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Safety Consideration in the Development of Improved Stone Jaw Crusher for Quarry Operations

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Abstract - There is need for safer design and development of stone jaw crusher taking with due consideration of the necessary safety and required improvement on the operation and maintenance of the machine. The study area were quarry industries in Akure, Ondo State, Nigeria, information gathered through structured interview, questionnaire and technical checklist revealed that severe injuries involving dust, noise, vibration account for more than 59% of all severe accident while 7% fatal injury for noise and 24% of dust were reported at Quarry operations in Akure, Ondo state respectively. Moreso, preventive and corrective maintenance culture were always employed in some of the visited quarry industry in order to prevent total breakdown of crushing machine. The results showed that most accident occurred due to the negligence and carelessness of operator, fall from heights, slips and trips, objects being ejected from crushers, injury by heavy physical and manual handling of heavy loads, accidents with electricity, defective toggle plate, excessive vibration and noise causing noise-induced hearing loss, dust causing chronic long lung disease such as asthmatic, accident due to entangling with unguarded machine part. This study established the hazards of the job and its safety consideration in the development of improved stone jaw crusher for quarry operation will in no small measure reduce the risk and improve the safety of both the workers and the machineries in the quarry industries. To decrease accidents further, researchers recommend additional efforts in the development of improved stone jaw crusher with new control technologies, training materials and dissemination of information on best practices.

Keywords: *Maintenancace practice; Questionnaire; Quarry industries, Mining industries, survey, Technical Checklist*

1. INTRODUCTION

Safety is a field of engineering that deal with accident prevention, risk of human error reduction and safety provided by the engineered systems and designs. Safety cannot be over-emphasized in engineering due to the role it plays in every home and industry, sudden unexpected dangerous occurrence do disrupt smooth operation of machine and may lead to hazards, danger or harm particularly accident, injury and death to personnel, other person and things around the operator while doing work. With the rapid industrialization, the use of stone jaw crusher in both Quarry and Mining industries which are rapidly growing in scale and

functionality, it has become more and more difficult to guarantee safety practices, thereby resulting into frequent accidents (Adebisi et-al 2007). Therefore, there is need for adequate consideration for safety in both design and development of crushing machine. The ultimate goal of safety is to prevent injury and ill-health in the workplace. Adequate workplace precautions must be provided and maintained to prevent harm to people at the point of risk (The Safety, Health and Welfare at Work Act 2005). Workplace precautions to match the hazards and risks are needed at each stage of business activity. The workplace precautions may include provisions such as machine guards, local exhaust ventilation, safety instructions and systems of work (N.Wagner, M.Nithiyananthan and L.Farina (eds) 2009). Stone crushing industry is an important industry sector in the country engaged in producing crushed stone of various sizes depending upon the requirement which act as raw material for various construction activities such as road construction, bridges, and highways among others. Researchers at the National Institute for Occupational Safety and Health (NIOSH) have been concerned with the interaction of workers and machinery and with the number of severe accidents classified as struck-by or caught-in (Burgess-Limerick & Steiner, 2006a; Ruff, 2007; Schiffbauer, 2005; Venem, Shutske, & Gilbert, 2006).

The stone crushing plant employs many people both skilled and unskilled who are involved in the entire process of mining, crushing and transportation of the crushed stone. The plant's ideal location is supposed to be near growing towns or cities so as to supply the demand for the stone and at the same time near the source to the stone to be crushed. The process involved in crushing large size stone boulders into different size of crushed stones depending upon the requirements in the demand sectors. The important stages involved in stone crushing activity are primary crushing, screening, secondary/ tertiary crusher, screening, conveyance, storage of raw boulders and crushed stone and transportation of both raw and crushed stones. The raw material i.e. raw stone boulders are obtained from mining of the stone from quarries and hand picking etc. Typical process of stone crusher is briefed as shown below:

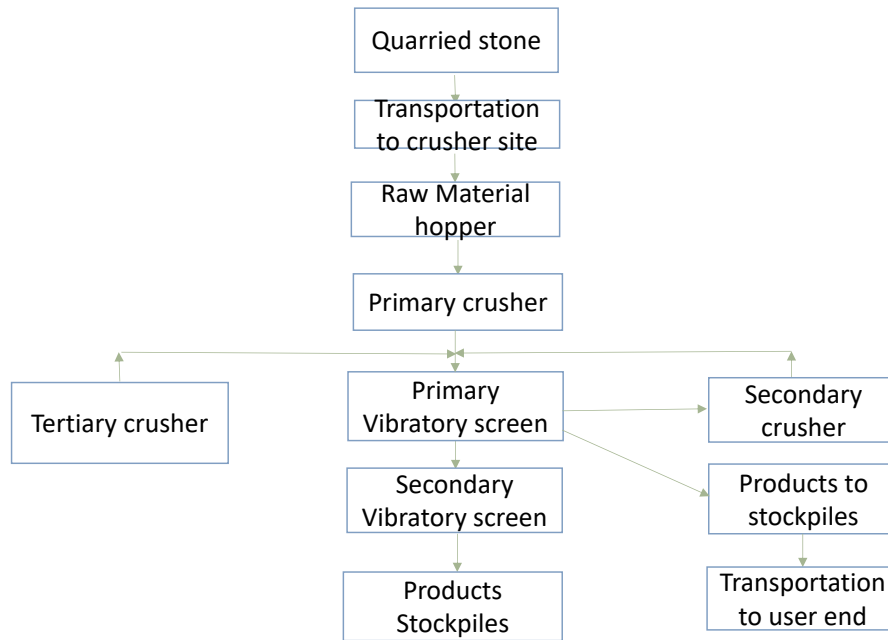


Figure 1: Typical process of stone crusher (10)

Typical Sizes of Stone Crushers

There are large variations in the types of stone crusher setup across the country depending on geographical locations, type of demand for crushed products, closeness to urban areas, type of raw material, availability of plant and machinery locally etc. Primarily the stone crusher industry sector could be divided in three categories small, medium and large. The typical characteristics of each category of stone crushers are briefly discussed below

Small size stone crushers	Typically the stone crushers with a production capacity ranging from 3 to 25 Tonnes Per Hour
Medium size stone crushers	Medium size stone crushers will have a production capacity in the range of 25 - 100 Tonnes Per Hour
Large stone crushers	Typically having two or more numbers each of primary, secondary and tertiary type crushers with at least two or more vibratory screens with mechanized loading, unloading conveying operations and producing more than 100 Tonnes Per Hour crushed stones.
Source: Comprehensive Industry Document Series: COINDS/78/2007-08 (CPCB)	

Table 1: The typical characteristics of each category of stone crusher

2. METHODOLOGY

In this report, accidents and possible injuries related to jaw stone crushers were investigated with the objective of suggesting risk management measures. Data on jaw stone crusher related injuries over a period of ten years were collected from five Quarry industries within Akure territory. This information was collected through:-

- i- Self administered questionnaire
- ii- Structured interview
- iii- Technical checklist

2.1 Self-administered Questionnaire

A questionnaire which has five sections with twenty-two questions was designed and administered to the visited quarry within Akure territory and was given to managers for distribution to employees, completed questionnaire were

returned. The questionnaire was designed to know the possible accidents associated with Jaw stone crusher, possible injuries and the remedies to these problems. Also, maintenance practices employed were investigated. The questionnaire section A contains demographic information of respondent, section B has operational information, section C consists of health and accidents related issues, section D has question on maintenance practice culture while section E is policy implication.

2.2 Structured Interviews

Interviews were conducted with varying responses from workers ranging from production manager to the operator. Interviews using mostly, open-ended questions allowed detailed and qualitative information were collected,

which supplemented and in some cases clarify data collected through questionnaire and technical checklist.

2.3 Technical checklist

A technical checklist was used to rate the Jaw crusher observed in the visited Quarry Sites. The checklists assessed were:

- (i) Machine and tool designed
- (ii) Machinery guarding
- (iii) Personal Protective Equipment
- (iv) Site environment
- (v) Machine Installation

2.4 Data analysis

Statistical techniques were employed to analyze collected data in order to obtain answer to the questions. The data collected was statistically analysed from the questionnaire which was administered from the quarry site, and their maintenance practices cultures were also looked into and investigated for better optimal performance. The data analyzed will help the best practices that will lead to superior performance, that will improve safer operation of quarry industries. Internal analysis was conducted to identify areas for improvement, the goal of internal analysis is to identify weaknesses that need improvement in the quarry industries.

4. RESULTS AND DISCUSSION

4.1 Operational Information

The daily working hour of operating the crushing machine by the operators per day as analyzed in the data collected was found to be eight hours, this eight hours of working introduced by the management will reduce over-

working of operators. Moreover, it will increase the lifespan of the machine and improved its working efficiency, since it was not over-used for long period of hours. Stating further in the interview conducted that weekend half working hours is mainly meant for servicing and maintenance of their various equipment and each parts of crushing machine for its smooth and better working condition.

4.2 Data Analysis provided on the usage of PPE for each operators working on jaw crushing machine

Based on the result of interviews and administered questionnaire conducted for every operators working in the visited quarry industry, It was observed that personal protective equipment was always provided for all and sundry working in quarry site which reduced level of hazard and injury to be contacted during the operation of crushing materials. The data collected which was represented in pie chart below show that 93% operators were always provided with effective PPE that implied that the quarries management were seriously working to improve the safety and reduce the level of accident / injury on daily basis. As PPE serves as a barrier between the hazard and the workers, if the barrier fails there is no back up and the worker is directly exposed to the hazard. When PPE is provided the employer must ensure that workers are wearing the equipment properly at all times, this can be accomplished through routine inspections throughout the yard. Appropriate training on how to wear PPE is needed for all workers and management. Here are the stated list of PPE claimed by the operators that they were being provided for by the management.

- (a) Face mask
- (b) Safety boot
- (c) Safety goggles
- (d) Hand glove
- (e) Nose cover / protective respirator
- (f) Helmet
- (g) Apron

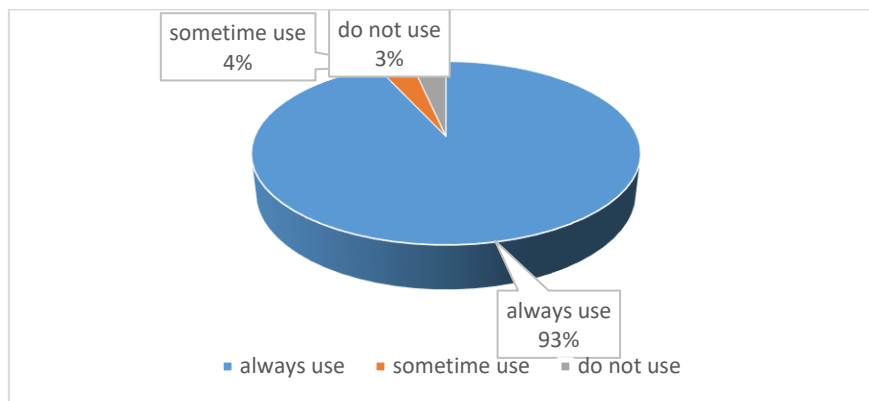


Figure 2: Percentage of Data on Effective usage of PPE

4.3 Number of accidents related issues on jaw crushing machine

Out of the total returned questionnaire (41%) of the responses revealed that they had experienced one injury or the other while (59%) claimed that they had seen someone else injured. There were differences in the way these questions were answered, because some viewed some injuries as minor compared to others and therefore chose not to account for such.

4.4 Nature of the injuries reported on the jaw crushing machine

Through the oral interviews and the self-administered questionnaire, it was reported that the major level of injury on the use of jaw crusher machine was a serious / fatal one which affected part of the body, which was most of the time happened as a result of negligent of operators. Some of the part of the body affected as claimed by respondents were as following, eye blind caused by dust, hand amputation, finger amputation, noise-induced hearing loss, cancer of the lung caused by inhaling of dust and musculoskeletal disorder

(MSDs) caused by vibration and it could sometime lead to death immediately its happened

4.5 Effects of Vibration, Noise and Dust on operators

All the respondents reported that there were effect of vibration, noise and dust on the operators and people working close within the environment of the crusher. The major effect of vibration is musculoskeletal disorders (MSDs) which were injuries and pain in the body joints, ligaments, muscles injury, nerve injury and tendon injury, inflammatory conditions that could cause impair normal activities, this is in line with Canada Centre for Occupational Health and Safety (2014):"Work-Related Musculoskeletal Disorder" available at www.ccohs.ca/oshanswers/diseases/rmirsi.html. For effect of noise, the exposure to noise and noise-induced hearing loss continues to be problematic for the operators. The major effect of dust in the quarry industry is that it causes chronic lung diseases such as chronic obstructive (asthmatic)

bronchitis or silica-related lung scaring (silicosis) which is in conformity with the work of Wagner, et.al (eds) (2009) "Safety and Health in the stone crushing industry". Thus, the analysis of the useful copies of questionnaire received were presented on the effect of vibration, noise and dust. Figure 3. shows the percentage effect of vibration on different accident categories. Forty-one (41) percent of the respondents reported that they have experienced minor injury as a result of accident caused by vibration, fifty-nine (59) percent reported that they have experienced serious injury due to vibration accident and none reported fatal injury. In principle, the safety measures put in place for the workers can only prevent them from fatal injury, meaning that, they are still being exposed to minor and serious injuries. Plate A gives the full insight on the operator, operating the crushing machine in an unsafe working condition thereby exposing to vibration and dust pollution effect.



Plate A: Jaw Crusher with Operator

Figure 4 shows the percentage of effect of noise on different categories. Thirty-four (34) percent of the respondents reported that they have experienced minor injury base on the accident caused by noise, fifty-nine (59) percent respondents reported that they have experienced serious injury as a result of accident caused by noise and seven (7) percent of respondents reported that they have experienced fatal injury on the use of crusher. This shows that PPE has not been frequently used as it was expected to be used. Figure 5 buttress on the percentage of effect of dust on different categories. Twenty-one (21) percent of the respondents

reported that they have experienced minor injury caused by dust, fifty-five (55) percent of operator reported that they have experienced serious injury as a result of accident caused by dust, twenty-four (24) percent reported that they have experienced fatal injury based on the accident caused by dust. Meaning that, the operators are directly exposed to dust pollution which study shows that the safety put in place was not effectively working, thereby there must be re-designed of machine by the introduction of engineering dust control system in order to curtain the fatal effect of dust injury on the part of the body of operators and management.

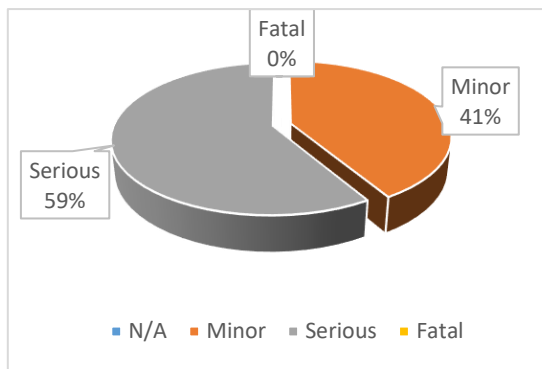


Figure 3: Percentage effect of vibration

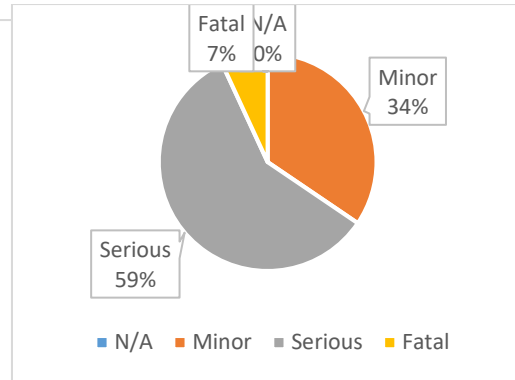


Figure 4: Percentage of effect of noise

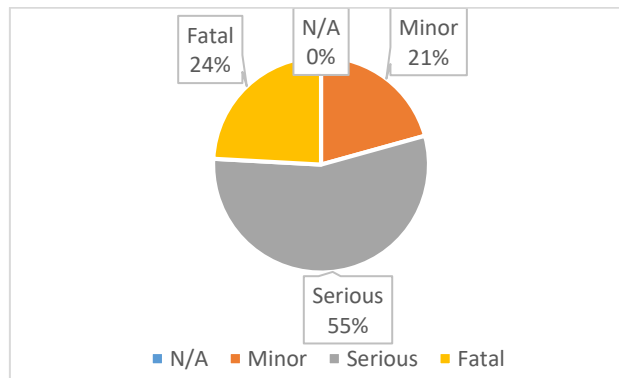


Figure 5: Percentage of effect of dust on different accident categories

4.6 Source of Accidents on the jaw stone crusher machine

Analysis of the data showed that accident often occur due to negligent of operator of not observing the laid down safety procedures which eventually caused accident and injuries to the operator. The source of accidents/ Injuries analyze in the report of questionnaire were as following:

1. Accident from operating unguarded rotating machine parts
2. Accident results from inhaling dust coming out from crushing materials
3. Accident due to electric shock
- 4 Accident experience from vibration effect while operating the jaw crusher machine
- 5 Accident from inability to make available appropriate PPE, thereby directly expose to hazard

4.7 Maintenance Culture Practice

The maintenance culture practice system in the quarry industry was necessary to be done in order to improve the mechanical equipment which are daily in use for more efficiency performance and to prevent its total breakdown in service. The maintenance culture practice for about ten years

was analyzed in the visited quarries, it was reported in the interview conducted that preventive and corrective maintenance culture were often in used in the maintenance operation of the quarry which have prevented total breakdown of operation but there is more to be done in term of getting needed wear parts which needed total replacement in the machine. They claimed further that they were being confronted with the problem of non-availability of parts in the market, delay in the shipment of the equipment parts from the source country were some of the problems encounter in the maintenance practice culture. Machines used beyond their working limits or used inappropriately are more likely to develop fault which may affect the occurrence of accidents. It was also reported that when low grade machine parts are used to replace worn out ones, such results into faulty machine operation which often caused accident in the usage of the machine. The industry which use adequate machine parts and does not work the machines beyond their limit tend to have low injury frequency. The data analyze below present the types of maintenance strategy put in place for use in the maintenance culture practice as gathered in administered questionnaire.

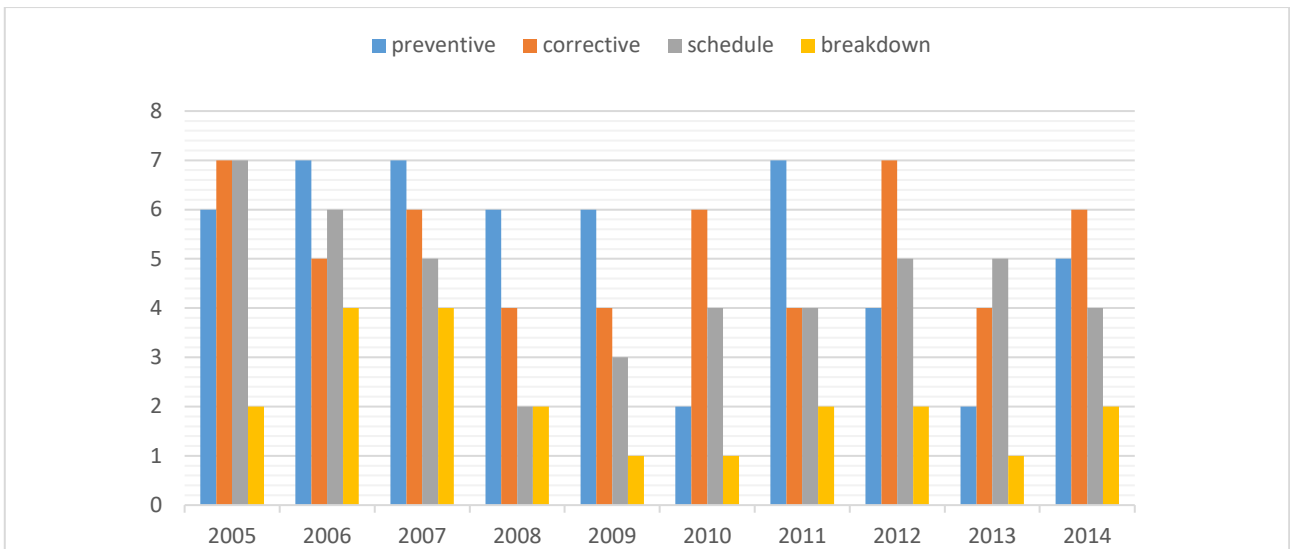


Figure 6: Data analysis for types of maintenance strategy used for maintaining crushing machine.

4.8 Machine Design

The large portion of machines observed were poorly designed. There is need for proper re-designing of the machine by incorporating a new safety devices gadget into the system such as sensor to alert in case of operator getting nearer to the hazardous area, protection of transmission parts which will guide the moving parts that is dangerous to be getting near to. It was suggested in the administered questionnaire that erecting a barrier between the operator and the crushing machine will effectively reduced and minimized the level of hazard and incident of injuries on the daily usage

of the machine in quarry industry. Moreover, dust generated in quarry industry pose a threat to all the personnel working in the industry, there is need to urgently control the effect of dust by re-design the machine using engineering dust control system e.g. water spray control system to reduce the effect of dust. The attributes rated for machine design are as follows:

1. Exposed rotating parts (shaft, transmission belt wheel etc.)
2. Operator being standing on the crusher platform operating the machine which pose a threat to his health by directly exposed to vibration effect.
3. Poorly located emergency stop
4. Existence of traps (between parts)

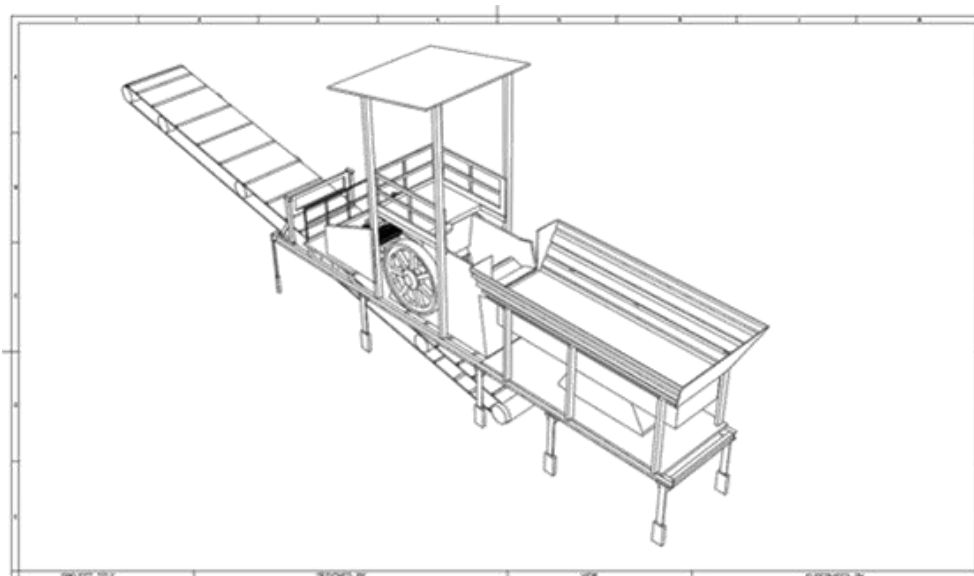


Plate B: Engineering detail drawing of stone jaw crusher

5. RECOMMENDATIONS

1. Jaw stone crusher machine should not be installed in the wind-blowing direction in order to reduce and minimize the effect of dust in the industries.
2. There should be a barriers between the machine and operators, this will thereby eliminate the hazard in which operators are frequently known to be exposed to
3. Innovative sensors to detect the presence of workers near hazardous components should be incorporated to the machine
4. Emphasis on safety interventions and training should be directed towards conveyor systems, especially for tasks associated with machine maintenance, repair or clean-up
5. Provision of machine guard to the rotating shaft and transmission parts to the machine, this will prevent operators having direct contact with those unsafe machine parts.
6. The use of "lock-out-tag out" (LOTO) systems for safe locking of power sources so that no one can accidentally switch on the machine while others are working on it.
7. To install Earth Leakage Circuit Breakers (ELCB) in all circuits to protect the operators from electrical hazard.
8. Inexperience personnel should not be allowed to operate any machine.
9. Correct maintenance practice and strict adherence not beyond the machine capacity should be ensured.

6. CONCLUSIONS

1. Pressure of work on operators and inadequate safety awareness programme by the management influences the continued unsafe working conditions
2. Maintenance culture in quarry industry is still not very adequate in the country with increase in maintenance, repair or clean-up, level of workplace environment will be made safer
3. Non-adherence to the safety regulations and installation of the machines to the direction of wind-blowing is one important factor responsible for the unsafe condition in workplace
4. Old crushing machine whose design still poses safety threats are in use and therefore, create an unsafe environment in the workplace.
5. Non-availability of equipment part due to the delay in shipment plan will cause long break down of the machine thereby reducing the working efficiency of the operation of the quarry industry.

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