MAJOR PROJECT REPORT

ON

HAZARD IDENTIFICATION AND RISK ASSESSMENT OF A CONSTRUCTION PROJECT

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Submitted by

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DECLARATION

I, Sadique Hassan, Roll No. 2K20/ENE/08 student of M. Tech (Environmental Engineering), hereby declare that the project Dissertation titled "Hazard Identification and Risk Assessment of a Construction Project" which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of and Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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ABSTRACT

Any industry's performance is determined on how they detect hazards, analyse the risks associated with them, and reduce them. that associated risk to a tolerable level which can either be further brought down or it is so low that it can be ignored. If we talk about the construction industry in particular, it involves various procedural activities and complexity of the system and machinery involved always have some amount of the Hazard associated with it. Of all the occupational accidents happening in India, the construction industry alone constitutes about 24% of the total fatality (Patel & Jha, 2016). Therefore, the EHS leader should fully understand Zero Harm Vision's philosophy and encourage others to behave safely and respect the environment. Must be able to identify the link between excellent safety and good business operations, as well as be up to date on industry standards. They must be able to communicate and display leadership at all levels of the organisation, as well as be committed to taking action at all times.

First element for observing safety at site begins with good leadership and commitment leaders must encourage and demonstrate safety commitment, excellence and leadership by example. The second factor is risk control. Firstly, identification of risk takes place such as, working on height, vehicles, plants and machinery, tunnel, excavation, form-work, lifting operation, working in confined spaces, electrical work, working near public places and hot work. The third factor is setting goals and objectives that must be measurable, achievable, and appropriate and must be timely. The fourth aspect is training and skills that include assessment of training needs and periodic training for all employees. Toolbox speaks to be done to create awareness about the safety procedure and to discuss strategies to avoid incidents and follow safe practices. Stakeholder engagement is the fifth and final elements. The sixth step is inspection, followed by internal and external audits in addition to that there's also a monthly safety meeting, a safety notice board, and a newsletter. The final elements is the review and modification of existing control measures for better sand safe workplace.

Risk management has many stages namely Classification of work activities involving hazard, Identification of hazard in each activity, Identification of Risk, Assessment of Risk, Control measures, Elimination of Risk by redesign/ change or process, Control measures- use of Personal Protective Equipment (PPE) and Monitoring. There is a hierarchy of control measures adopted i.e. the process of elimination, substitution, followed by engineering and administrative control and at last Personal protective equipment. As the part of this project, Hazard Identification and Risk assessment of process involved in the building construction project of S-Block Delhi High Court have been carried out. Then to calculate the risk rating based on the semi quantitative risk matrix, and to compare the risk rating before and after applying the control measures. Then a statistical analysis was carried out to determine the effectiveness of the control measures implemented.

Hazard identification and risk assessment may be used to set priorities so that the most dangerous scenarios are handled first, followed by those that are less likely to occur and create severe issues. In this study Hazard Identification and Risk Assessment Process was carried out and it was found that out of total identified hazards, 39% were of high risks, 53% of the hazards were of moderate risk rating whereas, critical risk was about 2%. And after applying the control measures, these risks were significantly brought down to moderate and low risks. For this study actual site observation was collected along with the indicators (Leading & Lagging), work force engagement by communicating with them about their work environment and soliciting their feedback on potential health risks, working hours, and other potential dangers. Reviewing of documents such as the first aid report, safety observation, checklist for work permit, site audit reports, Department Procedure Manual (DPM), Work Instruction, and laid out Standard Operating Procedure (SOP) and comparing it with the field practice.

Keywords: *Construction Project, Environment Health and Safety (EHS), Hazard Identification and Risk Assessment (HIRA), matrix method*

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ABBREVEATIONS

ALARP	As low as reasonably practicable
BOCW	Building and other Construction Workers
DPM	Department Procedural Manual
EHS	Environment Health and Safety
ETA	Event Tree Analysis
FMEA	Failure Modes and Effects Analysis
FMECA	Failure mode effects and criticality analysis
FTA	Fault Tree Analysis
HAZOP	Hazard and Operability Analysis
HIRA	Hazard Identification and Risk Assessment
HIRAC	Hazard Identification, Risk Assessment and Control
HSE	Health Safety and Environment
ICT	Information and communication technology
ILO	International Labour Organisation
MSDS	Material Safety Data Sheet
OSH	Occupational Safety and Health
PPE	Personal protective equipment
RASH	Risk Assessment of Safety and Health
SOP	Standard Operating Procedure

CHAPTER 1
INTRODUCTION

1.1 Background

Real estate and infrastructure construction make up the construction sector, which accounts for around 9% of India's GDP. It employs more over 51 million people, making it the second-largest employer after agriculture. By 2025, India is predicted to overtake China as the world's third largest building market (Sethi, 2022). Of all the occupational accidents happening in India, the construction industry alone constitutes about 24% of the total fatality reported (Patel & Jha, 2016). To be successful, any industry must fulfil not just its production needs, also it must also fulfil the safety compliances and standards for all the stakeholders involved. On a constant basis, the industry must discover hazards, analyse related risks, and reduce risks to a bearable level. The method of Risk assessment is a way of systematically identifying and analysing the dangers connected with a particular activity and assigning a risk rating to each hazard. Because the risks cannot be totally removed, it is necessary to identify and assess an accident risk level that may be given quantitatively or qualitatively.

The existing hazards in the construction industry and the magnitude and the complexity of processes and equipment involved, hazards are likely to be there and cannot be naturally safe. There will always be the possibility of major mishaps, irrespective of how properly the machinery or processes are designed. It is commonly acknowledged in the industry that various risk assessment approaches help significantly to improving the safety of complex processes and equipment. In many sectors, risk assessments of all hazardous equipment, machinery, and activities are required by law, taking into consideration the processes for operation, maintenance, monitoring, and management. Hazard Identification and Risk Analysis HIRA is the process of identifying the unsafe events that causes hazards, and to analyse the process by which the unsafe event occurs and the estimation of the consequences and the likelihood of the undesirable effect.

There are many standards and rules regarding the occupational safety and health management at workplace such as ILO-OSH, ISO:45001:2018, IMS and BOCW Act, 1996 which created an impact and helped in creating the awareness regarding the occupational safety and health and hygiene. The guidelines emphasise continuous development of the organization's safety standards. However, despite all of these efforts, safety standards have not improved as projected in recent years (Sousa et al., 2014a). The negative impact of not controlling these risk causes work days lost, loss of lives, severe injury and also negatively impact on the financial perspective.

On comparing, the construction industry with other sectors with respect to the occupational safety and health, it is three time riskier than any other industry(Arewa & Farrell, 2012). There are three broad categories in which the risk associated with the construction industry is mainly categorised(Zalk & Heussen, 2011). The risk involved are mainly chemical risks due to prolonged exposure to welding fumes, toxic gases, solvents etc, whereas the physical risk is caused to workers because of heat, noise working at height, on or under unstable structure, due to electric shock because of coming in contact with live wires or energized sources. Also, mechanical risk is due to handling the equipment carelessly, during lifting operations etc. and environmental risk is due to the excess of noise or discharge of untreated waste directly or by excessive dust or fume causing air quality to deteriorate. As a result, a risk management method is required that can handle both safety and environmental and quality concerns.

The most difficult task for a low-income country like India is ensuring that occupational health and safety standards are properly implemented. Given the dynamic nature of building projects, training all personnel is a key priority. Most workers have received training in a certain sector, but the nature of construction projects forces individuals to perform tasks in which they are not trained and may or may not have little expertise. As a result, choosing a construction company's attitude to occupational health and safety is critical. The process of HIRA is to detect and assess hazards, as well as the activity processes that lead to hazards and the risk of hazardous occurrences. A number of approaches, ranging from simple qualitative processes to advanced quantitative procedures, are available to help detect and analyse threats. Use of multiple hazard analysis strategies are advised since each technique has its own set of advantages and disadvantages. The FMEA, HAZOP, ETA, and other risk assessment approaches are only a few examples. The utility of each above-mentioned hazard identification technique depends upon the situation and the industry is employed. For a construction process since the process is very dynamic in nature, site observation by walking around or by taking the survey results.

1.2 Risk

Risk is the chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard. When a person is exposed to a danger, there is a risk or likelihood that he or she may be injured or suffer an undesirable health outcome. The consequences of risk is not just limited to human health it may also cause the loss of equipment or it may have harmful effect on the environment. Risk in general is the function of likelihood of occurrence of the accident and the severity of the harm caused.

1.3 Incident

An unplanned or unintended workplace related occurrence that caused, or had the potential to cause injury, illness, property and/or material damage or loss. Typical example is; Unsafe conditions or behaviour, Near misses, Injuries, illness, fatalities, Damage to equipment, product, Spills and releases etc. However, the terms accident, incident, near miss and safety observation are often confused with each other, Accident is an unexpected event which results in serious injury to or illness of an employee and may also result in property damage. Incident is an instance of something happening, an unexpected event or occurrence that doesn't result in serious injury or illness but may result in property damage. Near Miss is an "active" circumstance i.e. an event and fortunately does not result in an injury. In workplaces, near miss situations are common occurrences though they are often ignored. However, near misses can be looked on as a free lesson to learn how to prevent accidents from occurring.

Safety Observation is a "passive" circumstance, i.e. there is a situation, behaviour, condition that could potentially result in an incident. There are a large number of metrices that can be tracked to provide management with an accurate assessment of how an organization is doing with respect to safety. Lagging Indicators are the indicators that are passive in nature and are used as a safety observation such as number of incidents and injuries, incident rate, Total lost workdays, employee survey results. Whereas, Leading indicators are the root-cause analysis, percentage of workers with safety training completed, and number of safety inspections completed.

1.4 Some commonly used terminologies associated with Hazard Identification & Risk Assessment

The following are some of the key terms involved with hazard identification and risk assessment.

a) Harm**:** Illness or physical injury or any kind of deterioration to health of peoples either directly or indirectly and consequently result of damage to property or to the environment.

b) Hazard: A hazard is a source of possible injury or negative health effects on a person or people. A hazard is a circumstance that provides a risk to people's lives, property, or the environment. Most risks remain latent, with merely a theoretical chance of injury, but when they become active, they can cause an emergency(www.hsa.ie).

c) Hazardous situation: A situation in which a person is put in danger or exposed to a hazard.

d) Hazardous event: It is defined as a situation which ultimately results in harm is called as a hazardous event.

e) Accident: An unforeseen event that causes significant injury or sickness to an employee, as well as possible environmental or cause property damage.

f) Incident: An unplanned or unintended workplace-related occurrence that caused, or had the potential to cause injury, illness, property and/or material damage or loss.

g) Near Miss: An "active" circumstance, i.e. an event takes place and fortunately does not result in an injury. Near misses are prevalent in the workplace, however they are frequently overlooked. Near misses, on the other hand, might be viewed as a free education in how to avoid mishaps.

h) Safety Observation: Safety observation is defined as the behaviour or situation that could possibly result in the occurrence of incident. It is passive in nature.

i) Lagging indicators: Lagging indicators measure the occurrence and frequency of events that occurred in the past, such as the number or rate of injuries, illnesses, and fatalities. Some of the lagging indicators are, Number of incidents and injuries, Incident rates, Total lost workdays, Employee Satisfaction survey results

j) Leading indicators: These indicators are used to track events that lead to injuries, illnesses, and other accidents, as well as to identify possible issues with your safety and health programme. Good leading indicators are: Specific, Measurable, Accountable, Reasonable and Timely. Hazard observations, root-cause analysis, percentage of workers with accomplished safety training, number of conducted safety inspections, and so on are some examples of leading indicators (Sheehan et al., 2016).

k) Risk: The most often used definition of risk in regard to occupational safety and health is "risk is the possibility that a person may be hurt or experience unfavourable health consequences if exposed to a danger." (www.hsa.ie). In other words, Risk refers to a hazard's potential or likelihood of causing harm to a person, property, or the environment. The severity of possible harm to a person or the environment, as well as other criteria such as the number of persons exposed, determine the extent of the risk. A hazard is anything that has the potential to cause harm, but a danger is something which might cause severe harm (bluerisk website).

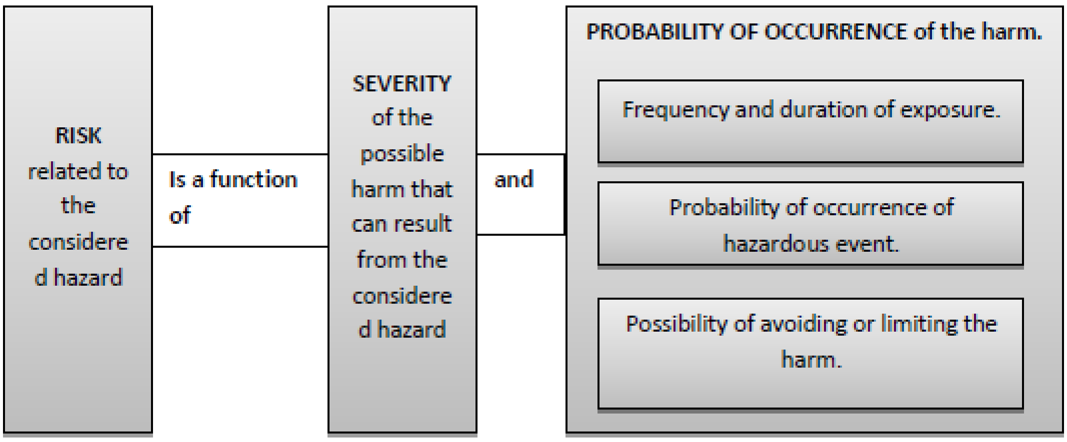


Fig 1.1 The Definition of Risk (Sahu, 2010)

l) Acceptable Risk: The phrase "acceptable risk" refers to the possibility of an event occurring with such a low probability of occurrence and little repercussions that groups and individuals in society are prepared to take or be exposed to the risk of the event occurring.

m) Protective measure: The combination of risk reduction strategies taken to achieve at least the tolerable risk. Protective measures include risk reduction by inherent safety, protective devices, and personal protective equipment, information for use and installation and training.

n) Personal protective equipment (PPE): It refers to the protective gear worn by employees to keep them safe from environmental hazards. The main function forming a barrier in between possible hazardous substance and the healthcare worker, PPE prevents the worker from coming into contact with a hazardous agent or piece of equipment, significantly reducing the chance of damage or disease. Respirators, gloves, safety shoes and ear protection are examples of PPE used in the workplace, based on its specification and use.

Table 1.1 IS Codes for PPEs

IS Codes	**Description**
IS:1197-1967	Equipment for eye and face protection during welding
IS:1989-1986(Part I & II)	Leather safety bots and shoes.
IS:2925-1984	Industrial Safety Helmets
IS: 3521-1983	Industrial safety belts and harness
IS: 3738-1975	Rubber Knee boots
IS: 4770-1968	Rubber Gloves for electrical purposes
IS: 5983-1978	Eye Protection
IS:6994-1973 (Part I)	Industrial Safety Gloves
IS: 9623 - 1980	Recommendation for the selection, use and maintenance of respiratory protective devices

o) Severity: The extent of the damage to the institution, its people, and its goals and objectives resulting from a risk event occurring. In terms of occupational safety, it is used for the degree of injury/illness due to any Hazard.

1.5 Different Forms of Injury

- Serious Injury is defined as any injury which results in the permanent deformity to body parts or permanent loss of any section of body or resulting in permanent loss of sight, hearing is categorised in the serious injury.
- Reportable Injury are those injuries other than serious injury which requires and enforced absence of the person that is injured from the work site for a period up to 3 days or more.

Minor Injury means any injury which results in enforced absence from work of the person exceeding 24hrs and less than 72 hours.

1.6 Hazard Identification Techniques

It's critical to use the best identification approach since it not only gives the right amount of information, but it can also be used to pinpoint threats in specific regions. When selecting a method, there are several aspects to consider. Many strategies have identical goals and, when used appropriately, should provide similar outcomes. Hazard identification procedures are organised approaches for recognising fault situations that contribute to hazards and reducing the risk of missing potentially dangerous occurrences. All of these need a great deal of knowledge and experience. Some of the Hazard Identification Techniques are listed below.

1.6. 1 Hazard and Operability Analysis (HAZOP)

HAZOP (Hazard and Operability Analysis) is a systematic research that uses a comprehensive approach to evaluate the safety and operability of complicated process equipment or the manufacturing process. The HAZOP method further The HAZOP method further uses: Systematic technique to evaluating safety and operability, highlighting any deviations from the safe situation, During the creative construction of the envisaged scenario of events, arising from a departure from the safe situation, the principle of brainstorming is applied, the reason for possible deviation from the standard procedure is to be identified followed by speculating probable consequences (Kotek & Tabas, 2012). Following steps are the part of discussion of the HAZOP team;

Fig. 1.2 Steps of HAZOP

1.6.2 Failure Mode and Effect Analysis (FMEA)

The main goal with regards to an FMEA process is to find possible cases of hazards in a process by looking at the probable modes of failure for each component of the process. Due to the complicated interplay of the failures, FMEA has trouble detecting risks that need the failure of more than one process component. During the assessment, the following stages are carried out:

- Describe the system. The process must first be described in depth for that reason it may be subdivided into a logical, hierarchical, or reliability block diagram. Establish the basic principles and purposes of the study
- Carry out the study. Firstly, all objects in the different systems or subsystems created by the graphical breakup of the process should be recognised. After that, a list of all conceivable failure modes for these objects should be compiled.
- Report the results.

1.6.3 Fault Tree Analysis (FTA)

A fault tree analysis (FTA) is a problem-solving technique for identifying the source of any occurrence of accident, near-misses, safety observation failure or any kind of damage or unintended loss. It's a visual representation of the routes that begins at the top and leads to a predicted and unwanted loss occurrence. To estimate the probability and prevent the predictable and unwanted outcome, the probability of such an event occurring can be entered and propagated using an FTA model (Khan & Husain, 2001)

1.6.4 Event Tree Analysis (ETA)

Event tree analysis (ETA) considers the possible events that lead to the event. It has a multi-purpose usage, it can be utilised in the field of risk management, quality control management, etc. It is an analytical approach that illustrates all possible outcomes from an accidental (initiating) incident, considering established safety barriers, as well as other events and causes. Examining all important unexpected occurrences (which has already been identified by the primary hazard that have been identified by a preliminary hazard investigation, a HAZOP, or any other method). In a complicated system, the ETA may be used to identify all possible accident situations and sequences also, design and procedural problems, as well as the possibility of various consequences from an unintended occurrence, can all be identified.

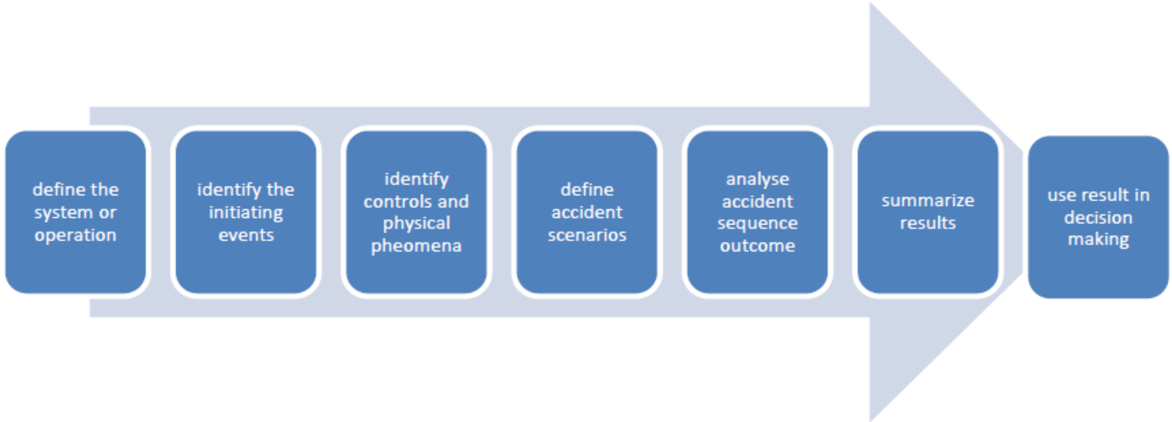


Fig. 1.3 Procedure of ETA

1.6.5 Failure Mode Effect and Critical Analysis (FMECA)

This method of Hazard identification follows the same process as FMEA, however there are two extra procedures to complete.

- Assess the severity of the failure's consequences. The degree of the failure is often defined as ranging from total loss of capability with death to minor influence on success with no casualties.
- Determine how frequently the failure's consequence occurs. Examining prior data for similar processes to the one under discussion, running under similar conditions, is the simplest way for determining occurrence frequency. Additional variables can be employed to translate frequencies from unconnected processes if no adequate data is available.

1.7 Risk Assessment

One of the components of the whole process is risk assessment which involves the following three tiers;

- Preliminary Site Examination,
- Detailed Site Evaluation,
- Priority Site Investigations and Recommendations.

The existing site conditions and the level of the exposure to the people in the surroundings are the two fundamental criteria that are to be taken in account for all above three tiers of site evaluation

The mechanism for assessing risk is chosen at this step. The magnitude of the risk's impact on activities, as well as the likelihood of occurrence, are determined at this level. When deciding on the consequences of any event and the likelihood of its recurrence, the current countermeasure to reduce risk might be considered. A single risk might have many effects on several occurrences. In the course of this stage, the degree of risk of any specific activity is determined, and appropriate steps is undertaken to keep the risk under the allowable limits, so that the risk is kept as low as reasonably practicable. Risk analysis is used to predict any undesirable occurrence, estimate the damage potential of such circumstances, aid in decision-making in such situations, and assess the effectiveness of control measures.

1.8 Methods of Risk Assessment

The method of risk assessment can be broadly divided into three categories namely qualitative, semi-quantitative, quantitative.

1.8.1 Qualitative Method

Qualitative risk analysis is a method of measuring or scoring risk based on a person's assessment of the severity and likelihood of its consequences. The aim of qualitative risk assessment is to come up with a suitable list of hazards that must take precedence over others. It uses the parameters of likelihood/probability and the severity of the hazard. This method of risk assessment can even be referred to as the first line of defence for the project manager. By concentrating on the most dangerous dangers first, project managers may better organise their time and resources. It aids in the elimination of potential project detractors, such as dangers that are unlikely to do significant harm to the project.

1.8.2 Semi Quantitative Method

To circumvent some of the drawbacks associated with qualitative risk assessment, semi-quantitative methodologies are now commonly adopted. Qualitative risk assessments produce a more detailed priority ranking of risks, whereas semi-quantitative risk assessments produce a more detailed prioritized ranking of hazards. Semi-quantitative risk assessment goes one step farther than qualitative risk assessment by assigning values or multipliers to the likelihood and outcome groups. Multiplication of frequency levels with a numerical rating of consequence may be used in semi-quantitative risk assessment approaches. There are several scale combinations that can be used.

The matrix of fig 1.3 shows that, risk occurrence that is both possible (probability level = 0.01) and likely to have a large impact (consequence level = 1000) has a risk level of 10. If the concerns were equivalent, this occurrence would carry the same risk as another that was more often (0.1) but had less severe (100) repercussions. It demonstrates that the risk ratings have been weighted in this example to emphasise higher-consequence occurrences. This is commonly done to show a company's reduced tolerance for higher-impact incidents. This step can be difficult to justify, and it might be deceptive by exaggerating some risk events.

		Consequence Level				
		1	2	3	4	5
Likelihood level	Descriptor	Insignificant	Minor	Moderate	Major	Catastrophic
1	Almost Certain	1	10	100	1000	10000
0.1	Likely	0.1	1	10	100	1000
0.01	Possible	0.01	0.1	1	10	100
0.001	Unlikely	0.001	0.01	0.1	1	10
0.0001	Rare	0.0001	0.001	0.01	0.1	1

RISK RATING
EXTREME
HIGH
MODERATE
LOW

Fig. 1.4 Basic Semi-quantitative Risk Rating Matrix (Sahu, 2010)

1.8.3 Quantitative methods

The method of estimating risk using data is known as quantitative risk analysis. In addition to estimation of risk, this method of further analyses how much the risk's impact will cost the company. The goal of quantitative risk analysis is to further specify how much will the impact of the risk cost the business. This is accomplished by predicting or estimating a result based on what is previously known. Data must have been analysed over a lengthy period of time or seen in various circumstances to be eligible for quantitative risk analysis. Quantitative risk assessment is being increasingly employed in the mining and minerals sector because it helps decision makers understand business requirements to support financial choices, collating financial risks equitably to environmental and social hazards, and the process should be transparent, consistent, and logical.

Estimates of consequence can be established using any reliable metric chosen based on the application's nature. The risk quotient is used to establish the priority and distinguish between risk events by on a comparative basis adopting a standardised risk assessment and identifying the events that pose the greatest threat. The risk quotient is equal to the generally used expressions 'anticipated cost' or 'expected value' when the implications are represented in financial terms. Additional outputs of quantitative risk assessment that are used to develop and support risk management strategies show profiles of event likelihoods and cost-benefit relationships (progressive costs to implement a risk management strategy versus reduction in risk or reduction in the estimated future cost of risk events). Fully quantitative risk assessment is not very useful for environmental impact study type risk assessments, where there are many diverse environmental and social issues that need to be evaluated and their risk communicated to the community and other stakeholders.

1.9 Need for Risk Assessment

The modern topic of environment, health, and safety was born out of industrial disasters and growing public awareness of risks to the natural environment and human health. In the construction project, risk was classified into critical, high, medium, and low risk levels using risk assessments. It is used in the assessment of risk as a decision-making tool by understanding the hazard and integrating evaluations of likelihood and severity to create an estimate of risk. This will assist to prioritise risks and offer information on the possibility of harm emerging and degree of harm. Safety officers and engineers at construction site will be able to adopt safety enhancements in this manner. To make a construction site a safe and better workplace appropriate step will be taken.

The goal of a Hazard Identification and Risk Assessment (HIRA) study is to guarantee that there is a structured procedure for hazard identification, risk assessment, and control to successfully manage dangers that may arise in the workplace. This project work has been undertaken keeping in mind the aforementioned problems in the construction industry related to occupational safety and health with the following objectives. Literature review on the topic of Hazard Identification and Risk Assessment. Study of Risk Assessment Methodologies. Listing of all possible Hazards for different activity related to construction project. All of the findings are analysed, and recommendations for improving safety standards are made.

CHAPTER 2
REVIEW OF LITERATURE

A hazard is "an inherent physical or chemical characteristic that has the potential for causing harm to people, property, or the environment," whereas risk is usually defined as the combination of the severity and probability of an event (Macdonald & Mackay, 2004) . "Hazardous process" means any process or activity in relation to an industry specified in the First Schedule where, unless special care is taken, raw materials used therein or the intermediate or finished products, by-products, wastes, or effluents thereof would, cause material impairment to the health of the persons engaged in or connected therewith, or result in the pollution of the general environment (*India. The Factories Act.*, 2022). Hazard identification means the identification of undesired events that lead to the materialization of the hazard and the mechanism by which those undesired events could occur (Malaysia, 2008).

(Khan & Abbasi, 1999) studied the optimal risk analysis (ORA), and the ORA study covered the following points: Identifying and screening potential hazards. Consequence analysis, which includes creating accident scenarios and estimating damage potential. Hazard analysis based on qualitative hazard assessment and operability research (optHAZOP). Modified fault tree analysis for probabilistic hazard assessment (MFTA). In the work of (Haslam et al., 2005) he conducted the accident studies and collected qualitative information on the cause of each incidents. Method of Data collection included interviews with the personnel involved in accident and their supervisors. He concluded in his study that, Levels of involvement of key factors in the accidents were 70% of accidents problems arising from workers or the work team, 49% accidents was due to problem in worksite. 56 % accidents were due to inadequate usage of PPEs at the site, it was observed that 27% of the accidents were due to poor condition of material and their suitability and 84% of the reported injuries and deficiencies with risk management.

The limitations of simple risk matrix was discussed by (Anthony TonyCox, 2008) The results of the study reveal, the limitations of mathematical properties of risk matrices and shows that they have the following limitations. Likelihood and severity are the two inputs of the risk matrices and it is based on the subjective interpretation, and the same quantitative dangers may be rated differently by various people. Because of these flaws, risk matrices should only be used with caution and only when embedded judgments are fully disclosed. The analysis done by (El-Sayegh, 2008) carried out detailed study and analysed the construction industry in the UAE. He analysed that the primary risks in the UAE construction business are assessed and analysed in this study, and how they must be handled. For the building industry in the UAE, created a likelihood impact matrix. According to the study, the responsibility for construction-related accidents should be subcontractor.

The analysis done by (Zeng et al., 2008), it was examined that, In the construction business, OHS management systems and OHSAS 18001 are being implemented. He performed survey questionnaires and interviews. Based on data from registered accidents from building operations over the last three years, the construction sector's OHS status is deemed to be unsatisfactory. To make the process simpler, the OHSAS 18001 standard is being integrated with the ISO 9001 quality management system. Integrated management system might save resource inputs and eliminate redundancy on basis of the conformance of ISO 9001 and OHSAS 18001.The study in 2008 (Zayed et al., 2008) used the risk index model to assess the effect of the sources of the risk and its uncertainty on a construction project. According to the findings of the study, risk connected with the project may be measured in three steps: I Risk identification: Risk identification is the initial stage in the risk management process. (ii) Risk assessment: risk and uncertainty evaluation assess the significance of risk sources, their likelihood, and their impact. (iii) Risk mitigation: risk mitigation is a strategy for reducing or eliminating vulnerabilities.

(Wilkerson & Wilkerson, 2008) results of the study revealed that the computation of the mean of a collection of data in a sample used for an observational study is part of statistical analysis. Hypothesis testing is a technique for drawing conclusions about a population under investigation. It is assumed that the mean will be equal to zero in the null hypothesis (Wilkerson & Wilkerson, 2008). When two sets of data are being observed, the paired t-test is employed as a sort of hypothesis testing. Because each value from the first sample is paired with a value from the second, the data in a paired t-test are dependent. The difference between the means of two data sets is the parameter utilised to construct the inference.

(Zalk et al., 2011) Concluded that, construction employs around 7% to 10% of the worldwide workforce. However, the industry is responsible for 30 to 40% of all occupational fatalities globally: at least 60,000 each year. The dangers are comparable across the world, and many of them are safety-related. This toolbox design concept incorporates worldwide input on diverse ways for conducting a qualitative risk assessment and generating a risk 'band' for a specific requirement as per the project. Risk-bands have been used to identify the appropriate level of training for supervising construction projects, as well as the appropriate control mechanisms to guarantee that the job is executed safely. The study done by (Karimiazari et al., 2011) to find out the appropriate model for risk assessment using a Fuzzy TOPSIS and uses the Nominal Group Technique (NGT) for the decision criteria. Since Risk assessment is an important step in risk management. Despite the fact that many academics and researchers recognise the necessity of risk assessment models in projects, researchers have paid little attention to choosing the right model for the study. Unclear and inaccurate data and the frequency of involvement of numerous people influences this dilemma.

(Yoon et al., 2013) The results of this study reveal, between 2006 and 2011, there was a 67 percent drop in accident rates and a 10.3 percent reduction in fatal accidents among the top 100 construction companies in South Korea because of the introduction of Occupational Health and Safety Management System. According to the study results, site general managers and OHS managers have varying levels of OHSMS awareness. The variations were in the motivation for establishing OHSMS, the external assistance required for implementation, and the issues and efficacy of OHSMS implementation. In this study, it was discovered that introducing OHSMS dramatically lowered both work-related and fatal accident rates. A study was conducted to determine the variations in OHSMS understanding amongst site general managers and OHS managers. Further study with good data collecting is needed to determine the impact of these changes on safety as well as other advantages.

The results of the study carried out by (Sousa et al., 2014) revealed that, plenty of the activities established during the execution stage of building projects are potentially risky environments with a range of dangers to personnel's safety and health. Considering the fact that the current study focuses on the execution stage, the design stage also offers substantial potential to control occupational safety and health risk in practise. 60 percent of fatal construction accidents might be avoided in the European Union (EU) if proper procedures were defined during the design stage and building sites were planned and organised properly. Produced statistically meaningful findings at the execution stage for design parameters related to occupational safety and health, demonstrating that occupational accident control must commence in the design phase with designers and contractors.

The analysis done by (Al-Anbari et al., 2015) in the year 2015 used the RASH (Risk Assessment of Safety and Health) approach for building construction was established. Risk was categorised into two parts: health and safety. It is statistically acceptable and has double the accuracy of typical risk assessment methods. Risk Assessment of Safety and Health (RASH) approach for building construction was created in this study, with hazards categorised as Safety Risks and Health Risks. Based on a field survey in Oman, 11 indicators indicating safety concerns and 8 factors reflecting health risks were found. In the study carried out by (Choudhry et al., n.d.) he carried out extensive literature survey and had concluded in the study that, Safety climate surveys, peer observations, and system audits/inspections might all be used to analyse employee views, safety behaviours, and environmental or situational aspects, respectively. Unsafe behaviour is the major cause of any unsafe act or unsafe condition and about 80% accidents are due to this reason.

(Abd El-Karim et al., 2017) in his study concluded that, construction project risk variables have been discovered. He divided safety risk factors into five categories and assigned a severity rating from very high to very low to each. The level is extremely high for fatalities, very high for serious injury, moderate for medical care, low for first-aid, and very low for no injury effect. All parties engaged in a construction project, including the owner, contractor, and subcontractor, need to save money and get things done on schedule. Delays and inability to finish work within the agreed cost and time period are the most common reasons of construction project disputes. The project duration of a project is important to both the owner and the contractor in terms of cost.

The study in 2018 by (Purohit et al., 2018) on the basis of extensive literature survey determined the goal of a Hazard Identification and Risk (HIRA) study is to guarantee that there is a structured procedure for hazard identification, risk assessment, and control to successfully manage dangers that may arise in the workplace. Comprehending the hazards and integrating probability and severity to create a risk assessment, this is used as a help in the assessment of risk and also help in decision making to prioritise risks and offer information on the possibility of harm emerging and degree of harm. Individual risks are defined as "the likelihood of an individual bearing a given amount of hostility as a result of the materialisation of a certain danger." "The link between the frequency and the quantity of persons vulnerable to a given level of aggressiveness as a result of the materialisation of a certain hazard" is how societal hazards are defined. Individual and societal risks must be managed, and every effort should be made to reach a risk level that is as low as reasonably practicable (*Reducing Risks, HSE's Decision-Making Process Protecting People*, n.d.). In the study done by (Frank et al., 2008) analysed eight case studies and risks were identified and structured into standard format for their simple review and used basic risk management techniques to conduct a risk assessment They employed schematic analysis, risk assessment, and filtering as basic techniques. Fault Tree analysis, hazard and operability analysis, failure mode effect analysis was used as an advanced tool, and also produced a severity classification table that classifies consequence severity into noticeable, important, serious, extremely serious, and catastrophic categories.

Along with causing harm to human health due to illness or injury hazards identified during construction project can also cause harm to the environment. Therefore, continuous monitoring of air, water, noise along with waste management is the integral part of this study. Structures which are still not past their design life and are in good serviceability condition, in order to create more room to fulfil the present needs, these structures are demolished which created a huge amount of construction and demolition (C&D) waste. The biggest challenge lies in the safe disposal of these waste in a sustainable manner (Bansal & Singh, 2007). Similarly, disposal of untreated waste directly into water bodies degrade the water quality parameter. Due to the escalating pollution load, the water quality parameters worsened and this problem is a global concern (Singh, 2017).

There is need for improvement and adoption of emerging technologies in the construction space. For that the author (Rui et al., 2022) used Inferential analysis and relative importance index were used to achieve the research objectives. The findings from this research showed that project characteristics would influence the adoption of emerging technology for construction safety and the economic factor is the most influential barrier to adopting emerging technologies for construction safety

CHAPTER 3
MATERIALS AND METHODOLOGY

Before the implementation of the control measures risk analysis is used to determine the chances of the workers being subjected to an accident or illness at workplace, which could be a result of any situation uncovered during hazard assessment process. When a person is exposed to a potentially dangerous circumstance, they are at risk. The possibility that exposure to a danger may result in an accident or a health problem is known as risk. It is a statistic to measure the possibility of severity of an injury. Analysis of risk is an important part of the disaster management planning cycle because it determines which disaster mitigation strategy should be adopted to prevent future losses. Any endeavour to mitigate the effects of a disaster necessitates an assessment of the hazards that exist, their predicted severity, who or what they may affect, and why. The activities we can take to lower their risk are determined by our understanding of what makes one individual or group more susceptible than another, as well as the means and capacities available. Risk assessment is a sequence of interconnected actions that result in a picture of the dangers and vulnerabilities that cause disasters.

3.1 Hazard Identification and Risk Assessment Process

Steps Following are the different steps of risk assessment procedure to be followed while carrying out the HIRA process are as follows

3.1.1 Hazard Identification

All work activities in various departments were thoroughly evaluated in order to identify all potential dangers involved in the nature of job or workplace. To identify occupational dangers, the following strategies were used:

- Inspection at the workplace by walking around the area of work.
- Including the employees in the discussion related to the environment of workplace, daily working hours and the disasters noticed by them.
- Examining the Department Procedure Manual (DPM), Work Procedures, and Standard Operating Procedures (SOP) and comparing them to existing process.
- Going over past Incident Reports.

- Examining Material Safety Data Sheet (MSDS).
- Evaluating the records regarding first aid injury/losses.
    - Examining an employee's medical records.

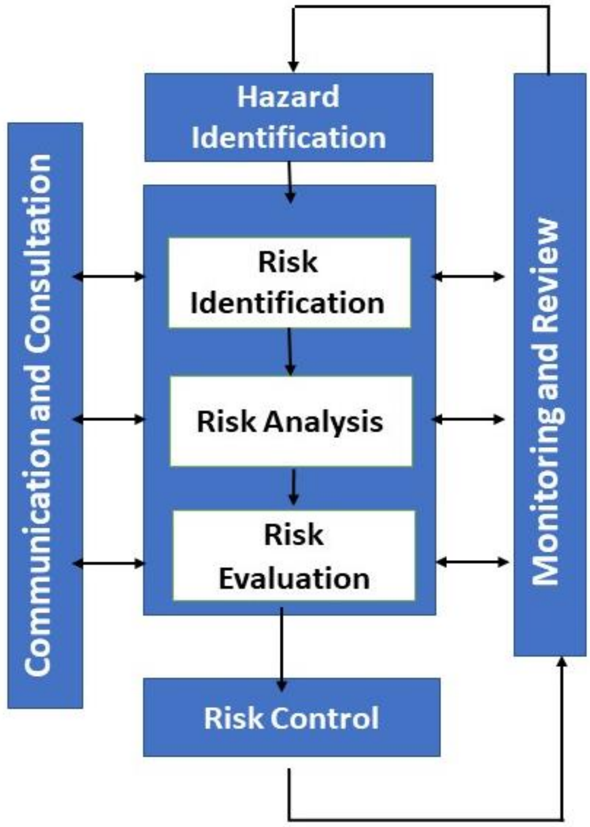


Fig.3.1 Flow chart of Risk Management Process

3.1.2 Identification of Risk

When the Identification of Hazards are complete then next step is to determine the risk associated with the identified hazards, which may be done by reviewing previous incident reports, injury data records/First Aid, reviewing Material Safety Data Sheets, and reviewing all employees' health records.

3.1.3 Assessment of Risk

Based on the identification of the hazard and its potential risks, the risk is assessed using two parameters: likelihood and severity. The likelihood reflects the probability that the damage will occur, while the severity describes the seriousness of the injury/illness.

The risk assessment will consist of a list of current risk management measures, determining the possibility of occurrence (probability), analysing the possible severity of potential dangers, environmental elements, and determining the risk / level of impact based on the likelihood and severity. For each of the Safety & Health danger, Environmental aspect, the availability of existing control mechanisms must first be established, and the risk / impact level can then be determined by examining the efficiency of the current controls and the implications of their failure.

3.1.3.1 Likelihood

The likelihood of an incident occurring is classified in Table 3.1. It refers to the likelihood of the consequences.

Table 3.1 Description of Probability

Likelihood (L)	Value	How Likely are the Consequences?
Certain to Occur	**5**	Expected to occur in most circumstances
Very Likely	**4**	Will Probably occur in most circumstances
Possible	**3**	Might occur occasionally
Unlikely	**2**	Could happen some time
Rare	**1**	May happen only in exceptional circumstances

3.1.3.2 Severity

The degree of damage that can be produced by risks or the environment element as a result of an event is referred to as severity. The severity of the situation is determined by the table below.

Table 3.2 Description of Severity

Severity	Value	How Severely could someone be hurt?
Catastrophic	**5**	Death or permanent disability
Major	**4**	Serious injury, hospital treatment required
Moderate	**3**	Injury requiring medical treatment and some lost time.
Minor	**2**	Minor injury. First aid only required
Insignificant	**1**	Injuries requiring no treatment or first aid

3.1.4 Matrix for Risk Assessment

When performing a comprehensive risk assessment, the probability matrix method is a popular tool for assessing risk severity, and it may be used to analyse risks at all levels of the organisation. The probability matrix is a valuable tool for evaluating and grading the potential impact of different dangers. This enables businesses to not only better determine the general severity of a risk, but also to define the primary contributing factors for each risk.
The impact level can be calculated by picking the relevant row for Likelihood and the proper column for severity; the intersecting cell is the Impact/Risk level. (Rout & Sikdar, 2017).

Table 3.3 Matrix for Risk Assessment

		Likelihood (L)				
		Rare (1)	**Unlikely (2)**	**Possible (3)**	**Very Likely (4)**	**Certain to Occur (5)**
Severity	**Catastrophic (5)**	Moderate	Moderate	High	Critical	Critical
	Major (4)	Low	Moderate	High	High	Critical
	Moderate (3)	Low	Moderate	Moderate	High	High
	Minor (2)	Low	Low	Moderate	Moderate	Moderate
	Insignificant (1)	Low	Low	Low	Low	Moderate

3.1.5 Risk Control

After the assessment of the risk, we can prioritize the hazard with the highest risk rating so that they can be treated first. Therefore, in this step we have to adopt, identify and continually improve on all the types of safe practicable measures for removing and to lowering the likelihood of the injury/illness in the workplace. Controls should be chosen to lower the impact level to an acceptable impact limit based on the risk / impact level identified. To achieve this, reduction in the Likelihood and/or Severity is done.

Table 3.4 Rating of risk

Risk Rating (L x S)	Risk Rating
1 to 4	Low Risk
5 to 10	Moderate
11 to 18	High
19 to 25	Critical

Consider risk minimization according to the above hierarchical control while establishing measures or contemplating adjustments to current controls.

Table 3.5 Control measures based on risk rating

Risk Rating	Description	Action
1 to 4	Low Risk	It could be deemed acceptable, and further reduction may not be required. Control measures should be implemented and recorded if the risk can be managed swiftly and efficiently.
5 to 10	Moderate	Identification and management of hazard control, including the use of interim measures if necessary. The actions taken, as well as the date for completion, must be documented on the risk assessment.
11 to 18	High	The actions done, as well as the completion date, must be indicated on the risk assessment form and action must be taken right away to control the risk, as outlined in the hierarchy of risk control.
19 to 25	Critical	The actions done must be documented on the risk assessment form, together with the date when it was completed.

After identifying the risk control measures we have to Implement those risk controls. Hazard identified during the previous steps are tackled in order of the following precedence. Given in the fig. 3.2 as hierarchy of control,

Following is the list of the control measures form most effective to least effective,

a) Risk elimination
b) Safer alternatives to hazard detected.
c) Application of engineering tools
d) Implement administrative safeguards like safety procedures.
e) Administering personal protective tools, protecting the area from unforeseen dangers.

Controls must be implemented by a specific person and on a specific date for each metric. This guarantees that all necessary safety precautions are taken.

3.1.6 Residual Risks

The remaining risks that the proposed measures are unable to adequately eradicate or mitigate are referred to as residual risks. It must be verified that any remaining risks or consequences are certain to happen and manageable.

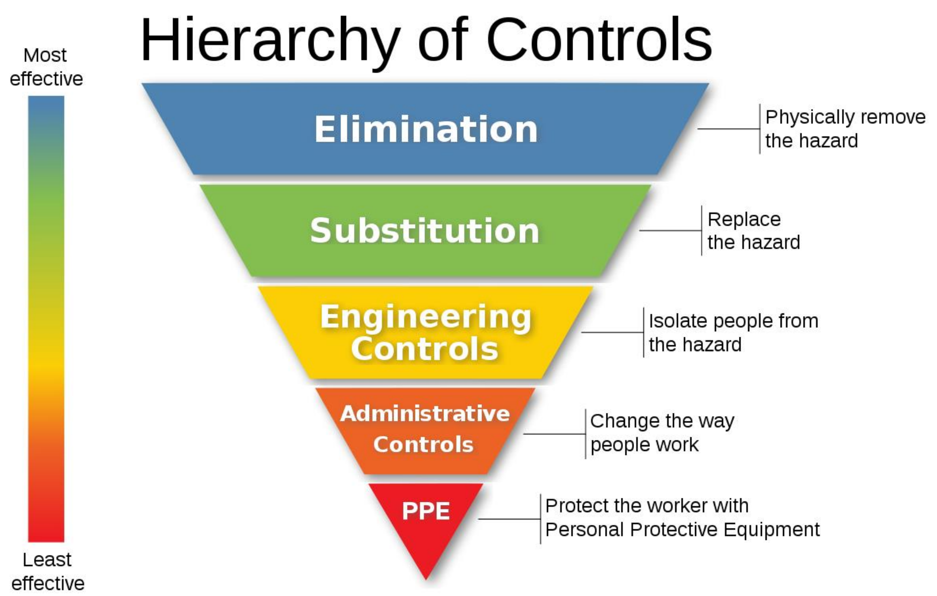


Fig 3.2: Hierarchy of controls
("Hierarchy of Controls", 2022)

3.1.7 Monitoring and Review

The process of Hazard Identification and risk assessment is continuous process and for its continual improvement we have to regularly review its effectiveness and control measures. At a typical construction project, Safety engineer in charge is responsible for the timely inspection and will perform frequent inspections to ensure that the procedures outlined in the Safe Work Method Statement are being followed. The risk management system of EHS is assessed on a regular basis, taking into account field audit findings, incident reports, and project comments. The EHS Risk Assessment must be updated on a regular basis.

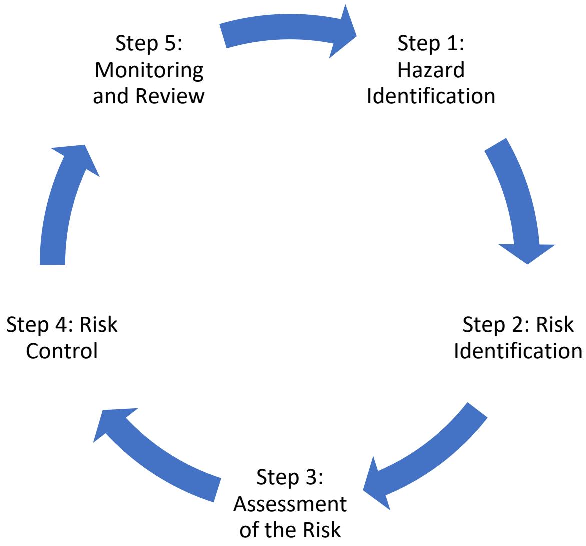


Fig. 3.3 Steps involved in risk assessment procedure

3.2 Statistical Analysis

To determine whether the mean difference between two sets of observations is zero, the dependent sample t-test, also known as the paired sample t-test, is performed. Using the method each entity is measured twice, that results in pairs of observations.

The paired sample t-test is commonly used in case-control studies and repetitive designs. Assume you're evaluating the effectiveness of a company's training programme. To compare the performance of a set of employees in the beginning and at the end of the program, paired sample t-test can be used. The paired t-test is employed in this scenario to assess and compare the risk levels of the risks before and after control measures are implemented (*T-Test,* 2022).

Assume variables x and y denoting Risk Rating before control measure and Risk Rating after control measure, respectively.

For testing the null hypothesis for the true mean difference to be zero, the following procedure is followed:

1.Evaluate the difference between the two observations on each pair by using equation (1), assuring positive and negative differences are clearly differentiated.

$$d_i = y_i - x_i \quad (1)$$

2.The mean difference, $\overline{d}$ is being calculated after the calculation of d_i

3. Compute the standard deviation of the differences, s_d .

4. Using the standard deviation, calculate the standard error of the mean difference, by using equation (2).

$$\text{SE}(\overline{d}) = \frac{s_d}{\sqrt{n}} \quad (2)$$

6. The t-statistic is being calculated, by using equation (3). This statistic follows a t-distribution with degrees of freedom n-1, under the null hypothesis.

$$T = \frac{\overline{d}}{\text{SE}(\overline{d})} \quad (3)$$

7. Tables of the t-distribution, are used for the comparison of values from T to t_n−1 distribution, resulting in p-value for the paired t-test.

3.3 Study Area

- **Location:** Dr Zakir Hussain Marg, New Delhi, Delhi 110003
- **Description:** The S-Block of Delhi High court is situated on Dr. Zakir Hussain Marg, in Delhi. The building is part of the expansion plan of the court to fulfil the requirements to provide prompt redressal to the need of the population. The project consists of two buildings namely, main block and ancillary block. The main block has 7 floors with three basements. For parking facility. The total built up area for the main block is 17250 sqm. Ancillary block on the other hand is four storied building to support the working of court in the main block. The total built up area of this building is 1650 sqm. This building is situated in the heart of Delhi. The project is used as out data source of this study.
- **Latitude longitude:** 28.6090ºN, 77.2361ºE
- **Map:**

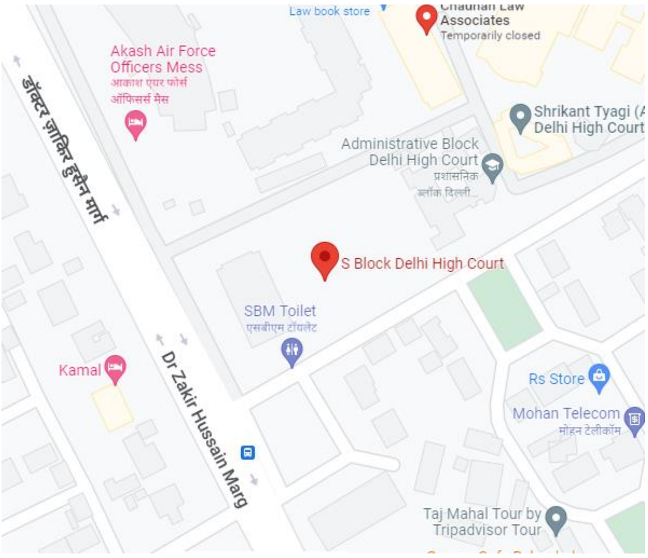


Fig. 3.4 Location of the site

3.4 Project highlights

- Name/ Identity of the project: Delhi High Court S-Block Project
- Client: CPWD Delhi
- Architect/Consultants: TCS Architects
- Contractor: M/s Swadeshi Civil Infrastructure Pvt. Ltd.
- Contract Type: Build Lump sum
- Duration: 3 years
- Value: 403 Cr

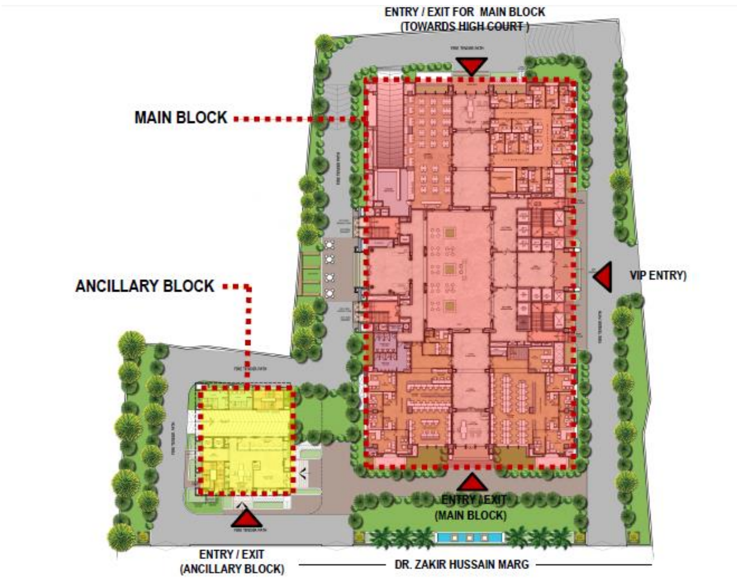


Fig. 3.5 Site Plan of the construction Site
(Source TCS Architect)

Fig. 3.6 Architectural Preview of the project
(Source TCS Architects)

3.5 Step by step of construction of Delhi High Court S-Block Project

The process started with the team making and placing the layout, then all the preliminary studies were carried out to ascertain the conditions before the actual process begins. After that Earth Retaining Structure were built to provide the lateral support to the soil and structures adjacent to our construction. Earth Retaining structures like Diaphragm wall and soldier piles were constructed in our project. A wall, that is continuous in type, serving as a retaining wall and a support for the subsurface construction, to support various construction activities and building projects such as dams, tunnel approaches, deep basements, and enclosures, is known as a Diaphragm wall. Diaphragm wall is an RCC structure where in-situ construction is done, panel by panel. Because the wall is normally constructed to reach significant depths, up to 50 metres, a technical excavation approach using a grab machine is used. The following sequence of work is followed to construct a diaphragm wall:

- Construction of the guide wall
- To design and form the diaphragm wall trench, excavation is done
- Bentonite slurry is used to support the trench cutting
- Reinforcement of the inert and placing of concrete is done to form the wall panel.

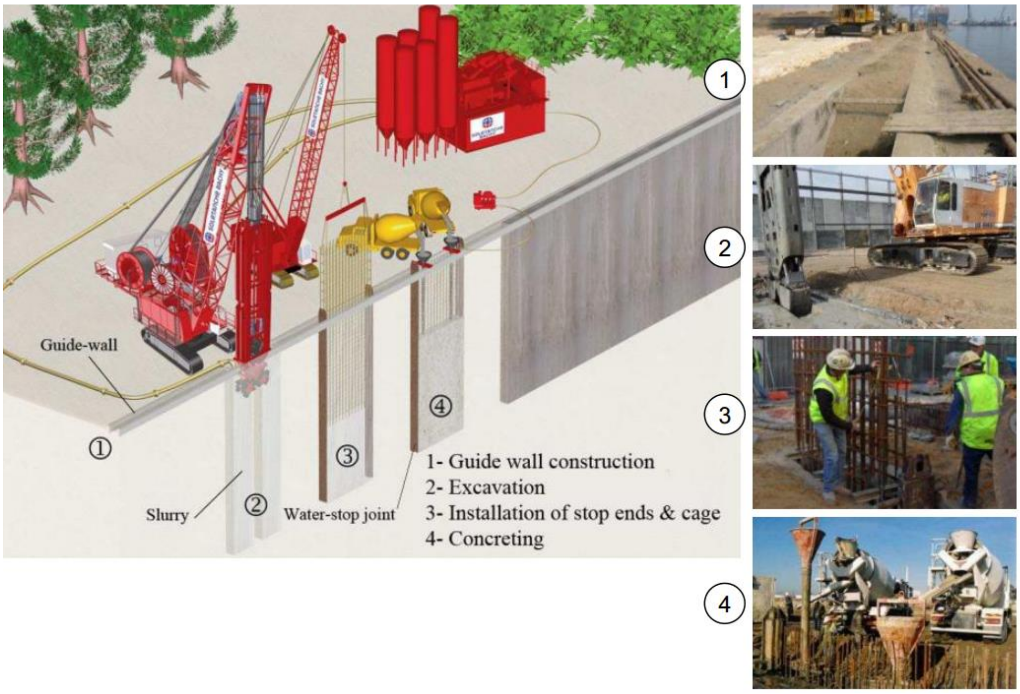


Fig. 3.7 Step by step construction of Diaphragm wall

Source ("What is a diaphragm wall or slurry wall? – Istasazeh Engineering Co", 2022)

After the construction of Diaphragm wall, excavation process begins it is carried out in the step wise fashion of 1.2 m at a time with the help of plant. Dumper trucks, which are meant to transport large-capacity goods over longer distances, used on/off site. The capacity of the dumper trucks varies from 5 to 15 m3, with some going up to 50 m3 or more. Backhoes are used for excavation below ground level. The bucket is inclined upwards to contain the loads and acts downwards to drag towards the machine. Backhoes are mostly used for trench or open excavation in large scale, but they can also be employed as loading machines. Waterlogging can also be a concern if the foundation is built below the subsurface water level. As a result, dewatering the excavation area is required to be done frequently. Several operations, such as laying bed concrete, laying RCC raft slabs, and masonry construction, must be completed within the excavation. After finishing the excavation, PCC layer is done and water proofing is done to the base of the soil. A raft foundation is being constructed, after following the above process. The following are the main phases in constructing a raft foundation.

- Determination of the depth, at which foundation will be applied.
- Excavation of the soil according to the required depth where the earth should be compacted. Using a waterproofing membrane.
- Application of a layer of planar cement-and-sand paste of 3 inches.
- Keeping reinforcement using spacers so that the desired gap is maintained

Vertical soil anchors are also included to keep the raft in place and give lateral support. Pour concrete until it reaches the specified depth. Curing will take place over a set length of time. Next step is to construct the superstructure as per the plan, the column reinforcement and the beam, slab reinforcement are provided and concreting is done as per the required grade and proper curing is done. Follow the same process till be attain the height as required and de-shuttering is carried out as the concrete gains enough strength as per the standards of the IS Codes. During all these processes welding, cutting, power tool operations etc were employed. After the superstructure was ready then the job of finishing as per the drawing. Which include brick work, electric work, paint job, water supply and plumbing pipe network, fittings, lifting operations etc are done simultaneously.

CHAPTER-4

RESULTS AND DISCUSSION

4.1 Overview

In this study, hazards were identified by the method of the walking around the site taking observations to inspect what is in the general construction area, involvement and knowing the perception of the employees regarding their worksite safety and the possible hazards they witnessed while carrying out activities. Studying and reviewing the standard operating procedure and procedural manual and comparing it with the regular practice. The data source of this assessment is the construction project of S-Block, High Court Building, situated at Delhi. Total of 56 hazards were identified for this project. The evaluation was processed in a tabular form (Table 4.1). The first column of the article is the activity which contains the major activity associated with our study project. The next columns denote the hazards associated, the risk involved with each hazard, the people at risk. Next column is the Existing control measures as per the standards, Additional control measures were also suggested for better control and reduction of risks. There is a column for assessment, in which Risk Rating is calculated. Risk rating is the function of likelihood of occurrence of that hazard and severity of the injury resulting from the hazard. Risk rating is the function of both likelihood of the occurrence of the hazard, and the severity of the hazard. After the application of control measures residual risk ratings are calculated which is also used to make the risk matrix after applying control measures (Fig. 3.2)

Moderate, High and critical can be identified from (Table 4.1). When the risk is above the tolerable level, control measures are taken to decrease it to a tolerable level if not eliminate it completely. As per the Hierarchy of control (Fig. 3.2) the risk can be completely eliminated if the source of that risk is removed from the site, but most of the times this solution is not feasible. Therefore, the presence of hazard in the system under consideration that can cause a risk with a risk rating beyond the acceptable limit and has the potential to cause injury or damage Therefore, if there is a risk in the system under consideration that creates a risk with a higher risk than is acceptable and it is assumed that it will cause injury or damage eventually, appropriate risk reduction measures should be taken (BOCW, 1996). To bring down the Risk rating to Low and Moderate level.

Table 4.1 Hazard Identification Risk Assessment and control table for S-Block, High Court

Activity	Hazard	Risk Involved	People at Risk	Existing Control Measures	Assessment			Additional Control Measures	Re-Assessment		
					L	S	Risk Rating		L	S	Residual Risk
WORKING AT HEIGHT	1.Falling from Height	Injury, Broken Bones, Serious Injury	Site workers and site staff, Visitors	1. For every work involving employees or items that might fall more than two metres, the contractor must conduct risk assessments. Work permit must be issued whenever work at height is to be undertaken. 2. When working at a height more than 2m Edge protection must be provided to stop materials and worker falling with the following guidelines; a) Guardrail 10m above the edge b) minimum 200m high toe board c) If gap more than 470mm intermediate guard rail provided. d) Rebar shall not be used as edge protection only standard pipes should be used.	3	3	9	1. Warning Sign in Local Language can be placed. 2. The Contractor shall provide and maintain safety net system in compliance to BS EN / IS Standards to catch persons falling during working at height. 2. The pipes shall be painted in reflective paints.	1	3	3

	2. Material Falling from height	Injury, Head Injury, Fatality	Site Workers, Site staff	1. Particular care must be taken while operating above places with public access, such as highways, walkways, and so on, to ensure that no items fall from the working area. 2. Edge protection to be provided as required 3. Construction safety net to be installed where ever required	2	4	8	Maintain current control.	1	4	4
	3. Risk of using Scaffolds	Injury, Severe Injury	Site Workers	1. Scaffold have a height and width ratio of at least 4:1 2. Mobile scaffolds are used on a firm and level surface. 3. All the materials stored on the platforms are properly secured. 4. Openings in working platform are safely covered/fenced. 5. For suspend scaffold, Harness is anchored to an overhead structure and not to the scaffold 6. All braces, clamps are secured, all sections pinned or appropriately secured 7. Guard rails provided	3	4	12	1. Scaffold meets electrical safety clearance distance (Ref. Procedure) 2. Scaffolds are inspected once in a week and also after prolonged interruption in the work	1	4	4

				between 0.9m and 1.2m high.							
	4. Falling from a Ladder	Injury,	Site Workers	1. Check if Ladder free from dent / deformity. 2. No rungs / steps missing. 3. Surface free of mud, oil, grease or substances. 4. check if All fittings / locking device are in place and in good condition.	4	1	4	Maintain current control	1	1	1
	5. Safety Harnesses / Fall Arresters	Injury, Fatality	Workers working at height	1. Inspect for cuts, burns & Tears. 2. The D- Ring and hook are distorted or damaged in some way. 3. Excessive loss of cross- section due to wear. 4. Both lanyard physical condition. 5. Lanyard and hook properly attached to each other.	3	4	12	Maintain current control	1	4	4
Excavation	1. Person Falling from Height	Serious Injury, Fatal	Worker working at pit, Operator of plant	1. For excavations exceeding 4 metres in depth, the Contractor shall appoint one banksman. 2. For Depth Exceeding 10 m Contractor must appoint additional	3	4	12	1.The guard rail pipes shall be painted in reflective paints.	1	4	4

				banksman 3. Two rows of horizontal rigid guardrails to prevent persons falling from height. 4. Rebar shall not be used as edge protection only standard pipes should be used.							
	2. Ingress of water	Slip, Injury	Worker	1. pumping sumps shall be established with pumps being readily available for use 2. Water seepage is one of major causes of soil collapse.	2	3	6	1 Additional ladder placed for use in the event of an emergency evacuation.	1	3	3
	3. Collapse of Soil/Earth	Serious Injury, Trap by fall of earth	Worker, Operator of plant	1Soldier piles are provided to support soil during excavation. 2. The excavation and installation of D-wall act a earth retaining structure. 3. A team comprising of contractor’s Construction manager and Safety Manager shall conduct a monthly Excavation Audit and the report shall be submitted	2	5	10	Maintain current control	1	5	5

	4. Underground Utility	Injury, Electrocution, Fire	Worker	1. All effort shall be made to locate and mark all underground utilities (Water / Gas pipe lines, Electric / telephone Cables etc.). 2. Adequate precaution & care shall be taken while working near to overhead / underground electrical lines. Once the underground utilities identified, Isolate these from source & ensure NO FLOW by providing Lockout /Tag Out.	2	4	8	Maintain current control	1	4	4
	5. Materials falling onto people working in the excavation pit	Serious Injury, Head Injury,	Workers, Site staff	1. No machinery, crane or mobile equipment shall be positioned or operated within 1.5mtr of the edge of excavation. 2. Only trained and authorized persons shall operate the earth moving equipment. 3. Deputation of trained banks man shall be ensured with all earthmoving equipment. All earthmovers operators/drivers/ banks men will be equipped with high visibility vest.	3	4	12	1. All vehicle must be equipped with an audible reverse alarm and kept in excellent operating order. 2. Under the direction of a banksman, reversing of vehicle should be done. 3. Where vehicles have to tip materials into	1	4	4

				4. Store items at least one metre away from the sidewalls of excavations. The material may fall into the excavation, increasing the risk of the sidewalls collapsing due to the additional weight.				excavations, use stop blocks to prevent them from over-running.			
Lifting Operations	1. Operator Working at Height	Serious Injury, Fatal	Operator, Work men	1. The work permit shall be issued for a single shift only. 2. During lifting, the area below must be blocked to prevent any illegal intrusion. 3. Provision of safe entry and exit to be made 4. Proper arrangement of the working platform with a toe guard to be made 5. Use of PPE 6. To avoid any form of catastrophe, a safety net must be placed according to the drawing and regulation..	3	5	15	Maintain current control	1	5	5
	2. Overloading	Fatality, Permanent deformity	Workers, Operator	1. All lifting machines at site must be well within their lifting capacity and must be in good working condition. 2. Automatic safe load	3	5	15	Maintain current control	1	5	5

				indicator (ASLI) shall be calibrated six-monthly by an approved agency and verified by the competent person 3. Crane operator and the supervisor must be well versed with the working load chart. 4. Load radius indicator must be equipped with a limiting device that prevents the crane from performing any lifting operations when it is overloaded.							
	3. Collapsing Structure	Serious Injury, Fatal	Workers, Crane Operator	1. Proper fixation following the standard procedure to protect against strong wind, unsafe loads, loads exceeding the safe weight limits, trapping/crushing risk 2. Shut down of operation during unsafe wind velocity, as per the manufacturer recommendations.	1	5	5	Maintain current control	1	5	5
	4. Falling materials	Serious Injury, Fatal	Worker, site staff	1. All Lifting operations must be undertaken by a registered operator, experienced supervisor and Lifting operation	2	4	8	Maintain current control	1	4	4

				and a sufficient trained rigger 2. All the load must be secured properly and must be checked by the supervisor, and a tag line is attached if required, prior to giving signal to the operator to start the lift. 3. All lifting machines, lifting appliances and lifting gears shall meet the requirements of Indian standards (IS 13367 (Part 1): 1992, Safe use of Cranes)							
	5. Power Lines in Vicinity	Electrocution, Fatality	Lifting	1.Proper grounding of the lifting appliance When working in the vicinity of an overhead power line. 2. Working in close proximity to live overhead power wires is prohibited unless a stringent Permit to Work system is in place.	1	4	4	Maintain current control	1	4	4
		Serious Injury,	Workers, Operator	1. A appropriate horn, headlights, and side lamps, as well as rear and stoplights and a flashing direction indication, must be installed on the mobile	2	4	8	Maintain current control	1	4	4

				crane. 2. The pneumatic tyres shall be maintained at the correct pressure at all times. 3. The position of derrick should be adjusted if the mobile crane is moving on a gradient.							
	6. Manual Lifting	Injury, Back injury.	Site workers	-Maintain a correct Posture. Overloading and carrying a bulky material should be avoided. -Should be in good health condition -Use of PPE and Gloves.	4	1	4	Maintain current control	1	1	1
WORK IN CONFINED SPACES	1. Toxic Gas, Fume or Vapour	Suffocation, Fatal, Nausea	Site Worker	1. Permit of work to be prepared by conducting the survey and has to be issued. 2. Multi gas monitor and full body harness should be made available before commencing the work. (d) if vertical exit is required, tripod and a lifeline hoist should be present.	2	5	10	Maintain current control	1	5	5

	2. Oxygen deficiency;	Suffocation, Nausea, unconsciousness	Site Worker	1. Obtain a suitable work permit 2. Persons with any medical conditions like heart disease, high blood pressure, breathing disorder shall not be allowed to work in confined spaces. 3. Ventilation Equipment.	2	4	8	Maintain current control	1	4	4
	3. Presence of Excessive Heat,	Suffocation, burn, Nausea, Losing consciousness	Workers	1. In addition, the contractor should make sure that monitoring for temperature and relative humidity should be there and any provision of ventilation if possible.	2	3	6	Maintain current control	1	3	3
SITE ELECTRICITY	1. Contact with Power Lines	Electrocution, Fatality, Severe injury	Worker, Technician, Site staff	1. Only authorised person is allowed to work on any live electric supply. 2. Every person working on Electrical installations or on electric supply line shall be provided with electrical hand gloves & electrical shock proof shoes of appropriate capacity, safety helmet and other PPEs according to the requirement.	3	5	15	1. Skull & bones symbols (as specified in IS: 2551) and danger notice in English and local language on every high voltage installation. 2. Procedure for CPR shall be displayed in HINDI or English and local language	1	5	5

				3. The DB and all switches must be kept in temporary shed/hoods to prevent from rainwater spray.				at prominent places. 3. All DG sets, Main Panels, Distribution panels & earth pits shall be tested & inspected on monthly basis by electrical engineer/ authorized electricians and report of the same shall be maintained.			
	2. Contact with Energized Sources	Electrocution, Fatality	Worker, Technician	1. Construction power supply shall be obtained by us only if the temporary power supply board installation conforms to I.E Regulation 2. The DB and all switches must be kept in temporary shed/hoods to prevent from rainwater spray. 3.Every person working on Electrical installations or on electric supply line shall be provided with electrical hand	3	5	15	1. A danger notice in Hindi or English & local language with a sign of skull & bones (as specified in IS: 2551) shall be fixed permanently on every medium, high & extra-high voltage installations 2. Procedure for CPR shall be	1	5	5

				gloves & electrical shock proof shoes of appropriate capacity, safety helmet and other PPEs according to the requirement.				displayed in HINDI or English and local language at prominent places. 3. All DG sets, Main Panels, Distribution panels & earth pits shall be tested & inspected on monthly basis by electrical engineer/ authorized electricians and report of the same shall be maintained.			
	3. Improper use of Extension and Flexible Cords	Electrocution,	Worker, Technician	1. Ensure all tools and wiring are properly grounded. 2. If cable laid in the above ground or underground should be laid as per the norms of Indian electricity rules 1956. 2. Only authorised person is allowed to work on any live electric supply and no unauthorised person	3	4	12	Maintain current control	1	4	4

				shall assist the same. 3. Flexible cables shall not be used for electrical appliances or tools unless they are double insulated and adequately protected from mechanical damage							
	4. Fire/Explosion	Burn	Site Workers	1. All electric circuits & apparatus shall be so arranged that there is no danger of becoming accidentally charged of any part or beyond their voltage limit. 2. It is to made sure that if in case AC and DC circuits are installed on the same support they must not come in contact. 3. Near transformers & DG sets provision of DCP 10 kg fire-extinguisher and at main panel CO2 4.5 kg fire-extinguisher shall be installed & maintained. First-aid box & electrical hand-gloves of appropriate capacity shall be kept available in sufficient quantity.	3	5	15	Maintain current control	1	5	5

WELDING AND CUTTING	1. Faulty/Unsafe Equipment.	Technicians, Welders	Burn, severe injury	1. Timely inspection of all the equipment by a competent person and records to be maintained. 2. Damage free cables, connections and flexible hoes with proper carrying capacity. 3. Work Permit, Daily Checklist, ELCBs, PPEs, Area barricading, Use of sheets	4	4	16	1. Usage of soapy water on regulator nuts to check for possible leakages. Regulator will be in conformity with the pressure. 2.if any damage to regulator. Repair work to be carried out only by speacilist.	1	4	4
	2. Physical Injury	Technicians	Burn	1. Proper PPE should always be worn during the process, (a) Correction welding shield, eye and face protection. (b) gloves (c) Safety footwear (d) aprons should be worn. (e) Vicinity must be free from any trace of flammable gases or substance.	4	3	12	1. Hot work permit to be issued by a competent person after completion of checks. (i) when doing the welding operation where others re working; (ii) environment should be free from risks or hazard.	1	3	3
	3. Fumes and Smoke	Suffocation, Nausea	Workers, Technicians	1. Whenever working in an enclosed area	4	2	8	Maintain current control	1	2	2

				provision of ventilation and fume extractor. 2. Welding should be done after cleaning of the surface to make it free from the contaminants that may result in obnoxious fumes. (like, paints, plastics)							
	4. Fire/Explosion	Burn, Serious Injury	Technician, Welders, Site worker	1. Close cylinder valves when flame is extinguished. 2. All hot parts and torches to be removed from work area when not in use or properly barricaded. 3. Provision of fire extinguishers, sand bucket near the workplace.	2	4	8	1. In case of any leakages, the cylinders to be moved to open area free from any source of ignition.	1	4	4
	5. Storage of compressed gases	Explosion Fire	Workers	1.Compressed gas cylinders to be stored in open air on a rigid surface. Flammable substances shall not be stored within 50 feet of cylinder storage areas. 2. There should be good access to the area, which should be kept clean and clear of combustible material,	3	4	12	1. It is important that the valves of so-called `empty' cylinders are kept closed as well as those of full cylinders and that plugs, shrouds and caps are kept in place on all	1	4	4

				including wood, packing materials and vegetation. If any protection is provided to prevent cylinders being exposed to the weather, it should be of non-combustible material and should not inhibit ventilation. The area should not be close to any source of heat. 3. Oxygen cylinders and flammable gas cylinders shall be stored separately, at least 6.6 meters (20 feet) apart or separated by a fire proof, 1.6 meters (5 feet) high partition.				cylinders. 2. This is necessary not only to prevent the escape of any residual compressed gas into the atmosphere but also to ensure that air is not sucked into the cylinder to form an explosive mixture inside it. All cylinders should be stored with their valves uppermost. 3. The storage area should be enclosed by a fence approximately 2 metres in height. The fence should be made of non-combustible material and should not inhibit natural ventilation,			

HANDLING MACHINERY	1. Storage	Minor Injury, Cut	Worker, Operator	1. All revolving parts, shafts, power tools, cutters, or any machinery shall be guarded and barricaded when not in use. 2. After carrying out the maintenance fencing should be again replaced before the machine is used again.	3	3	9	Maintain current control	1	3	3
	2. Machinery Maintenance	Cut, Injury	Worker, Operator	1. Only trained and experienced person should be allowed to repair, maintain machinery 2. Repair work to be carried out only when the machinery is completely stopped condition. 3. All the maintenance log to be well maintained at all the time.	3	3	9	Maintain current control	1	3	3
	3. Abrasive Wheels	Minor Injury, Cut	Worker, Operator	1. Guard must be fitted and to be kept at all the times when the machine is in use. 2. Provision of spindle speed to be clearly marked in rpm	3	3	9	1. Ring should be checked for any defects before mounting, and wheel should be changed only by a competent, experienced person.	1	3	3

PLANT AND EQUIPMENT OPERATIONS	1. Risk Associated with Plant and equipment operation	Serious Injury, Broken bone	Operator	1. Only well-maintained plant and equipments shall be allowed on site. 2. No unauthorised person shall be permitted to ride on plant. 3. Provision of atleast 6kg dry powder fire extinguisher, in all the mobile heavy plant for their easy access.	3	4	12	1. Daily inspection of the plant by their operators and the records to be well maintained for the inspection by engineer. 2. Provision of fire extinguishers in the storage areas also.	1	4	4
	2. Working in congested area	Suffocation, Fatigue Minor Injury	Operator Worker	1. Trained and experienced banksmen to be employed to guide the movement in congested area. 2. Provision of fire extinguishers in the storage areas also. To be used in case of emergency. 3. In case of deviation from the standard operating procedure the engineer can stop the work at any time.	3	3	9	1. Speed limits to be imposed for plant movement.	1	3	3
DEMOLITION	Unsupervised Work	Injury, Cut, Broken bone	Workers	1. Demolition work to be carried out in a controlled manner under the guidance of experienced person.	2	3	6	Prior to the demolition work, it must be checked that the area is free from all the utility	1	3	3

				2. PPE should be worn all the times. 2. All power supplies and services shall be disconnected before any demolition work commences.				and any hazardous substance.			
FALSE WORK / FORMWORK	1. Improper placement	Injury, Broken bones	Workers	1. Proper plan to be devised for formwork and it must have the strength to hold the work. 2. Proper Strength of the working platforms for the concrete placement operations, use of needle or different types vibrator and also support the movement of personnel during the operation.	3	3	9	1. Formwork of good quality must be used. 2. If working on height use of body harness 3. Proper inspection to be carried out by a competent person before the placement of concrete.	1	3	3
PILING AND DIAPHRAGM WALLS	1. Accidents during use of Piling Rig	Fatality, Permanent deformity	Operator, Work men & Staffs	1. Piling Rig is not a lifting equipment shall not be used for any lifting operation. 2. In case if the grab is detached during the process of piling, guide wall excavation, a proper plan for its retrieval should be there.	4	5	20	Maintain current control	1	5	5
	2. Hit hazard while swinging of	Hit Injury, Severe	Operator, Work men	1. Swing alarm shall be provided 2. Qualified operator	3	4	12	Maintain current control	1	4	4

	rig. Toppling of piling rig.	injury leading to fatality	& Staffs	shall be provided for operating piling rig. 3. Turn buckle should be provided for piling rig arresting with jack up platform. 4. Qualified foreman are provided for expert supervision							
	3. Falling into Excavated pits	Serious Injury Fatal	Operator, Work men & Staffs	1. Fencing to be provided around the excavated pit if not then it must not be left unattended to prevent accidents near the vicinity of pile. 2. Deployment of trained banksmen to guide the movement of heavy plant and equipment in the congested areas.	3	4	12	Maintain current control	1	4	4
	4. Bentonite Spillage	Slip, Injury	Vehicle Operator, workers	1. Storage tanks of bentonite polymers should be free from any leakages and additional bunds are provided around to prevent any spillage. 2. No Bentonite spillage shall be allowed on any roads.	3	3	9	Maintain current control	1	3	3

				3. In case of any spillage it must be cleaned thoroughly before vehicular movement.							
	5. Tremie lowering & Concreting	Serious injury, Hit Injury, Falling in pile, Fatal	Site workers and site staff	1. Working platform with handrails 2. In case of damaged rope or wires it cant be used it is to replaced with a fresh one. 3. Tremie should be placed in rigid stand 5. Authorized rigger and Khalasi shall be deployed for lifting activities	3	5	15	Maintain current control	1	5	5
D-Wall Anchoring	1. Mechanical Failure or collapse of sligs	Physical injury	Site workers and site staff	1. Barricade excavated areas. 2. TPI Must be done of Machines and lifting tools tackles. 3. Install warning sign.	3	5	15	W.P. Excavation have to applied if deep then 2m	1	5	5
	2. Collision due to operation of machinery	Physical injury	Site workers and site staff	1. Trained/experienced operator. 2. Install warning sign. 3. Wear luminous jacket."	2	3	6	Maintain current control	1	3	3
ERECTION	1. Risk Involved in Bar Cutting and Bending	Physical injury, Cut, Electric shock	Site workers and site staff	1. Adequate Leveling of machine with rain protection Shed 2. lubrication Leakage is control 3. Reinforcement Bar	3	3	9	1. Adequate Double Earthing 2. House keeping near the machine	1	3	3

				cutting guard 4. Adequate Guarding of Rotating Parts 5. Adequate Stopper fixing on bar binding machine 6. Daily Inspection of Machine by the concerned person				maintained properly			
	2. Risk involved in Structural Steel Erection	Physical Injury, Cut	Site workers and site staff	1. Provide a safe means of access and safe workplace for the stacking of structural steel components and ensure their stability. 2. Stacks should be so constructed to enable their removal by slingers without risk of them being struck or trapped. 3. consideration must first given to providing safe means of access and working platforms including ladders, scaffold etc.	4	3	12	Maintain current control	1	3	3
	3. CONCRETE POURING	Physical Injury,	Site Workers	1. For slab casting and concrete at height shuttering, supports, scaffoldings etc shall be inspected and certified by responsible/competent engineer for their	3	3	9	Maintain current control	1	3	3

				stability & intended load bearing. 2. If concrete pump is being used for concrete pouring, the concrete pipes shall have separate access route. It shall not be routed commonly through man access. 3. Worker, operator or helper shall not come between reversing miller and pump. It's highly hazardous. 4. Only the trained persons should operate the equipment. 5. Electrical connections and earthing of the equipment will be properly done. 6. Proper anchoring will be done between piping and equipment.							
	4. Scaffolding	Physical Injury,	Site Workers	Same as discussed above	3	3	9	Maintain current control	1	3	3
	4. BATCHING PLANT	Physical Injury,	Site Workers, Operator	1. Contractor shall submit the Batching plant site layout and design to the Engineer for Notice of no objection	3	3	9	1. Use of Signage in Local Language	1	3	3

				2. Compulsory PPE Zone and manual handling of cement must be avoided 3. Proper designing of all the stations and cable routing, location of DB etc. should not infringe with any other utilities.							
	5. FLOOR OPENINGS	Physical Injury,	Site Workers, Site Staff	1. If any hole is made to the ground or slab, barricading to be done to keep the people out of that. 2. Permanent barricading to be done if the hole is to be remain open. Provisions of edge protection with load carrying of 90kgs to be provided. 3. If fencing is not provided it must be covered, with the load carrying capacity of the cover being 200 pounds.	3	4	12	1. additional signage or a red flag to denote danger	1	4	4
House Keeping	1. Protruding Nails	Physical Injury,	Site workers Site Staff	1. De-Nailing should be done and proper house keeping should be done by a trained person. 2. Proper PPE protective shoe to be worn during the process	5	3	15	1. Surplus timbers skipped or transferred for use elsewhere.	1	3	3

				3. Documentation of housekeeping							
	2. Housekeeping at worksites	Physical Injury,	Site workers Site Staff	1.Scattered unused materials to be removed 2. Fencing and guarding of equipment's 3. Stacking and storing of materials 4. Excavated earth removed within a reasonable time. 1. Designated storage area for materials 2. Scraps/brickbats/rubbish scattered at site removal 3. Water not allowed to accumulate in work area for any reason	5	2	10	1. regular clearance of site if the unwanted materials and flammable objects like wood, cardboards etc.	1	2	2
	4. Labour Camp	Disease outbreak, Infection, Unsanitary condition	Site workers Site Staff	1. Surrounding areas of drinking water tanks/taps not hygienically cleaned/maintained. 2. Fogging to stop mosquito breeding. 3. Office, stores, toilet / urinals, properly cleaned and maintained. 4. Drinking water to be provided 5. Treating still water once every week with	5	3	15	1. Regular Health Check-up/Medical Camp	1	3	3

				oil in order to prevent mosquito breeding.							
Environmental Control	1. Dust Control	Suffocation, Breathing Problem	Site Workers, Site Staffs, People in Vicinity	1. Air Cannon to be used at site to control dust. 2. Spray of water to supress dust during the demolition. 3. During delivery of sand, aggregates and other similar material or due to vehicular movement spray of water to control dust and particulate matter. 4. Use of wet gunny bags to supress saw dust during the sawing operation and cutting of tiles and blocks.	4	2	8	1. Maintain enough storage at site to reduce the emission from transportation of material	1	2	2
	2. Water quality	Water Borne Diseases, Pollute Ground water	Site workers Site Staff	Water quality to be monitored for building of area > 20,000 sqm.	3	2	5	Maintain current control	1	2	2
	3. Noise monitoring	Hearing impairment,	Site Workers, Visitors, People in Vicinity	1. DG set should be kept in an enclosed box to control noise 2. Earplug shall be provided to person working in noisy area. 3. use of well maintained machinery at site.	4	2	8	1. Schedule the work to avoid simultaneous activities that would generate high noise levels.	1	2	2

				4. Equipment/ Plants to stop when not in use							
	4. Waste Management	Polluting the source, hazardous waste	Site Workers, Site Staff	1. any uncontrolled emission shall report immediately 2. Colored bins for segregating waste 3. No Toxic, corrosive or flammable substance in to public sewage system	4	2	8	maintain current control	1	2	2

Excavation	1. Person Falling from Height	Serious Injury, Fatal	Worker working at pit, Operator of plant	1. For excavations exceeding 4 metres in depth, the Contractor shall appoint one banksman. 2. For Depth Exceeding 10 m Contractor must appoint additional banksman 3. Two rows of horizontal rigid guardrails to prevent persons falling from height. 4. Rebar shall not be used as edge protection only standard pipes should be used.	3	4	12	1.The guard rail pipes shall be painted in reflective paints.	1	4	4

	2. Ingress of water	Slip, Injury	Worker	1. pumping sumps shall be established with pumps being readily available for use 2. Water seepage is one of major causes of soil collapse.	2	3	6	1 Additional ladder placed for use in the event of an emergency evacuation.	1	3	3
	3. Collapse of Soil/Earth	Serious Injury, Trap by fall of earth	Worker, Operator of plant	1Soldier piles are provided to support soil during excavation. 2. The excavation and installation of D-wall act a earth retaining structure. 3. A team comprising of contractor's Construction manager and Safety Manager shall conduct a monthly Excavation Audit and the report shall be submitted	2	5	10	Maintain current control	1	5	5

	4. Underground Utility	Injury, Electrocution, Fire	Worker	1. All effort shall be made to locate and mark all underground utilities (Water / Gas pipe lines, Electric / telephone Cables etc.). 2. Adequate precaution & care shall be taken while working near to overhead / underground electrical lines. Once the underground utilities identified, Isolate these from source & ensure NO FLOW by providing Lockout /Tag Out.	2	4	8	Maintain current control	1	4	4

	5. Materials falling onto people working in the excavation pit	Serious Injury, Head Injury,	Workers, Site staff	1. No machinery, crane or mobile equipment shall be positioned or operated within 1.5mtr of the edge of excavation. 2. Only trained and authorized persons shall operate the earth moving equipment. 3. Deputation of trained banks man shall be ensured with all earthmoving equipment. All earthmovers operators/drivers/ banks men will be equipped with high visibility vest. 4. Store items at least one metre away from the sidewalls of excavations. The material may fall into the excavation, increasing the risk of the sidewalls collapsing due to the additional weight.	3	4	12	1. All vehicle must be equipped with an audible reverse alarm and kept in excellent operating order. 2. Under the direction of a banksman, reversing of vehicle should be done. 3. Where vehicles have to tip materials into excavations, use stop blocks to prevent them from over-running.	1	4	4

Lifting Operations	1. Operator Working at Height	Serious Injury, Fatal	Operator, Work men	1. The work permit shall be issued for a single shift only. 2. During lifting, the area below must be blocked to prevent any illegal intrusion. 3. Provision of safe entry and exit to be made 4. Proper arrangement of the working platform with a toe guard to be made 5. Use of PPE 6. To avoid any form of catastrophe, a safety net must be placed according to the drawing and regulation..	3	5	15	Maintain current control	1	5	5

	2. Overloading	Fatality, Permanent deformity	Workers, Operator	1. All lifting machines at site must be well within their lifting capacity and must be in good working condition. 2. Automatic safe load indicator (ASLI) shall be calibrated six-monthly by an approved agency and verified by the competent person 3. Crane operator and the supervisor must be well versed with the working load chart. 4. Load radius indicator must be equipped with a limiting device that prevents the crane from performing any lifting operations when it is overloaded.	3	5	15	Maintain current control	1	5	5

	3. Collapsing Structure	Serious Injury, Fatal	Workers, Crane Operator	1. Proper fixation following the standard procedure to protect against strong wind, unsafe loads, loads exceeding the safe weight limits, trapping/crushing risk 2. Shut down of operation during unsafe wind velocity, as per the manufacturer recommendations.	1	5	5	Maintain current control	1	5	5

	4. Falling materials	Serious Injury, Fatal	Worker, site staff	1. All Lifting operations must be undertaken by a registered operator, experienced supervisor and Lifting operation and a sufficient trained rigger 2. All the load must be secured properly and must be checked by the supervisor, and a tag line is attached if required, prior to giving signal to the operator to start the lift. 3. All lifting machines, lifting appliances and lifting gears shall meet the requirements of Indian standards (IS 13367 (Part 1): 1992, Safe use of Cranes)	2	4	8	Maintain current control	1	4	4

	5. Power Lines in Vicinity	Electrocution, Fatality	Lifting	1.Proper grounding of the lifting appliance When working in the vicinity of an overhead power line. 2. Working in close proximity to live overhead power wires is prohibited unless a stringent Permit to Work system is in place.	1	4	4	Maintain current control	1	4	4

		Serious Injury,	Workers, Operator	1. A appropriate horn, headlights, and side lamps, as well as rear and stoplights and a flashing direction indication, must be installed on the mobile crane. 2. The pneumatic tyres shall be maintained at the correct pressure at all times. 3. The position of derrick should be adjusted if the mobile crane is moving on a gradient.	2	4	8	Maintain current control	1	4	4
	6. Manual Lifting	Injury, Back injury.	Site workers	-Maintain a correct Posture. Overloading and carrying a bulky material should be avoided. -Should be in good health condition -Use of PPE and Gloves.	4	1	4	Maintain current control	1	1	1

WORK IN CONFINED SPACES	1. Toxic Gas, Fume or Vapour	Suffocation, Fatal, Nausea	Site Worker	1. Permit of work to be prepared by conducting the survey and has to be issued. 2. Multi gas monitor and full body harness should be made available before commencing the work. (d) if vertical exit is required, tripod and a lifeline hoist should be present.	2	5	10	Maintain current control	1	5	5

	2. Oxygen deficiency;	Suffocation, Nausea, unconsciousness	Site Worker	1. Obtain a suitable work permit 2. Persons with any medical conditions like heart disease, high blood pressure, breathing disorder shall not be allowed to work in confined spaces. 3. Ventilation Equipment.	2	4	8	Maintain current control	1	4	4
	3. Presence of Excessive Heat,	Suffocation, burn, Nausea, Losing consciousness	Workers	1. In addition, the contractor should make sure that monitoring for temperature and relative humidity should be there and any provision of ventilation if possible.	2	3	6	Maintain current control	1	3	3

SITE ELECTRICITY	1. Contact with Power Lines	Electrocution, Fatality, Severe injury	Worker, Technician, Site staff	1. Only authorised person is allowed to work on any live electric supply. 2. Every person working on Electrical installations or on electric supply line shall be provided with electrical hand gloves & electrical shock proof shoes of appropriate capacity, safety helmet and other PPEs according to the requirement. 3. The DB and all switches must be kept in temporary shed/hoods to prevent from rainwater spray.	3	5	15	1. Skull & bones symbols (as specified in IS: 2551) and danger notice in English and local language on every high voltage installation. 2. Procedure for CPR shall be displayed in HINDI or English and local language at prominent places. 3. All DG sets, Main Panels, Distribution panels & earth pits shall be tested & inspected on monthly basis by electrical engineer/ authorized electricians and report of the same shall be maintained.	1	5	5

	2. Contact with Energized Sources	Electrocution, Fatality	Worker, Technician	1. Construction power supply shall be obtained by us only if the temporary power supply board installation conforms to I.E Regulation 2. The DB and all switches must be kept in temporary shed/hoods to prevent from rainwater spray. 3.Every person working on Electrical installations or on electric supply line shall be provided with electrical hand gloves & electrical shock proof shoes of appropriate capacity, safety helmet and other PPEs according to the requirement.	3	5	15	1. A danger notice in Hindi or English & local language with a sign of skull & bones (as specified in IS: 2551) shall be fixed permanently on every medium, high & extra-high voltage installations 2. Procedure for CPR shall be displayed in HINDI or English and local language at prominent places. 3. All DG sets, Main Panels, Distribution panels & earth pits shall be tested & inspected on monthly basis by electrical engineer/ authorized electricians and report of the same shall be maintained.	1	5	5

	3. Improper use of Extension and Flexible Cords	Electrocution,	Worker, Technician	1. Ensure all tools and wiring are properly grounded. 2. If cable laid in the above ground or underground should be laid as per the norms of Indian electricity rules 1956. 2. Only authorised person is allowed to work on any live electric supply and no unauthorised person shall assist the same. 3. Flexible cables shall not be used for electrical appliances or tools unless they are double insulated and adequately protected from mechanical damage	3	4	12	Maintain current control	1	4	4

	4. Fire/Explosion	Burn	Site Workers	1. All electric circuits & apparatus shall be so arranged that there is no danger of becoming accidentally charged of any part or beyond their voltage limit. 2. It is to made sure that if in case AC and DC circuits are installed on the same support they must not come in contact. 3. Near transformers & DG sets provision of DCP 10 kg fire-extinguisher and at main panel CO2 4.5 kg fire-extinguisher shall be installed & maintained. First-aid box & electrical hand-gloves of appropriate capacity shall be kept available in sufficient quantity.	3	5	15	Maintain current control	1	5	5

WELDING AND CUTTING	1. Faulty/Unsafe Equipment.	Technicians, Welders	Burn, severe injury	1. Timely inspection of all the equipment by a competent person and records to be maintained. 2. Damage free cables, connections and flexible hoes with proper carrying capacity. 3. Work Permit, Daily Checklist, ELCBs, PPEs, Area barricading, Use of sheets	4	4	16	1. Usage of soapy water on regulator nuts to check for possible leakages. Regulator will be in conformity with the pressure. 2.if any damage to regulator. Repair work to be carried out only by speacilist.	1	4	4
	2. Physical Injury	Technicians	Burn	1. Proper PPE should always be worn during the process, (a) Correction welding shield, eye and face protection. (b) gloves (c) Safety footwear (d) aprons should be worn. (e) Vicinity must be free from any trace of flammable gases or substance.	4	3	12	1. Hot work permit to be issued by a competent person after completion of checks. (i) when doing the welding operation where others re working; (ii) environment should be free from risks or hazard.	1	3	3

	3. Fumes and Smoke	Suffocation, Nausea	Workers, Technicians	1. Whenever working in an enclosed area provision of ventilation and fume extractor. 2. Welding should be done after cleaning of the surface to make it free from the contaminants that may result in obnoxious fumes. (like, paints, plastics)	4	2	8	Maintain current control	1	2	2
	4. Fire/Explosion	Burn, Serious Injury	Technician, Welders, Site worker	1. Close cylinder valves when flame is extinguished. 2. All hot parts and torches to be removed from work area when not in use or properly barricaded. 3. Provision of fire extinguishers, sand bucket near the workplace.	2	4	8	1. In case of any leakages, the cylinders to be moved to open area free from any source of ignition.	1	4	4
	5. Storage of compressed gases	Explosion Fire	Workers	1.Compressed gas cylinders to be stored in open air on a rigid surface. Flammable substances shall not be stored within 50 feet of cylinder storage areas.	3	4	12	1. It is important that the valves of so-called `empty' cylinders are kept closed as well as those of full cylinders and that plugs, shrouds and caps are kept in place on all cylinders. 2. This is necessary not	1	4	4

				2. There should be good access to the area, which should be kept clean and clear of combustible material, including wood, packing materials and vegetation. If any protection is provided to prevent cylinders being exposed to the weather, it should be of non-combustible material and should not inhibit ventilation. The area should not be close to any source of heat. 3. Oxygen cylinders and flammable gas cylinders shall be stored separately, at least 6.6 meters (20 feet) apart or separated by a fire proof, 1.6 meters (5 feet) high partition.				only to prevent the escape of any residual compressed gas into the atmosphere but also to ensure that air is not sucked into the cylinder to form an explosive mixture inside it. All cylinders should be stored with their valves uppermost. 3. The storage area should be enclosed by a fence approximately 2 metres in height. The fence should be made of non-combustible material and should not inhibit natural ventilation,			

HANDLING MACHINERY	1. Storage	Minor Injury, Cut	Worker, Operator	1. All revolving parts, shafts, power tools, cutters, or any machinery shall be guarded and barricaded when not in use. 2. After carrying out the maintenance fencing should be again replaced before the machine is used again.	3	3	9	Maintain current control	1	3	3
	2. Machinery Maintenance	Cut, Injury	Worker, Operator	1. Only trained and experienced person should be allowed to repair, maintain machinery 2. Repair work to be carried out only when the machinery is completely stopped condition. 3. All the maintenance log to be well maintained at all the time.	3	3	9	Maintain current control	1	3	3

	3. Abrasive Wheels	Minor Injury, Cut	Worker, Operator	1. Guard must be fitted and to be kept at all the times when the machine is in use. 2. Provision of spindle speed to be clearly marked in rpm	3	3	9	1. Ring should be checked for any defects before mounting, and wheel should be changed only by a competent, experienced person.	1	3	3
PLANT AND EQUIPMENT OPERATIONS	1. Risk Associated with Plant and equipment operation	Serious Injury, Broken bone	Operator	1. Only well-maintained plant and equipments shall be allowed on site. 2. No unauthorised person shall be permitted to ride on plant. 3. Provision of atleast 6kg dry powder fire extinguisher, in all the mobile heavy plant for their easy access.	3	4	12	1. Daily inspection of the plant by their operators and the records to be well maintained for the inspection by engineer. 2. Provision of fire extinguishers in the storage areas also.	1	4	4
	2. Working in congested area	Suffocation, Fatigue Minor Injury	Operator Worker	1. Trained and experienced banksmen to be employed to guide the movement in congested area. 2. Provision of fire extinguishers in the storage areas also. To be used in case of emergency. 3. In case of deviation from the standard operating procedure the	3	3	9	1. Speed limits to be imposed for plant movement.	1	3	3

				engineer can stop the work at any time.							

DEMOLITION	Unsupervised Work	Injury, Cut, Broken bone	Workers	1. Demolition work to be carried out in a controlled manner under the guidance of experienced person. 2. PPE should be worn all the times. 2. All power supplies and services shall be disconnected before any demolition work commences.	2	3	6	Prior to the demolition work, it must be checked that the area is free from all the utility and any hazardous substance.	1	3	3

FALSE WORK / FORMWORK	1. Improper placement	Injury, Broken bones	Workers	1. Proper plan to be devised for formwork and it must have the strength to hold the work. 2. Proper Strength of the working platforms for the concrete placement operations, use of needle or different types vibrator and also support the movement of personnel during the operation.	3	3	9	1. Formwork of good quality must be used. 2. If working on height use of body harness 3. Proper inspection to be carried out by a competent person before the placement of concrete.	1	3	3

PILING AND DIAPHRAGM WALLS	1. Accidents during use of Piling Rig	Fatality, Permanent deformity	Operator, Work men & Staffs	1. Piling Rig is not a lifting equipment shall not be used for any lifting operation. 2. In case if the grab is detached during the process of piling, guide wall excavation, a proper plan for its retrieval should be there.	4	5	20	Maintain current control	1	5	5

	2. Hit hazard while swinging of rig. Toppling of piling rig.	Hit Injury, Severe injury leading to fatality	Operator, Work men & Staffs	1. Swing alarm shall be provided 2. Qualified operator shall be provided for operating piling rig. 3. Turn buckle should be provided for piling rig arresting with jack up platform. 4. Qualified foreman are provided for expert supervision	3	4	12	Maintain current control	1	4	4
	3. Falling into Excavated pits	Serious Injury Fatal	Operator, Work men & Staffs	1. Fencing to be provided around the excavated pit if not then it must not be left unattended to prevent accidents near the vicinity of pile. 2. Deployment of trained banksmen to guide the movement of heavy plant and equipment in the congested areas.	3	4	12	Maintain current control	1	4	4

	4. Bentonite Spillage	Slip, Injury	Vehicle Operator, workers	1. Storage tanks of bentonite polymers should be free from any leakages and additional bunds are provided around to prevent any spillage. 2. No Bentonite spillage shall be allowed on any roads. 3. In case of any spillage it must be cleaned thoroughly before vehicular movement.	3	3	9	Maintain current control	1	3	3
	5. Tremie lowering & Concreting	Serious injury, Hit Injury, Falling in pile, Fatal	Site workers and site staff	1. Working platform with handrails 2. In case of damaged rope or wires it cant be used it is to replaced with a fresh one. 3. Tremie should be placed in rigid stand 5. Authorized rigger and Khalasi shall be deployed for lifting activities	3	5	15	Maintain current control	1	5	5
D-Wall Anchoring	1. Mechanical Failure or collapse of sligs	Physical injury	Site workers and site staff	1. Barricade excavated areas. 2. TPI Must be done of Machines and lifting tools tackles. 3. Install warning sign.	3	5	15	W.P. Excavation have to applied if deep then 2m	1	5	5

	2. Collision due to operation of machinery	Physical injury	Site workers and site staff	1. Trained/experienced operator. 2. Install warning sign. 3. Wear luminous jacket."	2	3	6	Maintain current control	1	3	3

ERECTION	1. Risk Involved in Bar Cutting and Bending	Physical injury, Cut, Electric shock	Site workers and site staff	1. Adequate Leveling of machine with rain protection Shed 2. lubrication Leakage is control 3. Reinforcement Bar cutting guard 4. Adequate Guarding of Rotating Parts 5. Adequate Stopper fixing on bar binding machine 6. Daily Inspection of Machine by the concerned person	3	3	9	1. Adequate Double Earthing 2. House keeping near the machine maintained properly	1	3	3
	2. Risk involved in Structural Steel Erection	Physical Injury, Cut	Site workers and site staff	1. Provide a safe means of access and safe workplace for the stacking of structural steel components and ensure their stability. 2. Stacks should be so constructed to enable their removal by slingers without risk of them being struck or trapped. 3. consideration must first given to providing safe means of access	4	3	12	Maintain current control	1	3	3

				and working platforms including ladders, scaffold etc.							

	3. CONCRET E POURING	Physica l Injury,	Site Workers	1. For slab casting and concrete at height shuttering, supports, scaffoldings etc shall be inspected and certified by responsible/competent engineer for their stability & intended load bearing. 2. If concrete pump is being used for concrete pouring, the concrete pipes shall have separate access route. It shall not be routed commonly through man access. 3. Worker, operator or helper shall not come between reversing miller and pump. It's highly hazardous. 4. Only the trained persons should operate the equipment. 5. Electrical connections and earthing of the equipment will be properly done. 6. Proper anchoring will be done between piping and equipment.	3	3	9	Maintain current control	1	3	3
	4. Scaffolding	Physica l Injury,	Site Workers	Same as discussed above	3	3	9	Maintain current control	1	3	3

	4. BATCHING PLANT	Physical Injury,	Site Workers, Operator	1. Contractor shall submit the Batching plant site layout and design to the Engineer for Notice of no objection 2. Compulsory PPE Zone and manual handling of cement must be avoided 3. Proper designing of all the stations and cable routing, location of DB etc. should not infringe with any other utilities.	3	3	9	1. Use of Signage in Local Language	1	3	3
	5. FLOOR OPENINGS	Physical Injury,	Site Workers, Site Staff	1. If any hole is made to the ground or slab, barricading to be done to keep the people out of that. 2. Permanent barricading to be done if the hole is to be remain open. Provisions of edge protection with load carrying of 90kgs to be provided. 3. If fencing is not provided it must be covered, with the load carrying capacity of the cover being 200 pounds.	3	4	12	1. additional signage or a red flag to denote danger	1	4	4

House Keeping	1. Protruding Nails	Physical Injury,	Site workers Site Staff	1. De-Nailing should be done and proper house keeping should be done by a trained person. 2. Proper PPE protective shoe to be worn during the process 3. Documentation of housekeeping	5	3	15	1. Surplus timbers skipped or transferred for use elsewhere.	1	3	3
	2. Housekeeping at worksites	Physical Injury,	Site workers Site Staff	1.Scattered unused materials to be removed 2. Fencing and guarding of equipment's 3. Stacking and storing of materials 4. Excavated earth removed within a reasonable time. 1. Designated storage area for materials 2. Scraps/brickbats/rubbish scattered at site removal 3. Water not allowed to accumulate in work area for any reason	5	2	10	1. regular clearance of site if the unwanted materials and flammable objects like wood, cardboards etc.	1	2	2

	4. Labour Camp	Disease outbreak, Infection, Unsanitary condition	Site workers Site Staff	1. Surrounding areas of drinking water tanks/taps not hygienically cleaned/maintained. 2. Fogging to stop mosquito breeding. 3. Office, stores, toilet / urinals, properly cleaned and maintained. 4. Drinking water to be provided 5. Treating still water once every week with oil in order to prevent mosquito breeding.	5	3	15	1. Regular Health Check-up/Medical Camp	1	3	3

Environmental Control	1. Dust Control	Suffocation, Breathing Problem	Site Workers, Site Staffs, People in Vicinity	1. Air Cannon to be used at site to control dust. 2. Spray of water to supress dust during the demolition. 3. During delivery of sand, aggregates and other similar material or due to vehicular movement spray of water to control dust and particulate matter. 4. Use of wet gunny bags to supress saw dust during the sawing operation and cutting of tiles and blocks.	4	2	8	1. Maintain enough storage at site to reduce the emission from transportation of material	1	2	2

	2. Water quality	Water Borne Diseases, Pollute Ground water	Site workers Site Staff	Water quality to be monitored for building of area > 20,000 sqm.	3	2	5	Maintain current control	1	2	2
	3. Noise monitoring	Hearing impairment,	Site Workers, Visitors, People in Vicinity	1. DG set should be kept in an enclosed box to control noise 2. Earplug shall be provided to person working in noisy area. 3. use of well maintained machinery at site. 4. Equipment/ Plants to stop when not in use	4	2	8	1. Schedule the work to avoid simultaneous activities that would generate high noise levels.	1	2	2
	4. Waste Management	Polluting the source, hazardous waste	Site Workers, Site Staff	1. any uncontrolled emission shall report immediately 2. Colored bins for segregating waste 3. No Toxic, corrosive or flammable substance in to public sewage system	4	2	8	Maintain current control	1	2	2

Further these hazards were categorised on basis of its nature, namely Physical, Electrical, Mechanical, Environmental, Biological, Chemical/Toxic, Heat/Temperature, Fire/Explosion. Below Pie chart shows the percentage distribution of these hazards.

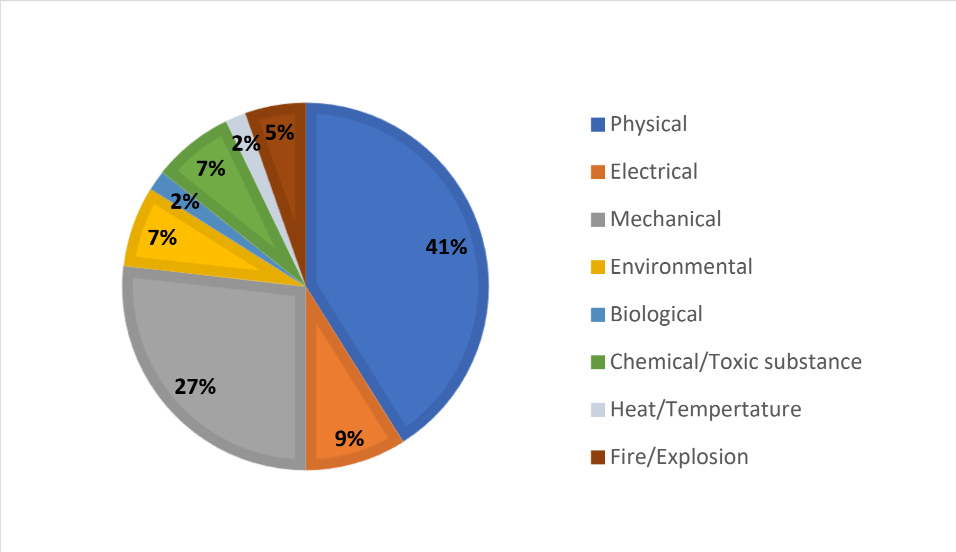


Fig 4.1 Frequency distribution of different hazard class in the construction project

From the detailed risk assessment (table 4.1) risk ratings were obtained, and on comparing the risk ratings before and after taking the appropriate control measurers there is a significant reduction in the risk rating. For better understanding and the to understand the criticality of each hazard, risk matrix (Table 3.3) is used. Risk matrix before and after application of control measures gives the idea of level of control at the site for each hazard marked with a symbol.

Table 4.2 Reference table for Risk Matrix

WORKING AT HEIGHT			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
H1	Falling from Height	9	3
H2	Material Falling from Height	8	4
H3	Working on Scaffold	12	4
H4	Falling from a Ladder	4	1
H5	Safety Harness/ Fall Arresters	12	4
EXCAVATION			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
E1	Person Falling from Height	12	4
E2	Ingress of water	6	3
E3	Collapse of Soil/Earth	10	5
E4	Underground Utility	8	4
E5	Materials falling onto people working in the excavation	12	4
LIFTING OPERATION			

Symbol	Hazards	Risk Rating	Residual Risk
L1	Operator working at height	15	5
L2	Overloading	15	5
L3	Collapsing Structure	5	5
L4	Falling materials	8	4
L5	Power Lines in Vicinity	4	4
L6	Operating Mobile Cranes	8	4
L7	Manual Lifting	4	1
WORK IN CONFINED SPACES			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
C1	Toxic Gas, Fume or Vapour	10	5
C2	Oxygen deficiency;	8	4
C3	Excessive Heat,	6	3
SITE ELECTRICITY			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
EL1	Contact with Power Lines	15	5
EL2	Contact with Energized Sources	15	5
EL3	Improper Use of Extension and Flexible Cords	12	4
EL4	Fire/Explosion	15	5
WELDING AND CUTTING			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
W1	Faulty/Unsafe Equipment	16	4
W1	Physical Injury	12	3
W3	Fumes and Smoke	8	2
W4	Fire/Explosion	8	4
W5	Storage of compressed gases	12	4
HANDLING MACHINERY			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
M1	Storage	9	3
M2	Machinery Maintenance	9	3
M3	Abrasive Wheels	9	3
PLANT AND EQUIPMENT OPERATIONS			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
PL1	EQUIPMENT OPERATIONS	12	4
PL2	Working in congested area	9	3
DEMOLITION			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
D1	Unsupervised demolition	6	3
FALSE WORK / FORMWORK			

Symbol	Hazards	Risk Rating	Residual Risk
F1	Improper Placement	9	3
PILING AND DIAPHRAGM WALLS			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
P1	Accidents during the use of piling Rig	20	5
P2	Swinging/Toppling of Rig	12	4
P3	Falling into Excavated Pits	12	4
P4	Bentonite Spillage	9	3
P5	Tremie lowering & Concreting	15	5
D-WALL ANCHORING			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
DW1	Mechanical Failure or collapse of slings	15	5
DW2	Collision	6	3
STRUCTURE ERECTION			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
S1	Bar Cutting and bending	9	3
S2	Structural Steel Erection	12	3
S3	Concrete Pouring	9	3
S4	Scaffolding	9	3
S5	Batching Plant	9	3
S6	Floor Opening	12	4
HOUSE KEEPING			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
HK1	Protruding Nails and sharp object	15	3
HK2	Housekeeping at worksites	10	2
HK3	Housekeeping at Labour Camp	15	3
ENVIRONMENTAL CONTROL			
Symbol	**Hazards**	**Risk Rating**	**Residual Risk**
EN1	Dust Control	8	2
EN2	Water quality Monitoring	5	2
EN3	Noise monitoring	8	2
EN4	Waste Management	8	2

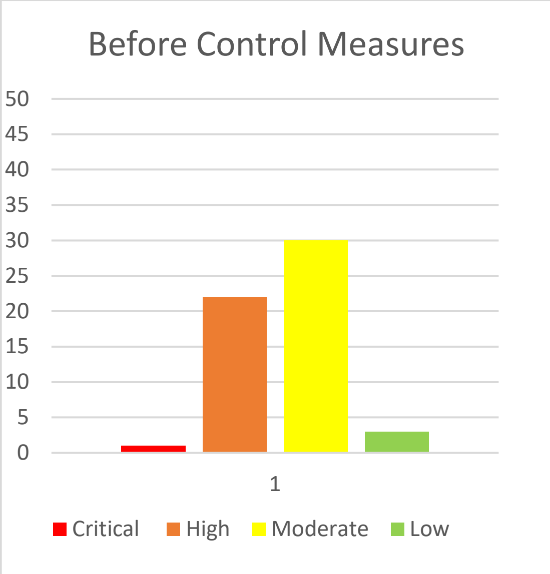
		Likelihood (L) -->				
		1	2	3	4	5
Severity -->	5	L3	E3,C1	L1, L2, EL1 EL2, EL4, P5 DW1,	P1	
	4	L5	H2, E4, L4, L6, C2	H3, H5, E1, E5, EL3, W5 PL1, P2, P3, S6	W1	
	3		E2, C3, D1, DW2	H1, M1, M2 M3, PL2, F1 P4, S1, S3, S4, S5	W2, S2	HK1, HK3
	2			EN2	W3, W4, EN1, EN3, EN4	HK2
	1				H4, L7	

Fig. 4.2 Risk Assessment Matrix before the control measures

After finding the risk ratings for all the identified hazards, control measures were implemented on the priority basis based on the risk ratings.

		Likelihood (L)-->				
		1	2	3	4	5
Severity -->	5	E3, L1, L2, L3, C1, EL1, EL2, EL4, P1, P5, DW1				
	4	H2, H3, H5, E1, E5, L4, L5, L6, C2, EL3, W1, W4, W5, PL1, P2, P3, S6				
	3	H1, E2, E4, C3 W2, M1, M2, M3, PL2, D1, F1, P4, DW2, S1, S2, S3, S4, S5, HK1, HK3				
	2	W3, HK2, EN1, EN2, EN3, EN4				
	1	H4, L7				

Fig 4.3 Risk Assessment Matrix after the control measures



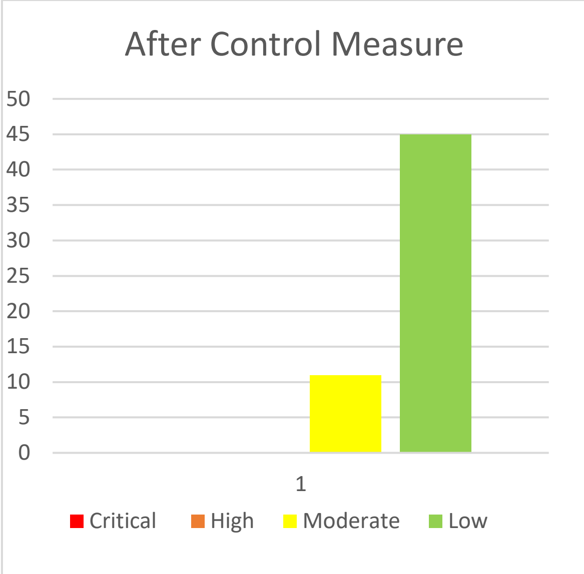


Fig 4.4 Reduced extreme and high-risk rating to acceptable limit after the implementation of control measures

From Risk Matrix (Fig. 4.2), out of the total identified hazards, P1 i.e. accidents during use of piling rigs was identified as critical, 22 hazards were identified as high risk which are shown in orange in the risk matrix these are, L1, L2, EL1, EL2, EL4, P5, H3, H5, E1, E5, EL3, W5 PL1, P2, P3, S6, DW1, W1, W2, S2, HK1, and HK3. Risk identified as critical and high was significantly reduced by applying measures of control and continuous review and monitoring. These hazards have their risk rating in the range of 11 to 18. Out of all the hazards, 30 were identified as moderate risk L3, E3,C1, H2, E4, L4, L6, C2, E2, C3, D1, DW2, H1, M1, M2, M3, PL2, F1, P4, S1, S3, S4, S5, EN2, W3, W4, EN1, EN3, EN4, and HK2 having the risk rating in the range of 5 to 10 and three of them were identified as Low risk namely H4, L7, and L5. These risk on application of control measures were significantly brought down and the residual risk after the application of control measures (table 4.1). 11 risks were in the moderate rating E3, L1, L2, L3, C1, EL1, EL2, EL4, P1, P5, and DW1which require further monitoring and 45 risks were in the Low risk rating.

After the risk assessment, out of the total 30 moderate hazards 27 were brought down to Low risk level, and remaining three remained in the moderate risk category. High risk rating before application of control measures were 22 and after application of control measures 16 of them were reduced to Low risk rating, and remaining was converted to moderate. Likewise, 1 critical risk was brought down to moderate risk rating.

On basis of the average risk rating for all the activities (table 4.2), two of the most critical activity having the highest likelihood to cause severe injury/damage is piling and diaphragm wall construction process (Average Risk Rating= 13.6) and during the site electricity works or due to the negligence in handling or unsafe practices (Average Risk Rating 14.25). Detailed control measures (Table 4.1) for these two activities are mentioned. Therefore, the use of Hazard Identification and risk assessment process and the use of matrix method to analyse these risks gave us an insight to prioritize this risk and control/ eliminate them on basis of their criticality.

4.2 Statistical Analysis

To confirm the observation that Statistical analysis was done using GraphPad's website ("T test calculator", 2022). For this test *P* value < 0.05 was considered as significant. (Table 9).

Table 4.3 Statistical Analysis of Risk reduction after control measures.

	n	Mean	Standard Deviation	Standard Error Mean
Before control measures	56	10.23	3.52	0.47
After Control Measures	56	3.54	1.04	0.14
Difference		6.70		
The mean of Before Control Measures Minus After Control Measures equals 6.70; 95% confidence interval of this difference: (5.88 - 7.51); *t*-value: 16.5239; Degree of freedom (df): 55; The two-tailed P value < 0.0001 this difference is regarded very statistically significant by conventional criteria.				

For the 56 possible hazards that were identified, Outcomes from paired-samples *t*-test show that mean value of risk rating before taking control measures was M= 10.23 and the standard deviation, SD = 3.52 and after taking the control measures mean of risk rating was significantly reduced to M=3.54 and the standard deviation reduced to SD=1.04 at the significance level of 0.0001 ($P < .0001$, $t = 16.5239$, Degree of freedom $d_f = 55$, $n = 56$, 95% Confidence Interval for mean difference is form 5.88 to 7.51). After implementing control measures, the risk was reduced by around 6.70 points on average. So as per the calculation of the *t*-Test the risk has been brought down to a Low risk level. Also, the 95% confidence interval for the Risk Rating difference is 5.88 to 7.51 which again is in the moderate zone and shows a better risk control in terms of health safety and environment can be done at a construction site using the Hazard

Identification and Risk Assessment process and establishing control measures as a part of the study helped in bringing down the residual risk in the acceptable zone.

4.3 Discussion

It was discovered in this cross-sectional investigation that by implementing mitigation strategies, high risk rating hazards might be lowered to an ALARP level. The implication of the findings was that conducting a regular Hazard Identification, Risk Assessment, and Control Measures (HIRAC) study can help in lowering the risk of injury or any kind of accident in the construction industry. The construction sector's key pillar is Health, Safety, and Environment (HSE), and it is necessary to keep in mind that unsafe and unhealthy environment at workplace is expensive from every aspect, especially in these challenging economic times. Furthermore, case studies suggest that strong Occupational Safety and Health management is related to better results and profitability of an organisation. There are 3 ways for the analysis of risk. They are:

- Qualitative
- Semi-quantitative.
- Quantitative

Semi-quantitative risk assessment goes one step ahead of qualitative risk assessment by assigning values or multipliers to the likelihood and outcome groupings. However, semi-quantitative risk assessments are now commonly employed to address few drawbacks of qualitative risk assessments. It could also entail frequency levels being multiplied. There is no way to completely remove all risks. For hazards rated critical or high, immediate action is necessary, which may involve directions to stop working or isolate the danger till permanent remedies are installed. For moderate risks, documented control plans with roles and completion deadlines must be prepared.

4.3.1 Measures Taken to Prevent the Risk

Preventive measures are introduced in the process to minimize any injury at workplace or reduce the possibility of accident at work.

The following measures were used :

a. Controlling risk through engineering

- Remove – Any equipment that is unsafe for the standards of health of the working space or the organisation should be avoided during construction.

- Reduce – Facilitating the workplace by installing exhaust fans, can reduce the level of risk.
- Replace – Any equipment or tool that possess high-risk must be replaced by low-risk equipment.

b. Control by the administration

- Employee training – The employees must be aware of the risks involved, their harmful effects and the mitigation measures.
- The workers must be instructed for each activity performed.

4.3.2 Measures for the Protection from the Risk

a. Enclose the hazard

- Isolation of the hazard by using protective tools, machinery, guards etc.

b. Avoid the engagement of human

- Putting up barriers such as thermal, electrical, acoustic etc.

c. Enclose the individual

- To protect the worker from the remaining risk, Personal Protective Equipment (PPE) kit can be used (Fig 3.2)

4.3.3 Measures to Mitigate the Risk

A work accident or occupational sickness can occur when preventative and preventive measures do not work. The organization must be equipped (emergency readiness) and mitigating measures must be in place. Preventive methods are intended to lessen the degree of any property damage as well as risk to employees (Nunes, 2022).

4.3.4 Environmental monitoring and measures

The major goals of occupational exposure are as follows:

- To find out the degree of exposure of employees to harmful substances
- Assessment of the requirement to control the hazard, and
- Assuring that the control measures used are efficient enough.

To control dust, an air cannon will be utilised on the job site. During the management of excavation dirt and debris, or during dismantling, the contractor must spray water to reduce dust. When dust is anticipated to be formed during the transport and handling of all aggregate, sand as well as other comparable products, efficient water spraying must be done to saturate all stored goods, during dry weather conditions, with water. To control Noise Pollution, DG set should be kept in an enclosed box, Earplug shall be provided to person working in noisy area. Use of well-maintained machinery at site. Equipment/ Plants to stop when not in use. It will also aid in reducing the air pollution in addition to noise control.

To manage waste any uncontrolled emission shall report immediately use of coloured bins for segregating waste. Discharge of toxic, corrosive or flammable substance in to public sewage system is prohibited. Also, Housekeeping to be maintained at site to avoid the spread of any communicable diseases, spread of mosquito due to ponding and collection of water as a result of curing or in some cavities. Housekeeping is also necessary to make sure sharp nails are removed from the ground which may result in injury.

4.3.5 Trend Analysis

By documenting injuries and illnesses related to work, the Workplace Injury and Illness Trend Analysis Program aims to uncover unhealthy or hazardous environments. This data is used to focus on occupational health and safety education at workplace to put in efforts in order to avoid any further work-related accidents/illnesses among employees. Following attributes are involved in the Workplace Injury and Illness Trend Analysis:

- Monitoring of current workplace injuries and illness
- Classifying injuries and illnesses according to their kind, bodily part affected, occurrence or exposure, etc which is notified in Hazard identification and risk assessment table (table 4.1).
- Evaluating the trends in occupational injuries and diseases and if possible, plotting those trends on graph.
- Identifying any devices, products, or environmental elements that are frequently involved in work-related injuries or illnesses
- Finding out solutions, suggestions to minimize or prevention of possibility of any further work-related illnesses or injuries.

4.3.6 Monitor and review

Regardless of the approach chosen to eliminate or control the risk, an assessment of its influence on the use of the equipment, material, method, or environment is required to ensure that the solution does not lead to the current hazard or create a new hazard. It is also critical that everyone involved is told about the modifications and, if necessary, given proper information, training, and supervision to assure that each employee is protected against injury and health risks. It is also advised that the area supervisor conduct an assessment of the system or control frequently to find out its continued usefulness.

CHAPTER 5
CONCLUSION

Assessment of Health, Safety and Environmental Risk is very important for the success of any industry. In particular for a construction project, due to complexity and uncertainty involved. Therefore, defining and analysing dangers is the initial stages is the primary step for emergency preparedness and providing a safe workplace. Even though all threats should be handled, resource constraints frequently prevent this from happening all at once. Hazard identification and risk assessment can be used to prioritise so that the most dangerous circumstances are dealt first, followed by those that are less likely to take place and cause severe issues.

The study along with the results, concludes that in the S-Block, High Court building construction project, total 56 hazards were identified and for each hazard control measures were given as per the standards. It was observed that risk can be brought down by applying appropriate control measures. Here in this study 100 percent of the critical risk were brought down to moderate level, and 72 percent of High risk were reduced to Low risk by the effective implementation of the control measures. Out of all the activities, the risk associated with the process of handling electrical work was the highest followed by diaphragm wall construction. In both the cases there is a possible risk of fatality or causing severe injury. Therefore, it is advised for every construction project a detailed Hazard Identification, Risk Assessment and Control study must be undertaken. This aids in the achievement of three goals as follows:

1. Identifying important and high-risk hazards, which has been covered in Chapter 4 that must be addressed as soon as possible
2. Prioritize the risk based on their risk rating.
3. Reducing the risk to an ALARP level by implementing control measures as soon as possible.

The discussion revealed that future research directions could be in the following areas to achieve a holistic approach to resolving the environment health and safety issues related to a construction project:

- Investigating the link between employee behaviour and the safe workspace.
- Implementing awareness programmes involving safety issues, to improve workers' ability to defend themselves from accidents or injuries.

- Establishing an informative database for categorising the safety risk of different operations according to levels of the project.
- Conducting accident investigations to gain a better understanding of the cause of the disaster; and
- Using a single or a combination of ICT tools to improve the safety of a worker throughout the project lifetime, feasibility study for the application of wearable safety gadgets for the workers to continuously monitor their safety.

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