew you needed to be safe. It wasn't thrown in your face all the time. Now, it's becoming a bigger thing. I'd say the past 8 to 10 years have really, safety's been a bigger part of this quarry than what it was before."

| need of more dust collecting system | Quarry workers inquired of more dust collecting system for operations at the quarry | "The only thing that I really do when I'm on, I just kind of, once the rock's there already, I just kind of back away. I try to stay as far back as I possibly can. Because we do have dust collectors, and they work, it's just as much dust that comes off the
<table>
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<th><strong>Value in &quot;safety first&quot;</strong></th>
<th>Rocks, it's just a lot for one system to work, to do it all.</th>
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<td>Quarry workers prioritized the safety as their most important value at the quarry</td>
<td>&quot;it's seeing that these guys go out here with all their digits and they go home to their families. That's the main thing. I mean, you can get a paycheck anywhere, but if you don't watch what you're doing, there's ... luckily, we've not had that here and I hope we never do.&quot; &quot;Most important thing would be safety down here, because I mean it is a dangerous job.&quot;</td>
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<td><strong>Breakers as the most dangerous equipment at the quarry</strong></td>
<td>&quot;They are risky on the breaker, purely power's out when they planned it, so.&quot; &quot;The breaker is, about 99% of your injuries down here is on the breaker. Back problems, smashed fingers, stuff like that.&quot;</td>
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<td>Quarry workers emphasized the most dangerous machine as the breaker and described many workers have been injured on the breaker</td>
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<td><strong>Perception of younger workers as less careful</strong></td>
<td>&quot;I've noticed that safety is not priority to them right yet.&quot; &quot;The only thing I would like is for some of our younger guys to take the safety aspect of it serious. They're not at a point where safety is a big deal to them. They...&quot;</td>
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<tr>
<td>Self-perception of workers</td>
<td>think they're invincible. When you're 18 to 25 years old nothing can kill you.&quot;</td>
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<tr>
<td>Tough guy analogy</td>
<td>&quot;Like I've said, I've seen on this particular breaker, I've seen fingers get chopped off. I've seen a guy, he was &quot;so tough, he was a tough guy&quot;</td>
</tr>
<tr>
<td>Having a vision to be a supervisor</td>
<td>&quot;I was going in at a young age and it just kind of stuck. The different things that I could do as far as the equipment, things like that, learning new things. I've actually worked up to a supervisor now. I guess my hopes would be to become a manager at some point in time. I guess that's the reason.&quot;</td>
</tr>
<tr>
<td>Feeling proud and confident about the work</td>
<td>&quot;I applied different places but this is where I interviewed with, and I wanted to do the manual labor and be active during the day and do all that and it is interesting. I know people in the side shop that engrave those stones that I'm polishing, so</td>
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</table>
| **Satisfaction of the work** | I'm starting it and they're finishing over there. It's kinda interesting to be a part of it."
  "I've done everything from drilling stone, blasting stone, sawing stone, specialty stone, production stone, heavy equipment"

| **Quarry workers** | Quarry workers were satisfied with their work at the quarry which require putting hand-on activities and professional experience

| **Perception of safe working environment** | "I actually didn't know this place existed...[I have been] going on three years. Close to three. It's different. It's better than a factory job."

| **Quarry workers** | Quarry workers described a safe working environment as promoting a safe teamwork and following the safety guidelines

| **Everyone wearing PPE** | "And then your safety equipment, ear plugs, glasses, all your safety stuff that you need for that particular area."
  "Well you have to have all your PPEs, gloves, safety glasses, boots and earplugs"
<p>| Cleaning | Quarry workers perceived cleaning after and before the work can reduce the exposure to work hazards | &quot;if you don't keep it cleaned up, you could be doing something, step around to turn, and fall. You could trip over a piece of stone and if you had just pushed it out of the way, it wouldn't be there. You might trip over your own two feet, but if you trip over something that you ... to me, that's preventable. That's what I call preventable.&quot; |
| Effective communication | Quarry workers described that a safe work environment entails an effective communication between coworkers | &quot;Communicating and caution, all that stuff. It's what makes it work.&quot; &quot;If you don't communicate, then you don't know what's going to happen.&quot; |
| Everyone paying attention | Quarry workers perceived paying attention to each other and watching for others' operation can improve a safe work environment | &quot;Everybody has to pay attention out there. But it's definitely some of the equipment, if you get too close and they're not paying attention, you're not paying attention, it can not be good. On a breaker, you watch rocks being pushed in, it's behind you, so you've got to make sure, you start hearing that, you turn around and look and make sure there's no piece stuck out long and is going to hit you in the back or anything like that, or break off on the leg or something like that. And then your |</p>
<table>
<thead>
<tr>
<th>Looking for people/surroundings</th>
<th>Quarry workers emphasized watching for the people and surrounding is very important to promote safety during the operation</th>
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<td></td>
<td>&quot;Watching the rock, make sure it don't hit you. Looking out for other people riding or driving equipment because sometimes they can't see you in some of them big payloaders and stuff, so you got to kind of look out for yourself and for them.&quot;</td>
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<thead>
<tr>
<th>Workers' abilities to identify hazards</th>
<th>Quarry workers identified different hazards in each photo shared in the interview with photo elicitation and, sometimes, indicated additional hazards than those identified by safety managers</th>
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<tr>
<th>Hazards identified on the breaker</th>
<th>Quarry workers identified slip of</th>
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|                                  | "One of the nicest things they've done so far is put the dust collector up here. It
<table>
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<tr>
<th>Hazards identified on the excavator</th>
<th>Quarry workers identified dust, blast of saw segment, slip of floor, trip over water hose, fly-rocks, blast of electric line, noise, and weather as hazards; and not additional hazards was found</th>
</tr>
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</table>
| machine, dust, and fall from ledge as hazards; and additionally discovered blast of air hose, blast of hydraulic line, and trip over pallets as emergent hazards. Noise was only identified by the safe managers | helps a lot. 'Cause when you break the rock, dust just flies... because before, when you break it, you can't hardly see nothing. It's just dusty."

"I mean, you can strain your back too. Hurt yourself with your muscles and all that."

"they throw trash over here it hits something and bounces over here on this person's standing here."

" The potential for if you're in the track hoe or whatever, I mean, the likelihood of that hose busting, but you get a burn hazard, you know, from the hoses.""He could have a chemical reaction to it. Like the hoses here and these are all hydraulic. The hydraulic pump works everything. I had one bust there one day."

"That's probably one of the biggest things, because it is a hazard. Eventually it's going to get on the road, but it's ... And it's one of those hard ones to get. You try everything, try all kinds of dust collectors and stuff like that, but probably one of the biggest one is just all the dust, the dust that you have."
hazards identified on the saw

Quarry workers identified fly-rocks, repetitive posture, dust, noise, blast of electric line, blast of hydraulic line, and pinch by the breaker as hazards; and additional indicated full bucket of trash rocks as an emergent hazard

"And the floors, it's sort of hard to keep the ice off the floor because you've got to open the door to actually get the rock out and stuff like that. That's pretty much something we've got to live with."

"Yeah, they'll do that because of the rock. A lot of times what will happen is if a... the rock in there, you know, they're not square rock, they're on different kinda angles, or if it's all through so far, and if it breaks it could kick into the blade, there's some teeth that could come off. We've came in before, and every one of the teeth on the saw, it threw off."

Identification by safety training

Quarry workers primarily used their safety training to recall and identify work hazards at the quarry

"The most memorable that was good is likely the people I trained with on the breaker. Like getting those different perspectives. And then we do the bigger rock down there, but up here at this breaker, we do the smaller rocks called the threes ... how their height is. They're a lot smaller. You can pick up a piece like this and throw it up in the air. They're not heavy. Being able to do that one too and kind of cross training between the different types of rock ... you know, you learn about the safety with how to move your fingers more and be aware of them. But you also are more aware of what's
"I'd say it was probably the one on silicosis. The dust and stuff that we have up there. It actually opened my eyes too. I didn't think it was nothing but I mean, back, I can't remember when it was, there was a bunch of people died from it because there wasn't any ventilation in the tunnels they were drawing the rock in. Yeah. A bunch of people died because of it. And that actually opened everybody's eyes to silicosis and the issue that it is."

<table>
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<tr>
<th>Workers abilities to interpret the degree of severity</th>
<th>Quarry workers interpreted the degree of severity on different operations in the photos and used scenario and experience to estimate the severity</th>
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<tbody>
<tr>
<td>Severity on the breaker</td>
<td>Quarry workers broadly described the degree of severity on the breaker</td>
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"I've got it on my arm before, and it didn't bother me. It just smells awful"  
"I know one guy he likes to hand cut, but it is a little rough on your shoulders. Not painful, but you are a little more hunched over doing that. So after doing it for a few days ... I did it like three days last week. My shoulders were sore"
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<tr>
<th>Severity on the excavator</th>
<th>Quarry workers broadly described the degree of severity on the excavator</th>
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<td></td>
<td>&quot;I had a rock and went to pick it up and it got hung in the belt, the rock, corner of the rock, so that clipped my finger and the rock went and fell.&quot;</td>
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<td></td>
<td>&quot;And then the couplings if they don't have the pins in them, well they come loose, you can be injured on that or possibly killed. I don't know what them hoses, depending on where they hit you, you know? So I mean, basically injury, or possibility of getting- Especially that one, if that was to slide and you had, I mean it might not run completely on top of you but it wouldn't be a good day to go home and be sober. &quot;</td>
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<td></td>
<td>&quot;Well the one, I mean could result from serious injury or death. You know, that was a slide. And actually, it's the same on the others. You know, cause I mean you take if you were to trip off of this or fall off of this, it don't take a big fall to kill you. And you could get seriously injured or death off the trip hazards.&quot;</td>
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<tr>
<td>Severity on the saw</td>
<td>Quarry workers broadly described the degree of severity on the saw</td>
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<td></td>
<td>&quot; If one of them come off, the teeth hit you, and again, they don't kill, you, you probably don't want to be dead. &quot;</td>
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|                           | "Those teeth are braised on, kinda like weldin'. Probably not a good idea to be in
<table>
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<tr>
<th>Experience based interpretation of severity</th>
<th>Quarry workers used experience to interpret and describe the degree of severity</th>
</tr>
</thead>
</table>
| "Yeah it wasn't fun. Wasn't fun at all. You don't need how bad you need your fingers, your middle finger, until you can't use it. It was rough. And after that I've been a lot more observant than I was to begin with. I definitely...if I think it's...if I think it's not worth it I don't let them do it."
"We've had 30 people get their fingers over the last two years, and two of them broke them... just shattered and so... That's kind of a big deal." |

<table>
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<tr>
<th>Scenario-based interpretation of severity</th>
<th>Quarry workers simulated a scenario to</th>
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</table>
| "if the tips were to come off, you know you're hit by them, or you're walking back with that hose, you could slip and fall into that running blade and pretty much well, there, because we have had em thrown, throw the teeth off, and that can kill you as fast as that thing's spinnin'. But as long as the rope's up, then I think you're alright, cus' I don't think anyone's gonna walk in there." "you'd lose your hearing if you don't wear your protection and you're in there for a constant amount of time, you can lose your hearing. Or you can decrease your hearing, that's the same thing to me as losing it. I mean really, so I mean mostly everyone here wears plugs."

<p>| &quot;if the tips were to come off, you know you're hit by them, or you're walking back with that hose, you could slip and fall into that running blade and pretty much well, there, because we have had em thrown, throw the teeth off, and that can kill you as fast as that thing's spinnin'. But as long as the rope's up, then I think you're alright, cus' I don't think anyone's gonna walk in there.&quot; &quot;you'd lose your hearing if you don't wear your protection and you're in there for a constant amount of time, you can lose your hearing. Or you can decrease your hearing, that's the same thing to me as losing it. I mean really, so I mean mostly everyone here wears plugs.&quot; |</p>
<table>
<thead>
<tr>
<th>Interpret and describe the degree of severity</th>
<th>That's self-explanatory. The safe practice we use is we clean it every time we layer. &quot;If you get too close and they're not paying attention, you're not paying attention, it can not be good. On a breaker, you watch rocks being pushed in, it's behind you, so you've got to make sure, you start hearing that, you turn around and look and make sure there's no piece stuck out long and is going to hit you in the back or anything like that, or break off on the leg or something like that. And then your fingers, and watch what the other person is doing when they're stacking it, and you don't have your fingers where they're going to put it there.&quot;</th>
</tr>
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<tbody>
<tr>
<td>Quarry workers broadly or, in some sense, vaguely described the degree of severity</td>
<td>&quot;If we're going on the possibility of somebody walking back here to get that hose, then that's a serious threat.&quot; &quot;Yeah. That could typical pretty well out of you.&quot; &quot;Well that standing behind us probably pretty dangerous.&quot; &quot;That's probably not that severe. All of them. That or the wall.&quot;</td>
</tr>
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</table>
| Admiring experience to achieve improving the safety | Quarry workers admired experienced workers and believed that they can precisely interpret the hazards and execute adequate strategies to prevent accidents | "But the main thing is is just use what experience I know to help them not do something and get hurt, to explain to them why, so I don't just run and jump on somebody if they're doing something. They need to understand what they're doing."
"experience does help down here a whole lot. I mean I still got all my digits"
"I know what can happen because I've been here for a while, but I've had it a few times, so I try to definitely make sure that I'm not around it."

| Preventative Strategy | Quarry workers unintentionally adopted the hierarchy of controls to prevent accidents | "Wear their personal protective equipment. Wear their gloves, their glasses, earplugs... the best that they can...Sounds corny, but keep thinking of the next man. Don't think of just yourself, cause we work together, the people."
"you just have to make sure you wear the right shoes and you got your foot, and you got your PPE on, cause if you do fall, I mean, technically we're not required to

| PPE | Quarry workers worn PPE to prevent getting hurt and injuries | "Wear their personal protective equipment. Wear their gloves, their glasses, earplugs... the best that they can...Sounds corny, but keep thinking of the next man. Don't think of just yourself, cause we work together, the people."
"you just have to make sure you wear the right shoes and you got your foot, and you got your PPE on, cause if you do fall, I mean, technically we're not required to
wear hard hats unless we're next to a hallway. Where anything could possibly fall and hit you in the head."

"So it was the first time I had seen the black powder be put in. I didn't move unless he told me to move, after blew we were all back, but we got back in the truck ...and I got out of the door and just stood there and waited for him to give me my next move. I didn't walk out on the ledge or anything like that. So being aware of my surroundings and doing exactly what I'm told in a situation I'm unfamiliar with."

"But mainly the training we've had. Just what we get here, the fire extinguisher training. We get a little bit of everything, and we do it every year, annually. So required by insurance, but it's good to have. I mean really, I'll be the first to tell you, I don't want to go sit in a class. Nobody does, all day long. But it sticks with you, when you go every year. Like I say, the CPR and the first aid if I only done it when I first started, you ain't going to remember that. And they're not just good for here, it's good for out in the community. When you're out with your family, or over at Lowe's or Home Depot,
<table>
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<tr>
<th>Engineering Controls</th>
<th>and you see somebody fall down, you can use it. You have enough care to try to use it, the confidence, I guess you can say.</th>
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<tbody>
<tr>
<td>Quarry workers</td>
<td>&quot;The table that moves so that you can stack cause even we use five pallets high now. We use five pallet stacked to put the rock on. And the first ledge still kinda like long. With the levels it's not too bad because there so big, but, it'd be nice for just to adjust it where it's right there next to the belts, so you can just ... then it don't have very far to fall. So it's not balancing. That would be the biggest thing to be replaced.&quot;</td>
</tr>
<tr>
<td>Quarry workers</td>
<td>&quot; but it's seeing that these guys go out here with all their digits and they go home to their families. That's the main thing. I mean, you can get a paycheck anywhere, but if you don't watch what you're doing, there's ... luckily, we've not had that here and I hope we never do.&quot;</td>
</tr>
<tr>
<td>Quarry workers</td>
<td>&quot;In my head, most people just have to act as a team and you don't have to be best buddies with everybody but care about each other and not doing something that may hurt somebody else if they're not aware of what you're doing, or looking out for them if they're not seeing something</td>
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come down. Help them do the teamwork of realizing we all need to get outta here"
"Of course, the pinching is not that bad but up here you've got to have a whole lot of trust in the dude running the machine."

<table>
<thead>
<tr>
<th>Barriers to practicing safe operation</th>
<th>Quarry worker encountered barriers to practice safe operation at the quarry</th>
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<tbody>
<tr>
<td>Time constraints</td>
<td>Quarry workers described they have time constraints against the number of workers at the quarry</td>
</tr>
<tr>
<td>Sense of bothersome in teaching the novice workers</td>
<td>Quarry workers felt a sense of bothersome in teaching the novice workers</td>
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"Sometimes, there's no time."
"We just reeled a bunch of shocks and we didn't have time to blast"

"But we've got a lot of younger people starting that haven't had previous experience in this type or I guess any other construction type of settings, so sometimes it's because they don't know. They think, well, you gotta shove a rock in the breaker. It's gonna make you stop..." 
"It's kind of aggravating when you get a new person because you try to explain to them and they don't quite understand."
<table>
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<tr>
<th><strong>Deficits of safety training</strong></th>
<th>Quarry workers complained about some safety trainings are not as useful and applicable to their particular operation at the quarry</th>
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<tr>
<td><strong>Encountering barriers in communication</strong></td>
<td>Quarry workers encountered barriers to communicate effectively with coworkers in team operation</td>
</tr>
<tr>
<td><strong>&quot;the videos are actually a little awful. They're outdated and everything in the videos that we watched don't all apply to us. They're just mines in general.&quot;</strong></td>
<td><strong>&quot;The communicating with these two people is different from communicating with these two. But each side needs to communicate too when a packet...packet. When a pallet fills up, we yell and tell so they can hear us because everything's loud. We yell and tell them that we have the pallet. So they stop and bring everything back so they're not continuously shoving stuff down the belt, while we wait for the forklift to come in take the pallet, so we can wrap it up. For this its a lot of communication and knowing what the other person's doing. Being aware of when the forklift is coming up, because they might come up right behind you and think that you know that they are coming. But you have ear stuff in. You can't necessarily hear them sometimes.&quot;</strong></td>
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<tr>
<td>Getting used to the work process</td>
<td>Quarry workers got used to operation and became less attentive to work hazards</td>
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<tr>
<td>&quot;just know their hand gestures. The other will walk you through every step of what they want to do and say stuff. Some don't actually do anything. They'll just grab a rock and shove it through. So the communication on that end needs to improve. Maybe have, since everything is loud, maybe have hand signals unless words are needed. &quot;</td>
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<td>&quot;If you don't open your mouth and speak it, there's never gonna be nothing done about it. You can't complain about it if you don't bring it up.&quot;</td>
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<tr>
<td>Limited visibility of surroundings</td>
<td>Quarry workers had barriers to fully observe and watch for people and</td>
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<tr>
<td>&quot;there's always three people that are on that breaker. And then they have to find the fourth person. The newest guy has been with them for a good couple weeks now and staying down there with them. &quot;</td>
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<tr>
<td>&quot;So sometimes you wanna move around, but then some people just like doing the same thing because that means they don't have to shift and go elsewhere. They know what they're doing and can just continue on with that and not have to worry about anything else. &quot;</td>
<td></td>
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<tr>
<td>&quot;Looking out for other people riding or driving equipment because sometimes</td>
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</tr>
<tr>
<td>Topic</td>
<td>Description</td>
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<td>------------------------------</td>
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<tr>
<td>Seam in a rock</td>
<td>Quarry workers explained unexpected accidents are usually caused by seam/crack in the rock that leads to a blast of rock fragments.</td>
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<tr>
<td>complicated operation</td>
<td>Quarry workers complained and noticed that some operations are complicated and confusing to use.</td>
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<tr>
<td>Safety Intervention</td>
<td>Quarry workers received safety training and inspection help themselves to recall and remind of work hazards.</td>
</tr>
<tr>
<td>MSHA training</td>
<td>MSHA inspected the quarry for different strategies for them to utilize in the operation and provided safety training.</td>
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<tr>
<td><strong>&quot;Refresher course at the quarry&quot;</strong></td>
<td>The quarry safety managers provided safety training for quarry workers to improve safety knowledge and prevent accidents</td>
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| Workers' demands to improve safety | Quarry workers desired to improve safety by | |
| Improving the Safety Training | different strategies from their perspective | "That's necessary down here. You're not going to understand something quite as well from a video or reading a PowerPoint on it, or something like that. You need to see it and be aware of what's happening, and experience it multiple times before you're comfortable. "
"Seeing the things that have happened to other people in other places, really stuck with me. We do safety here, we do safety training here. We today, we do every single year, we do an 8 hour training. It's normally the same training every year. You kinda, you know what you're getting into."

| Longer conveyor belt and rubber finish on the breaker | Quarry workers emphasized that safety training can be better improved and designed for quarry workers and their operation | "Now that it's on this rubber, it still shoots out sometimes, but you can see, you're got a 12 foot conveyor here that helps to stop."

<p>| Overcoming the side effects of wearing respirator | Quarry workers complained about discomfort by wearing respirator which were optional for the operators | &quot;You can't have facial hair or nothing. It's not going to work.&quot; |</p>
<table>
<thead>
<tr>
<th>Implementing advanced technology to the operation</th>
<th>Quarry workers suggest to implement advanced technology to reduce the exposure to work hazards</th>
<th>&quot;Most of the time, it's [breaker] already failed, by the time we get it in, and we just pick it up … unless they come up with a different way to hold a rod, then not really.&quot;</th>
</tr>
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</table>
| Critical acceptance                             | Quarry workers critically accepted unexpected hazards and coworkers that they were frustrated for not having to prevent them from accidents | "I know a lot of times if you think you can go in it, clean it, and get out of the way, yep, 9 times out of 10 nothing's ever gonna happen. But that one little 10% that you got there is when somebody's gonna get hurt. So we always try to make sure somebody's down to watch and make sure they lock it out..."
"You'll go get mashed fingers, you'll get pinched fingers. A lot of it is ... it's natural. A lot of it is the rock, you can't control when it flips up. It's gonna do |
<table>
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<tr>
<th>Acceptance for unpredictable hazards</th>
<th>Quarry workers accepted that unpredictable hazards exist at the quarry</th>
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"You can't ever prepare yourself enough to actually know the rock, it'll do what it wants to do. It can hit pallet, bounce one way and you're ready for it to bounce another way, and you're ready for it to bounce another way, and you've got your hand there or something like that. So, it's a lot. It's really hard to get the feel, I guess, for it. Safely, but it's that. I haven't been caught by it. It hasn't been as many people as you would think for a rock quarry, that get hurt."

"Cause once that guy goes into a cut, man, he can let off pretty quick. But the hydraulics, those hydraulics in there, they work as fast as your mind does. You can't fix that."

"You can't ever prepare yourself enough to actually know the rock, it'll do what it wants to do. It can hit pallet, bounce one way and you're ready for it to bounce another way, and you're ready for it to bounce another way, and you've got your hand there or something like that. So, it's a lot. It's really hard to get the feel, I guess, for it. Safely, but it's that. I haven't been caught by it. It hasn't been as many people as you would think for a rock quarry, that get hurt."
| Sense of frustration for unsafe behaviors of workers | Quarry workers expressed a sense of frustration for workers who perform unsafely | "You can't fix stupid. If you know what I mean, if somebody goes beyond this, they're asking to get hurt. "  
"You would think it would be common sense to stay away from a big moving blade like that, but you'd be surprised." |
| Sense of frustration for workers being careless | Quarry workers expressed a sense of frustration for workers being careless and lackadaisical about work hazards | "At the time, he was funnin' cause he didn't get hurt, I told him, I said, "Man, don't ever do that." But that's what I'm saying is them air hoses they gotta be coupled together."  
The guys will tell you I fuss at them. They may hate me for it, but myself included, I've gotten hurt before. Everybody does. I don't care what you do or how long you're at a place of business, you get lackadaisical about stuff. That's why we have safety people here to come in and remind us, including me."  
"I mean, they've done all they can do with it. Except about everything, I mean everything is ... it ain't nothing foolproof. " |
| Sense of frustration for workers not listening | Quarry workers expressed a sense of frustration for workers who do not like to listen to advices for safety | "I said, "Man, move. That's gonna fall on you." I don't wanna know what the hell, he looked at me like ... I'm not trying to be bossy. Dude, that's going to hurt. I mean, move that's going to hurt. That's going to fall on you. "I know what I'm doing," that kid. Sure enough, it fell over on his shin, scarred him all up. All I can do is say I told you so. That's a hard lesson to learn..."

"These guys, I don't know how many times we've told them, the bucket can only hold so much, and they overfill it. Dumping this more often would really help safety. The pieces of that could roll off the side. It might hit you in the leg, or something like that."

| Moderators to safety behavior | Quarry workers improved safety to meet the needs of community and satisfy safety managers | "We have a neighbor just right up above the hill. She does not like dust whatsoever. We bought it without the dust |

| Community Compliance with dust | Quarry workers tried to keep the dust down to comply with community request |

"We have a neighbor just right up above the hill. She does not like dust whatsoever. We bought it without the dust"
| Maintaining safety to satisfy the managers | Quarry workers maintained the safety to satisfy their safety managers | "We've busted like three windshields out of this thing, out of the Bobcat. Throw a rock off and a piece breaks off, most of the time it's gonna hit the windshield. Cat busts up them. And then [the site coordinator] is not happy." |
| Supervisors' intervention to unsafe operation | Quarry workers acted to maintain safety to avoid getting violation by safety manager | "he [the site coordinator] doesn't like us to wear shorts." |