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Research Article

Analysis of Safety Management in Precast Construction Projects

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Abstract: Construction is the second-largest economic activity in India, next to agriculture. Construction workers constitute 7 to 8% of the world's labor force and this figure may be as high as 15 to 20% in some countries. Construction is one of the important economic activities in India. The construction industry offers employment opportunities to all people from highly skilled to unskilled labourers. At a construction site, several people work at the same time at the same different levels. Workers, machines, overhead cranes, all should have to work in a congested area. The work should be carried out at a tremendous speed. Thus, construction work is hazardous by its nature itself. This study will try to put safety management in construction projects as one of the important elements to project performance and success. The study will also emphasise the awareness and importance of safety management in a construction project. Injuries and fatalities resulted in accidents in the construction industry.

Keywords: Safety management, precast projects safety practices, PPE.

1. INTRODUCTION

Construction is regarded as one of the most dangerous industries on the planet. Every year, the number of buildings constructed for commercial, residential, and office reasons has increased. In a construction project, safety management is a critical component that must be addressed to maintain worker health and safety while also promoting productivity.
Risk exposure is higher in this industry than in any other. Poor construction planning, a lack of safety equipment, a lack of safety training, worker conduct, and a lack of understanding of site rules all contribute to high accident rates. Construction workers in India have the highest accident rate in the world.
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The goal of this study is to make safety management one of the most significant aspects of project performance and success in building projects. The study will also underline the necessity of safety management in construction projects and raise awareness of it.

2. LITERATURE REVIEW

According to S. Kanchana, P. Shivaprakash, Sebastian Joseph (2015), the Main Cause of Construction Accidents occur due to inappropriate use of Construction Equipment, inadequate knowledge of safety norms, poor construction management, and negligence of senior authority on-site and even by workers.
According to Chandan Mehra, S.M. Abdul Hussain, Asra Fatima (2016), most large firms do have a safety policy, on paper, but employees generally are not aware of its existence. The construction projects get delayed due to loss of working hours and other legal hassles. This ultimately accounts for cost and time overrun.
According to Mingyuan Zang, Tianzhuo Cao, Xuefeng Zhao (2017), it is realized that construction safety management should not be limited to merely the construction phase, but gradually proceed during the full building life cycle, conducting a comprehensive and thorough safety management.
According to Arif. H, Devadarssinni, Ashok Kumar, (2020) Internet of Things (IoT) devices and sensors are gathering job site data in a cheaper, efficient, and effective way than before imaginable. IoT allows for the information of a digital real-time job site map alongside the updated risks related to the works and notifies every worker when getting closer to any risk or entering a hazardous environment.

According to Ashok Arjun Avhad, Dr. G.A.Hinge,(June 2017) VR can be Used during various Phases of Construction projects for Safety Purposes and to Check on Overall Ongoing Work on Site.
According to J Teizer, framers for right time vs real-time construction safety and health presents the specific focus on assisted safety and health data gathering, analysis, and reporting to achieve a better safety performance.

3. RESEARCH OBJECTIVES

- To Identify and Evaluate Various Causes of Accidents on precast Construction Site
- To Carry out Site Survey with the help of Questionnaire to rank the Causes of Accidents
- To Suggest and Implement Advanced Construction Safety Solutions
- To Prepare Safety Plan for Precast Construction Site.

4. RESEARCH SCOPE

- The scope of the research project is to explore safety and control measures in pre-cast construction projects in India by questionnaire surveys of different precast projects in different parts of the country mainly focusing on projects of Pune and Mumbai.
- The actual implementation of advanced construction safety practices and methodologies practiced in western countries in the Indian construction industry. Implementation of cost-effective yet impactful safety tools on every construction site in India regardless of their scale of operation.

5. RESEARCH METHODOLOGY

The study was carried out on three pre-cast construction projects which consisted of Pune Maha Metro, ML Towers - Millennium Business Park at Navi Mumbai, and 6 Laning of Pune - Satara Highway, and required data was collected and analysed.

A structured questionnaire was used for this research. The questionnaire aimed to collect a wide range of opinions from the experienced professionals working in these construction sites and analyse the recorded data. The survey questionnaire was distributed amongst various stakeholders of the projects such as the Engineer, Project Manager, Construction Manager, Jr Engineer. To understand and analyse the best strategies and issues about safety management in construction projects a structured questionnaire tool for research methodology was used.

Respondents were asked to rate the common causes of pre-cast site accidents based on their occurrence and severity of the accident. They were supposed to rate on a scale of 1 - 5 with 1 being very low and 5 being a very high entity.

6. DATA COLLECTION AND ANALYSIS

Based on the study of various literatures some of the most common causes of accidents on Pre Cast Construction sites are mentioned below.

6.1 FALL FROM A HEIGHT

The main hazards working above a certain height are people falling and heavy objects falling leading to serious injuries occurring due to unsafe practices, inadequate edge protection, and negligence in the use of adequate PPE.

6.2 CRASHING OF PRECAST ELEMENTS

Fall of prefabricated elements such as girders, shear walls while lifting may cause serious damages to the elements and can be harmful to the workers around. This can be caused due to slips that occurred during lifting the elements.

6.3 NEGLIGENCE BY WORKERS

Unsafe work practices, unethical workplace behaviour, and ignorant attitude of the labourer may lead to serious accidents on site, and loss of life and resources may occur.

6.4 FAILURE TO USE RECOMMENDED PPE

Improper and Inadequate use of PPE may lead to injuries and can cause fatalities to the construction professionals due to falling from a height, struck by an object, contact with hazardous substances, electrocution.

6.5 UNSAFE DESIGN AND POOR CONSTRUCTION PRACTICE

Falls including persons and structures from a height represent the most serious safety risk to the pre-cast construction industry. Many of these falls occur due to unsafe workplaces and poor construction works.

6.6 STRUCK BY A VEHICLE

Vehicular accidents are one of the most fatal which involves a collision between construction vehicles such as crane, bulldozers, JCB, Trucks, and working professionals on site.

6.7 DISMANTLING OF HOOKS AND WIRE ROPES

These incidents occur during the lifting of goods and prefabricated elements with the help of hoists and cranes and can lead to serious consequences due to unexpected falling of the goods and elements from a height.

6.8 CRASHING OF REINFORCEMENT CAGES

A reinforcement cage is used to provide stiffness to the structure and is used in the casting of elements such as pillars. Since these cages weigh in tones collapse of these cages in between the activities could lead to severe injuries to the staff working and even pedestrians in some cases. Poor construction technique and negligence are amongst the main causes for such incidents.

6.9 OPERATION OF HOISTS AND TRACKS WITHOUT PROPER COMMUNICATION

Accidents on site can happen due to negligence and miscommunication amongst the hoist & crane operator and the instructor causing damage to the lifted goods and can prove injurious to the working personnel around them.

6.10 HOIST CABLE BREAKAGE

This type of accident leads to the breaking of the main hoist rope while lifting goods due to internal fracture and many other reasons and may lead to loss of life and resources and may cause undue delay in the project.

7. DATA ANALYSIS

Respondent's data was collected and analysed. The analysed data is displayed in a table and a bar graph is designed concerning the data corresponding.

From the collected data, the Occurrence index OI and Severity Index have been calculated for the various reasons causing an accident. There were 10 respondents combined including site engineers and construction managers of the three projects we collected data from.

7.1 OCCURRENCE INDEX (OI)

The occurrence index calculated is the probability of an accident to be occurred due to the corresponding reason. The formula for calculating the occurrence index

$$\mathbf{OI = \Sigma W/ (A*N)}$$

Where W is the weightage given to each factor by the respondents (1 - 5), A is the highest weightage which is 5 in our case and N is the number of respondents which is 10.

7.2 SEVERITY INDEX (SI)

The severity index calculated specifies the severity of the accident caused due to the corresponding reasons mentioned. The formula of severity index is the same as of occurrence index.

7.3 RELATIVE IMPORTANCE INDEX TECHNIQUE (RII)

It is used to determine the relative importance of the various causes and effects of delay in a construction project. The RII can be calculated as the multiplication of occurrence index and severity index.

RII = OI*SI

8.RESULTS

From the data collected and analysed following critical reasons were identified for causing accidents on precast sites and they are ranked according to their relative importance index RII.

Following are the notations depicting the critical reasons causing accidents.

NOTATIONS

A = FALL FROM HEIGHT

B = NEGLIGENCE BY WORKERS

C = CRASHING OF PRECAST COMPONENTS FROM A HEIGHT

D = DISMANTLING OF HOOKS AND WIRE ROPES

E = HOIST CABLE BREAKAGE

F = OPERATION OF HOISTS AND TRACKS WITHOUT COMMUNICATION

TABLE 1. CRITICAL REASONS CAUSING ACCIDENTS

S.NO	CRITICAL REASONS	OI	SI	RI	RANK
1	A	0.84	0.80	0.68	1
2	B	0.78	0.82	0.64	2
3	C	0.72	0.74	0.54	3
4	D	0.76	0.66	0.50	4
5	E	0.70	0.62	0.44	5
6	F	0.62	0.64	0.40	6

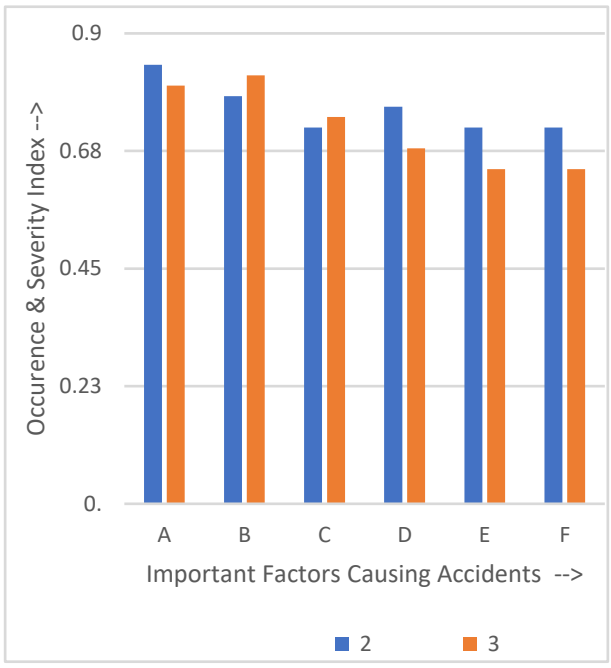

FIGURE 1. OI & SI FOR IMPORTANT ACCIDENTAL REASONS

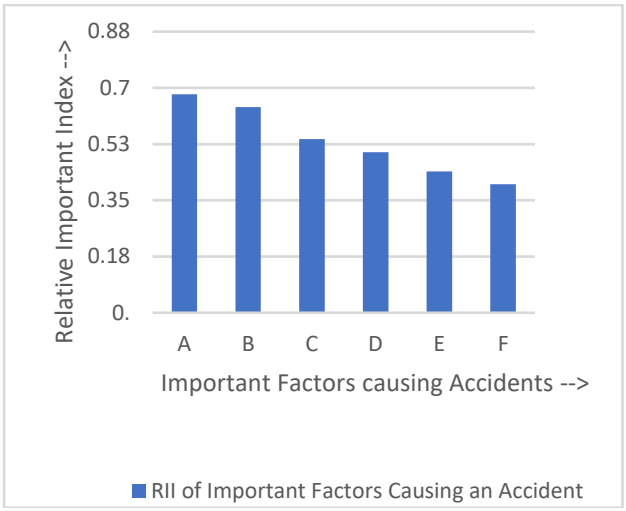

FIGURE 2. RII OF IMPORTANT FACTORS CAUSING ACCIDENTS.

9. SAFETY MANAGEMENT AND RISK MITIGATION TECHNIQUES

To minimise the risk of accidents on pre-cast sites various safety management plans should be proposed and executed. To avoid the risk of accidents due to the above-mentioned critical reasons and to create a safe working environment various mitigation techniques and advanced safety management technologies must be executed.

9.1 FALL FROM A HEIGHT

9.1.1 SAFETY PROCEDURES:

1. A thorough safety hazard inspection is the first step in preventing falls on a job site.
2. Following OSHA rules, determine the load-bearing capability of each place on-site, potential tripping hazards, unprotected edges, and places of excessive noise.
3. Workers are being educated and updated on fall prevention policies and the use of fall arrest equipment following OSHA rules.
4. Guardrails that are sturdy enough to prevent a fall must be built into a safe working platform.
5. When working on a high platform, wear appropriate PPE.
6. Before beginning work, any spills on the working platform must be cleaned quickly.

9.2 NEGLIGENCE BY WORKERS

9.2.1 MITIGATION TECHNIQUES :

1. Workers and staff are subjected to routine medical examinations to acquire records on their physical health.
2. Labourers' safety training and workshops are conducted regularly.
3. Workers are not allowed to enter the site unless they are wearing suitable PPE.
4. Higher authorities inspect the safe work procedures followed by the workers regularly, requiring the labor contractor to follow a safeguarded and safe work process with the employees.

9.3 CRASHING OF PRECAST COMPONENTS FROM A HEIGHT

9.3.1 MITIGATION TECHNIQUE

1. Concerning the elements to be hoisted, the use of appropriate hoists and cranes is required.
2. Rigging and hoisting should only be done on the material that requires novel or one-time handling techniques.
3. Workers must identify load weights and balancing points as part of the rigging procedure.
4. Smaller 2 to 10-ton Jib cranes can be mounted to a vertical column built into the plant's construction to allow for easy up/down and back/forth movement.
5. When space is restricted, a jib-connected forklift can be used as a tiny crane.
6. Vehicle safety inspections should be performed regularly by certified personnel.
7. Only operators who have been extensively trained and tested should operate the crane, and their competency should be demonstrated before any actual work begins.
8. On the ground, workers must keep a safe distance from the crane and the products being lifted.
9. To avoid mishaps, barricade the crane's swing radius.

10. Equipment should be maintained regularly.

11. Ensure that no unsecured wood blocks or short-length steels are transported on top of loads.

9.4 HOIST CABLE BREAKAGE

9.4.1 SAFETY TECHNIQUES

1. Never overload the crane above its rated capability.

2. Ropes and slings must be kept free of sharp bends, pinching, and crushing. Slings should be protected from sharp edges or corners of heavy loads by using corner saddles and other soft materials.

3. Ensure that wire rope or chain is never left on the ground for an extended period, on a wet surface, or in the presence of corrosive substances. They should be looped and hung from a rack so that they do not touch the floor.

4. Ensure that the hoist rope is never entirely wrapped around the hook or the cargo.

5. All riggers should receive proper training in safe working methods.

6. Rope slings should not be draped from beneath the weight.

7. Keeping all ropes and chains out of the way of flame cutting and electric welding.

8. Using guide ropes or tag lines to keep the load under control.

9.5 DISMANTLING OF HOOKS AND WIRE ROPES

9.5.1 MITIGATION STRATEGIES

1. The load should be rigged so that it is stable in the hook's saddle.

2. The worker should be aware of the rigging equipment's safe load restrictions, which must not be exceeded. Tags can be permanently attached to each sling, rope, and chain to do this.

3. Slings or other rigging devices that are appropriate for the load being lifted are used to secure the weight to the hook.

4. Before lifting goods with one leg, secure the unused legs of a multilayer sling.

5. Ensure that the running rope is not rigged against the pin, allowing it to spin out and drop the load.

6. Using spacers to provide correct load/shackle alignment.

7. All hooks, wire ropes, and shackles must be properly maintained and inspected.

8. Lifting and load positioning precision is adequate.

9. The intended path of the load to be moved in the shortest amount of time.

10. All swivels should be able to rotate freely.

11. Assuring that all of the equipment's walking surfaces are clean and free of grease and oil.

12. Safety latch hooks are used.

9.6 OPERATION OF HOISTS AND TRACKS WITHOUT COMMUNICATION

9.6.1 SAFETY MEASURES

1. A powerful audio warning signal is situated outside the crane's cab, with controls conveniently located for the operator.
2. Both sides of the equipment should have rearview mirrors.
3. Nighttime operation requires adequate lighting, including backup lights for mobile units.
4. The crane operator must remain focused on the crane operator at all times.
5. A crane in motion or operation should not be allowed to carry passengers.
6. Should not back up the crane unless it is certain that no one will be hurt.
7. If the eyesight is not clear, a signalman should be used while moving the crane.
8. Before moving the crane, sound an audible alarm.
9. When a hanging weight is nearing the personnel, sound an audible alarm to give them adequate time to find a safe place.
10. Hand signals must be used in a standard manner. The load should not be picked until the signal from the signalman has been received.
11. The operator must be able to understand all signals. If in doubt, the operator should halt the operation and wait for unambiguous signals.
12. The operator's signalman should be professionally certified, and no one else should be authorised to undertake the job.
13. To avoid any confusion, the crane operator should only receive signals from one individual.
14. To increase visibility, the signalman should wear orange gloves while signal.
15. When a load is suspended, crane operators must maintain control.

10 USE OF ADVANCED CONSTRUCTION SAFETY MANAGEMENT TOOLS

The world has seen gigantic changes in a wide number of elements throughout the twentieth century and beyond, including a massive revolution in the building industry. To address the shortage of skilled labor, the construction industry has turned to technology to better recruit and retain new workers. The following are some of the advanced technologies that are used around the world and that can be promoted in India.

10.1 VIRTUAL REALITY IN SAFETY TRAINING SYSTEM FOR WORKERS

1. A learner can better grasp and memorise safety rules, standards, and regulations by navigating through VR surroundings and experiencing various scenarios. Streamlining aids in the creation of numerous working contexts. Furthermore, randomisation is incorporated in the suggested system since it allows for a huge number of scenarios to be created. Each scenario depicts the consequences of the worker's numerous decisions; the trainee can swiftly cycle through multiple options and see the result of those decisions (or at least the more likely outcome). This aids workers in making more informed judgments about safety and memorising rules.
2. Trainees can experiment and explore in a safe and controlled environment using virtual reality. Employees can experiment with the consequences of their decisions without endangering themselves or their equipment.

They can see what can't be seen: risk levels, temperature, air quality, chemical exposure levels, and their consequences.

3. Crane operators can realistically operate a crane and encounter a variety of challenging situations, which will help them improve their decision-making skills and deliver an acceptable reaction. Various sorts of crane operations can be carried out in a variety of conditions, allowing them to be carried out with confidence.

10.2 APPLYING SENSORS AND IOT TO IMPROVE CONSTRUCTION SAFETY MANAGEMENT

1. The building sector is bringing real-time data into procedures that have been in place for decades. Sensor-based technologies have aided the transition from experimental investigation to practical applications after nearly two decades of research.

2. Internet of Things (IoT) devices and sensors are gathering job site data in ways that were previously unimaginable in terms of cost, efficiency, and effectiveness. The construction site is now primed for significant changes that will boost productivity, safety, process efficiency, and provide new tools.

APPLICATION OF SENSOR TECHNOLOGY AND IOT IN CONSTRUCTION SAFETY

10.2.1 GLOBAL POSITIONING SYSTEM GPS

1. Satellites, ground control stations, and user receivers make up the global positioning system or GPS. It has been widely used in construction safety management because of its ability to provide 3D coordinates such as points, lines, and planes in a fast, precise, and efficient manner under all weather conditions.

2. With the aid of GPS, quality inspection and construction resource management can be accomplished.

3. Advanced suggestions for construction management and labor safety measures are provided.

4. Provides a unique training and education platform for workers' safety.

10.2.2 RADIOFREQUENCY IDENTIFICATION RFID

RFID stands for radio frequency identification, which uses radio waves to identify a specific target. It can read and write data without coming into touch with the identification system mechanically or optically. Tags, readers, and antennae make up RFID. RFID is frequently utilized in construction safety management because it can precisely find single or multiple targets in static or dynamic indoor environments.

Can be utilized to create an unintended forewarning system.
RFID can provide a strong platform for real-time safety monitoring in hazardous areas.
The systems can be used for quality inspection when combined with other sensor-based technologies.

10.2.3 ULTRA-WIDEBAND

Ultra-wideband (UWB) is a wireless positioning mechanism that has only just been created. In the realm of wireless indoor positioning, it offers a lot of potentials.
UWB uses ultra-wideband signals, which have a wide spectrum range and are appropriate for high-speed and short-range wireless transition.
The following are some of the applications of UWB in construction safety.

1. Heavy machinery collisions should be avoided.

2. It forecasts the movement of machines and workers.

3. UWB protects workers from inadvertently entering harmful zones and tracks their harmful conduct.

4. Crane drivers can benefit from UWB. To improve the driver's context awareness, the labels at critical places on the crane were used to predict the crane's route and trajectory.

APPLICATION OF WIRELESS SENSORS IN CONSTRUCTION SAFETY

10.2.4 TEMPERATURE SENSORS

Shrinkage crack monitoring for mass concrete construction, concrete curing, aided management for winter construction and freezing technique construction, and temperature monitoring of structural components for enhancing installation accuracy are some of the most common uses for temperature sensors.

10.2.5 LIGHT SENSORS

Light sensors are mostly used for nondestructive testing of structural components such as concrete structures, pile foundations, steel structure welding seams, and so on.

11. SAFETY MANAGEMENT PLAN FOR PRECAST PROJECTS

The essential aspects of safety program management are presented in this article. It lays forth criteria for evaluating current safety programs and recommends the introduction of key features that demonstrate safety as a management function.
There are three sections to the safety management plan.

1. **Preliminary evaluation of the current safety program**
2. **The fundamentals of a safety program.**
3. **The safety program's post-evaluation is inferred.**

11.1 PRE-ASSESSMENT OF CURRENT SAFETY PROGRAM

Before designing and creating a new plan, management should review the company's and project's present safety management plan. An assessment of the current state of safety will aid management in identifying flaws and implementing the necessary changes and additions in their new strategy. This will aid in identifying the flaws in the current management strategy and providing solutions.
It is necessary to assess the following basic parts of the safety program:

1. MANAGEMENT LEADERSHIP
2. RESPONSIBILITY ASSIGNMENT
3. IDENTIFICATION AND HAZARD CONTROL
4. EMPLOYEE TRAINING
5. REPORTING ACCIDENT AND INVESTIGATION
6. EMERGENCY PLANS

BASIC COMPONENTS OF A SAFETY PROGRAM

It is difficult to develop a safety program that will apply to all precast concrete factories because each company's needs are different. A safety program must be tailored to a company's specific processes and operations. Management is now responsible for designing and defining a program within the restrictions of a certain plant's operations. A safety program, on the other hand, should include parts of the following fundamental elements:

- **MANAGEMENT LEADERSHIP**

Management's commitment to employee safety must be genuine and obvious. As a result, senior management must set realistic safety program goals and communicate them to all personnel. The goals of the safety program should be scrutinized by management in the same way that the goals of quality, cost, and production are scrutinized. Management must plan, coordinate, and control the overall program once the objectives have been determined.

- **RESPONSIBILITY ASSIGNMENT**

Employees' dangerous conduct and harmful working circumstances are the responsibility of management. Finally, the project manager is responsible for ensuring that the project's safety program objectives are met.

Because project sizes and organizational structures vary so significantly in the precast concrete products business, safety duties must be assigned following the project's management structure. In minor projects, the owner/operator may be the only person in charge; in larger projects, the plant manager, middle managers, and first-line supervisors are in charge.

- **HAZARD IDENTIFICATION AND CONTROL**

A concerted management effort to eliminate long-standing dangers and create a safer workplace might persuade employees that management cares about their safety on the job. However, before these dangers can be eliminated, management must first identify them.

The detection of dangers necessitates a thorough examination of all precast operational areas. To avoid interfering with normal work routines, the hazard identification process should be done in stages.

Checklists for safety inspections may aid in directing the group's inspection to the locations with the most dangerous work exposures. Following the initial inspection, a plan should be put in place for rectifying the defects found and conducting subsequent inspections.

- **EMPLOYEE SAFETY TRAINING**

Employee training is the most important aspect of a safety management program in terms of importance. Each employee must get specific training, including supervised on-the-job training. Working at a rebar bender, casting concrete, or operating a forklift, for example, may require training to develop a specific skill that cannot be performed safely without precise understanding. Safety training is founded on the premise that cultivating a positive mental attitude leads to the development of safe work and conduct habits. Checklists for safety inspections may aid in directing the group's inspection to the locations with the most dangerous work exposures.

- **REPORTING ACCIDENT AND INVESTIGATION**

Accident investigation is an important component of a safety/accident prevention program.

It pinpoints the causes of accidents so that similar incidents can be avoided through management actions such as mechanical upgrades, improved monitoring, or personnel training.
It identifies the "changes" or deviations that resulted in an "error" that resulted in an accident; it alerts employees and supervisors to the specific hazard, and it focuses attention on accident prevention in general.

Because unreported incidents teach us nothing, even small injuries and near misses should be examined. All levels of management are responsible for accident investigations. A witness may be able to clarify some of the events around the accident better than the wounded individual, especially if the injuries are mild. Through inquiries, all levels of management can learn how to prevent accidents.

- **EMERGENCY PLANS**

In the event of an emergency, such as an employee injury or a fire, management should have a written plan in place. The plan's goal is to clear up as much misinformation as possible so that an immediate constructive response can be taken to reduce the emergency's dangers.

The strategy should incorporate the following elements:

- Exits, fire extinguisher placement, and egress routes are depicted in diagrams.
- Procedures for notifying authorities about fires and other emergencies
- Emergency phone numbers for ambulance, doctor, hospital, fire, and police are required to be posted.

- Drill and training requirements
- First-aid treatment is provided.

11.2 POST ASSESSMENT OF THE SAFETY MANAGEMENT PROGRAM

The major goal of evaluation is to ensure that all levels of management are following the safety program effectively and appropriately. After any additions or changes to a safety program have been implemented, a post-assessment is conducted.

The purpose of the program's post-assessment is to:
- Identify severe flaws in the program's applications.
- Determine whatever corrective measures are required to improve the program's quality.
- Encourage supervisors and middle managers to apply for the safety program.

The following aspects of the program should be evaluated:
- Investigations into accidents
- Hazard management
- Conduct safety inspections and provide training in the area of safety.
- Management participation

12. CONCLUSION

Analysis of the data collected through the questionnaire survey and comparative study of the available works of literature helped in obtaining 10 important reasons responsible for accidents on precast construction sites. The results from the thesis concluded the six critical reasons responsible for on-site accidents which include fall from a height, negligence by workers, crashing of pre-cast components from a height, dismantling of hooks and wire ropes, hoist cable breakage, and operation of hoists and tracks without communication. Mitigation techniques were suggested for the above critical reasons which helped to minimise the hazards caused by them by 65% on pre-cast construction projects. Advanced technologies such as Virtual Reality and Sensors were proposed in the management of safety in these construction projects which will help the company and project mitigate the risks of hazards by 70% and a safe working environment can be created. A detailed safety management plan was proposed which will help the companies upgrade their safety policies on particular projects which will contribute to the reduction of accidents and mishaps on-site by 80%.

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