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An Investigation into Improving the Safety of Material Handling Equipment in the Construction Sector through Engineering Interventions and Safety Training

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Abstract*: Construction sites are widely recognized as high-risk environments for workers, often associated with frequent hazardous incidents and a higher rate of fatal accidents. Numerous studies have identified that a significant proportion of these accidents occur during material handling operations. Although many construction sites adopt various safety measures to create a secure working environment and reduce injuries, these efforts often fall short. A key issue is the lack of awareness among equipment operators regarding potential workplace hazards. Many of the incidents stem from inadequate safety protocols, resulting in both minor and major injuries.*

To address these challenges, it is essential to integrate several factors into modern construction practices, including advanced equipment, proper resource allocation, and effective overall management. Ensuring safety on construction sites requires the implementation of robust safety frameworks and the involvement of trained professionals with substantial expertise.

This research analyzes safety management practices on construction sites using questionnaire-based surveys, specifically focusing on the safety of material handling equipment. The survey was conducted across small-, medium-, and large-scale construction sites. Based on the findings, two sites were selected for implementing a safety awareness program aimed at enhancing worker safety in material handling operations.

The program was structured into three modules: general worker safety, equipment inspection, and safe material handling practices. Workers' knowledge was assessed both before and after the training, and a t-test analysis was conducted to determine the effectiveness of the safety education program. Based on the results, recommendations are proposed to further improve safety standards on construction sites.

Keywords: Hazard; risk; engineering control; Safety inspections; material handling; construction safety; safety management system; NIOSH; OSHA;PPE: training etc.

I. INTRODUCTION

1.1 Present condition of Indian construction sites

The Indian construction industry is one of the fastest-growing sectors, significantly contributing to the country's GDP and employment. However, despite this growth, the present condition of construction sites in India presents a mixed picture of progress and persistent challenges. Technological Advancements-Use of Building Information Modelling (BIM), drones, prefabrication, and automation is increasing in urban projects and Smart cities and green building initiatives are encouraging more efficient, Eco-friendly construction. Government Initiatives-Initiatives like PM Awas Yojana, Smart Cities Mission, Gati Shakti, and Make in India have boosted infrastructure development. And labour codes and RERA (Real Estate Regulatory Authority) aim to formalize and regulate the sector better. Improved Safety

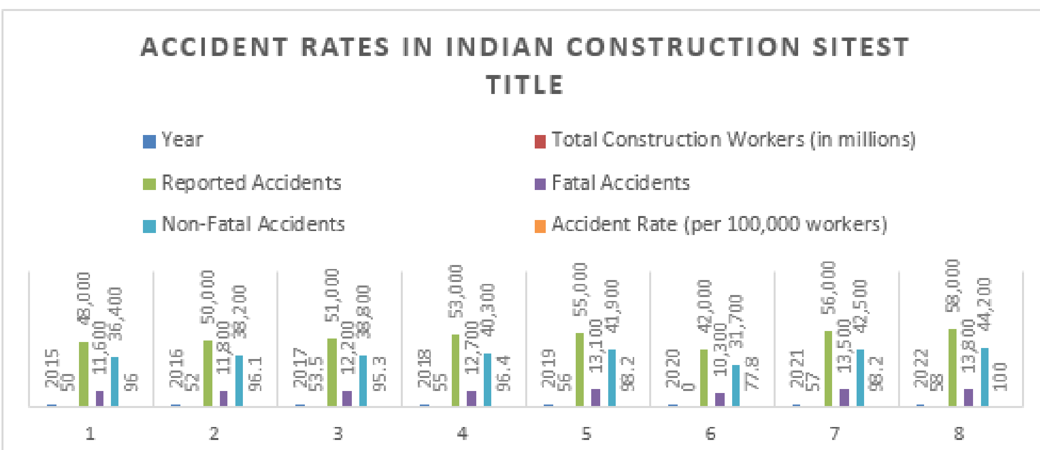
Awareness (Urban Areas)-Large firms are adopting better safety gear, signage, and training. Some tier-1 projects now follow international safety protocols.

1.2 Accident rates in Indian construction sites

Here is a table showing accident rates in Indian construction sites based on reports from the National Crime Records Bureau, Ministry of Labour, and academic studies.

Table: Accident Rates in Indian Construction Sites

Year	Total Construction Workers (in millions)	Reported Accidents	Fatal Accidents	Non-Fatal Accidents	Accident Rate (per 100,000 workers)
2015	50	48,000	11,600	36,400	96
2016	52	50,000	11,800	38,200	96.1
2017	53.5	51,000	12,200	38,800	95.3
2018	55	53,000	12,700	40,300	96.4
2019	56	55,000	13,100	41,900	98.2
2020	54 (COVID)	42,000	10,300	31,700	77.8
2021	57	56,000	13,500	42,500	98.2
2022	58	58,000	13,800	44,200	100



1.3 Safety management in construction sites

India's construction industry is one of the largest in the world, employing over 50 million people and contributing significantly to the country's GDP. However, it is also one of the most hazardous sectors, with a high rate of occupational injuries and fatalities. The dynamic, labor-intensive, and unorganized nature of construction work in India makes safety management a critical yet often neglected aspect. Although there are regulatory frameworks and growing awareness, safety management at construction sites in India remains a major challenge. There is a pressing need for stricter enforcement, better training, safety audits, and a stronger safety culture at all levels—from workers to developers—to reduce accident rates and improve occupational health in the Indian construction sector.

a. Nature of the Industry

- The construction sector in India is largely fragmented, with a significant portion operated by small and medium contractors.
- A large share of the workforce is unskilled, migrant, and informal, with limited training and awareness about safety practices.
- Rapid urbanization and infrastructure development often result in tight deadlines, leading to compromised safety standards.

b. Common Hazards

- Falls from height (scaffolding, ladders, incomplete structures)
- Electrocution from temporary wiring or ungrounded tools
- Collapses of excavations or buildings under construction
- Material handling injuries, crane accidents, and fire hazards

c. Legal and Regulatory Framework

- Governed by The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 (BOCW Act).
- Other applicable laws include the Factories Act, 1948, and Contract Labour (Regulation and Abolition) Act, 1970.
- Safety norms are prescribed by the Directorate General Factory Advice Service & Labour Institutes (DGFASLI) and National Building Code (NBC) 2016.

Despite these laws, enforcement is weak due to:

- Poor site inspections
- Lack of awareness among employers and workers
- Inadequate training and safety resources

d. Challenges in Safety Management

- Low safety culture among contractors and workers
- Limited use of Personal Protective Equipment (PPE)
- Lack of training and awareness on hazard identification and mitigation
- Poor record-keeping and under-reporting of accidents
- Fragmented responsibility—no centralized safety authority for construction sites

e. Recent Developments

- Increased emphasis on ISO 45001 (Occupational Health & Safety) standards
- Adoption of digital tools like safety audit apps and real-time site monitoring
- Government and industry initiatives promoting skill development and safety training (e.g., through the Construction Skill Development Council of India - CSDCI)
- Some large projects now adopt Behavior-Based Safety (BBS) and Inherently Safer Design (ISD) principles

1.4 Organization of the thesis

This research is presented in six chapters and 1 appendix with the next chapter consisting of the problem statement, briefing the problem considered. The third chapter discusses the available literature, briefing on the various problems taken up by authors and their methods of achieving efficient solution. Chapter four elaborates on the methodology of how the research work is being carried out in each step. Chapter five presents the results and discussions of the research

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work, which was carried out and the final chapter six, gives the conclusion for the research work with suggestions for further research. Appendix 1 presents the self-instructional set that was issued to workers.

1.5 Problem Description

Health and safety management at construction sites require qualified professionals with knowledge in administrative and engineering controls of safety for the equipment. Construction sites are regarded as one of the environments with higher levels of dangers to its employed workers and inadequate safety measures lead to accidents and uncontrollable occurrences, resulting in injury and property damage. Several studies have shown that most accidents happen during the material transfer process and hence, to curtail these occurrences, various elements need to be incorporated in the modern construction mechanisms such as equipment usage, personal protective equipment, and overall management.

a. Safety at Indian construction sites

Safety of material handling equipment (MHE) that are being used in construction sites require continuous and extensive studies to improve its safety controls. Each and every equipment has several built-in safety features differing from one manufacturer to the other. Further, the number of violations of regulatory safety requirements in Indian construction sites is on the increase by workers lack of knowledge on proper safety, defective equipment operation and irregular maintenance procedures. Also, human factors play a vital role in accidents caused by material handling equipment. To reduce the number of accidents, managements implement several safety measures to maintain a safe environment to the workers and protect them from injuries. But those measures are not sufficient, as most of the workers who operate MHE are not aware of the possible hazards around them and the necessary actions required to be taken to prevent those hazards.

Construction Site Hazards-According to occupational safety and health Administration, four big construction hazards are falls, electrocution, caught-in and struck-by accidents. Every year, workers die mainly due to struck-by accidents. Few other short-comings of safety at construction sites include,

i) Presence of working/walking areas below elevated work surfaces that expose workers to falling objects.
ii) Materials being moved overhead without safety precautions, exposing them to falling objects.
iii) Grinding or striking materials near working personnel creating hazard through flying objects.
iv) Pressurized air higher than 30 psi which drives oils and sharp particles through skin.
v) Walking, working or leaning under a crane boom when it is being dismantled or assembled.
vi) Working very closely to heavy equipment has potential of serious struck by hazards.
vii) Not wearing safety glasses or a face shields where flying hazards exist.
viii) Not using highly visible reflective vests to allow motorists and equipment operators to see workers‟ presence.
ix) Over lifting of the crane boom than the specified safety limit.
x) Workers in work zones being exposed to strike by hazards from construction equipment and motorist vehicles. Hence, proper safety arrangement is necessary.
xi) Improper maintenance of housekeeping in all storage areas.
xii) Lifting a load that is greater than the crane’s lifting capacity.
xiii) Operating the cranes beyond the safe operating limit near the overhead power lines causing electrocution.
xiv) Improper operation of hoists and not using sufficient protective equipment while working at height.
xv) Slings not having an identification number or a size and their maximum capacity not being listed on a flat ferrule or ring that is permanently attached to the sling.
xvi) Not listing the rated capacity for each type of hitch. If a choker is missing this tag, it must be destroyed immediately.
xvii) If it is a larger (more expensive) piece of rigging it can be retagged.

Pevention of construction site accidents- Accidents can be prevented with the implementation of safety management systems and its procedures at the construction sites. Florio et al (1979) expressed that it needs a systematic, explicit and comprehensive process for managing potential risks. Safety in construction sites deals with various areas such as

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excavation, scaffolding, work at height and manual and material handling equipment. The MHE safety is a science under research in the field of construction machineries, during operation or while assembly and disassembly. In future, it is necessary that the workers are trained to the required safety standards and make sure that those trained workers follow these safety procedures at the workplaces.

1.6 Methodology

Accident rates in Indian construction sites are serious despite the overall downward trend of accidents in recent years. Implementation and strengthening of safety management of MHE is a tough task and those MHE being used in construction sites require stringent and effective measures to improve on their operation safety. This research work is to study and analyze the safety management and the usage level of engineering controls in the construction sites through means of safety questionnaires for workers with specific reference to the material handling equipment in construction sites. To inculcate the cause of safety, a training program covering all the safety aspects related to the material handling equipment was conducted to 38 workers of two construction sites. Twelve safety modules from safety management system and engineering controls for the pre-program questionnaire were considered. Later, three descriptive modules focusing on construction safety were prepared and presented to the workers from which they were questioned again after the program to find out their safety knowledge level. The results obtained, were then statistically tested for significance through a t-test analysis.

1.7 Objectives of the research

The aim of this research work is to identify the hazards and risk assessment of safety systems and engineering interventions for the MHE workers such as crane operators and allied workers operating the MHE at construction sites and create an education of safety through an elaborate safety educational program. Since, construction sites are the most affected due to safety-related accidents, only the workers from the construction sites are selected. The main objectives of the research are as follows:

i. To ascertain the perception of a selected group of workers on the related work areas including, mobile crane operation, tower cranes, forklifts, heavy vehicles and its allied workers of different construction sites in India.

ii. To conduct a Hazard and Risk Assessment (HIRA) of safety management and engineering interventions for the engineering controls at the construction sites.

iii. To identify backlogs in various safety management systems and the level of management commitment in maintaining proper safety systems for the workers.

iv. Conduct questionnaire surveys among workers, calculate and analyse the knowledge level of workers about the standard safety procedures.

v. If the knowledge level is below the required level then the workers of those construction sites are to be involved in an elaborate safety education program.

vi. The aim of the program is to educate workers about the approaches and strategies for ensuring higher levels of safety and lower rates of accidents

vii. More specifically the following issues are taken for the above objectives.

a. To find out differences between hierarchical levels of workers in different dimensions related to safety.

b. To find out differences between levels of education among workers in different dimensions.

c. To find out differences between levels of age among workers in dimensions related to the research.

d. To find out differences different levels of experience among employees in dimensions related to research.

e. To find out differences between sizes of construction sites in different dimensions related to research.

1.8 Experimental Design-The research work of identifying safety levels in construction sites is carried out in two phases, involving assessments, questionnaire surveys and education programs conducted among workers at different construction sites.

Analysis Phase: Initially, by selection of random samples from construction sites. Then, conducting HIRA study to identify hazards requiring engineering controls that includes machine guarding, fencing, testing & examination of

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MHE, noise & vibration control and associated maintenance activities. Understand and identify the defects and shortfalls in the existing safety management systems in the selected sites. Distinctive research and analysis on the various areas of safety management systems is to be carried out and preventive methods are to be suggested to remove these hazards by implementing engineering intervention measures and controls for MHE safety.

Improvement Phase: Select the construction sites that require safety education and knowledge to handle MHE according to the operating standards. Design safety education program self-instructional set. In addition to engineering intervention, the hazards created by human errors and its remedies are to be included in the safety education program. Then to train the workers on the same modules with respect to handling, operating and maintenance activities of MHE.

The initial phase of this work takes up two segments of construction sites, small and medium-scale. Small-scale sites are those employing less than 50 workers and medium-scale sites employ between 50 and 100 workers. As, almost all large-scale sites are equipped with necessary safety procedures, they are not considered for this research.

1.9 Scope of the research- This research work aims at finding the perception of MHE workers towards safety-related dimensions. Safety of workers in construction sites have been an important concern and the managements attempt to bring down rates of accidents and also the number of accidents. Each and every management would strive to reach a „zero level‟ accident and 100 percent safety. Several measures and steps have been taken for this purpose. Each site has its own safety policy, procedures and approach. As most of the construction accidents are caused because of the machinery, un-rectified faults in machines are likely to give raise to accidents. People also cause them because of faulty handling. Several psychological factors influence the way these people handle the machines and work with them. Their perception towards safety is one important factor. The present research focuses on the accidents caused because of human factors and more particularly the perception of the workers towards safety and safety practices.

Workers in the construction sites generally have less education and training over safety and safety practices. The violation of safe practices, careless handling of MHE and tools is a common phenomenon. The managements are known to impart periodic training to their workers in the area of safety. However, the effect of such training is not known. This research work attempts to study and rectify this aspect.

1.10 Research Hypothesis

The following hypotheses were formulated for this research work, Hierarchy, education, age, experience and company of workers does not differentiate significantly the perception of workers on various safety-related dimensions

1.11 Research design

This research work is essentially a survey and education program with focus on finding the perception and knowledge of the workers towards safety in the various construction sites of India. Two different set of questionnaires to be prepared, one to be issued before the safety education program to identify the sites with lesser safety management systems and the other to be issued after the safety education program to find out the knowledge improvement among the workers. As it focuses on human factors, it is required to obtain data from all those involved in working with machines and gadgets from the low level workers to the supervisors

Sampling- The data for this research is collected from a total of 572 workers from about 58 construction sites in various parts of India. Among the 58 construction sites, 30 sites were small-scale and the other 28 were medium- scale sites and 300 workers from small-scale sites and 272 workers were from medium-scale sites.

Research Tool- The tool for the research is a structured questionnaire statement to find out the respondent’s perception towards safety. Three separate questionnaires to collect data from the workers were designed, one to shortlist construction sites and other two to check knowledge level before and after the safety education program. General worker safety knowledge and technical safety knowledge levels were considered in preparing the questionnaire in order to for find out their perception towards safety-related dimensions.

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II. LITERATURE REVIEW

1. The statistics of fatalities and injuries in construction sites were analysed by Helander (2024) and found that the hazards in the workplace are underestimated by workers. Nearly 6% of building costs are incurred by construction accidents. Neitzel et al (2023) found that cranes, which are used in material transfers, are involved in up to about one-third of all the fatalities in construction and maintenance sites.

2. The physical hazards of UV/EB technology was discussed by Goldenhar (2024), providing data on raw material toxicity, and describing the engineering controls and industrial hygiene practices being developed to assure workplace safety. This enables the end users of UV/EB technology to make a rational decision when choosing options for compliance. Paquet et al. (2019) used an ergonomic assessment method known as PATH (Posture, Activities, Tools and Handling) to measure the frequency of exposure to manual materials handling activities and other exposures for construction and other non-routinized work.

3. A risk estimation method was developed and tried at construction sites to study the likelihood of fatal accidents towards risk value, Marhavilas (2022). The common types of accidents and its causes were investigated by Fung et al (2020) and came out with effective and systematic rick assessment sheets for about 14 trades. In another article by Zwetsloot et al. (2021), four testing and certification regimes in the Netherlands were analysed for risk control effectiveness and identified critical factors affecting the risk control measures.

4. Fonseca et al. (2004) developed a knowledge-based method for the material handling processes in a conveyor-based system. Manu et al. (2013) studied how sub-contracting of workers affects the health policies that reach them from the management. A case study was presented by Tichon & Diver (2010), to investigate the benefits and drawbacks in the use of simulation in a construction training program using heavy, human-operated machinery such as rail, mining and construction sites and suggest an alternative to the current practices.

5. Arunraj et al. (2009) highlighted two important decisions that need to be made, selection of appropriate risk assessment techniques and implementing appropriate risk control measures.

6. El-Mashaleh et al. (2010), Hale et al. (2010), Makin & Winder (2008), McKinnon (2000) and Miller & Cox (1997) evaluated the safety management systems in various cultures and businesses while, Zin& Ismail (2012), Zhang &Sule (1989), Williams et al. (2010), Siu et al. (2003), Saurin et al. (2008) and Jannadi (1995) studied the behaviour, attitude, age and other human factors that affect the safety performance of workers in workplaces

III. METHODOLOGY

The tool for this research work has been prepared based on the various management elements on safety management systems and engineering interventions. The tool is prepared in such a way so as to reflect the availability of the safety management system in medium and small-scale construction sites.

PHASE I – Safety, Hazard and Risk Assessment- A stringent way to ensure post-disaster corrective action is to do a formal safety assessment. It is a rational and systematic process for assessing the hazards and risks associated with MHE and evaluate the possible engineering interventions for that lapse in the safety management systems and engineering controls. The first phase of this research work involves an elaborate procedure of hazard identification and risk assessment carried out in the construction sites.

Hazard severity / Likelihood	Fatal 5	Major injury 4	Significant 3	Lost time injury 2	
Frequent 5	**25**	**20**	**15**	**10**	**5**
Probable 4	**20**	**16**	**12**	**8**	**4**
Possible 3	**15**	**12**	**9**	**6**	**3**

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Remote 2	**10**	**8**	**6**	**4**	**2**
Improbable 1	**5**	**4**	**3**	**2**	**1**

Risk Rating (RR)	Explanation
16-25	Unacceptable/Intolerable, stop work, work not to be started until risk has been reduced
12-15	Very high/substantial, work should not start until risk has been reduced. If critical work progress, the problem to be remedied as soon as reasonably possible
9-11	High/significant, ensure controls are in place. Work should be closely monitored.
4-8	Medium/moderate, ensure controls are in place and working.
1-3	Low, ensure controls are in place and working. Monitor and ensure likelihood does not increase.

Figure 4.1 Risk rating index

PHASE – II: Safety Education Program for MHE

Based on the result analysis of HIRA, it was found that the knowledge level of safety among workers in several construction sites is less than required. The negative correlation coefficients prove the same. About 20 small-scale sites and 18 medium-scale sites have received negative correlation values. Hence, two sites were selected, one each from small and medium- scale sites which received the lowest correlation coefficient values and nineteen workers from each site were selected for the educational program.

Safety Education Modules- Three modules were considered to be very much in relevance for the self-instructional sets. The modules given as:

i. General worker safety
ii. Inspection and operation of MHE
iii. Safety of MHE environment

Pre- program safety questionnaire- Prior to issuing the self-instructional modules, the knowledge level of the workers is required to be recorded to evaluate increase in knowledge after the safety education program. Hence, a questionnaire was prepared inculcating questions related to the modules as such in the self-instructional set. The sub-sections of questionnaires under each module are shown below.

i. General worker safety – General working standards; Health and Safety; Personal protective equipment; Hazard and risk identification;

ii. Inspection and operation of MHE - Inspection of cranes; Worker behavioral safety; Tower crane and hydra crane inspection; operation of industrial trucks and dumpers;

iii. Safety of MHE environment - Safety of passenger and builder hoist; safety during storage and material handling; vehicle & moving equipment; prevention of fire and fire protection

IV. RESULTS AND DISCUSSION

The implementation of safety measures for workers operating with MHE at the selected small and medium-scale construction sites through the safety education program was completed encompassing all activities of the education program, including the issuance of the questionnaire surveys and collection of its results before and after the safety education program. Previously, permissions were sought and obtained from the managements of the construction sites

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that were selected. Proper explanation with analysis reports had to be provided to the managements for getting the permission to conduct the safety educational program.

On analyzing the result outcomes of the HIRA done in the 28 small and 28 medium-scale sites, the mean, standard deviation and correlation coefficients were tabulated and found that the standard deviations were high and correlation coefficients showed mostly negative values. This predicted that the knowledge level of the construction workers is not to the expected level and the high standard deviation level show that they are not aware on most of the safety requirements. In order to inculcate safety awareness among the construction workers, two construction sites, one from small-scale and the other from medium-scale that received the correlation coefficient was selected for a safety education program. And, to know the effectiveness of the safety education program, two questionnaires were prepared and issued to workers, one before the safety education and the other after the safety education program. The responses were collected from the workers and the results were tabulated as shown subsequently.

Pre-program questionnaire & result outcomes- The education program for workers connected to MHE was designed taking the factors arrived through the HIRA study. The designed safety education program was implemented among all the operating personnel of the selected small and medium construction sites. A total of 38 personnel related to MHE who attended, where imparted safety education program. A pre-program questionnaire survey was conducted before the safety education program and data was collected and analyzed to arrive at the effectiveness of the safety education program. About 120 questions with 40 questions each in the safety management and the engineering controls have been posted and required to be answered by the workers. They were required to answer all questions and each question carried 0.25 point. The relevant and correct answers were marked with 0.25 point and otherwise zero. Thus, the total correct answers were counted and its score was marked for the particular sub-division. The mean score of all workers in each sub-division is shown in Table 5.1. Site 1 refers to small-scale workers and site 2 refers to medium-scale workers

Table 5.1 Points obtained by workers before training

Sl. No.	General worker safety (Max.=10)		Inspection and operation of MHE (Max.=10)		Safety of MHE environment (Max.=10)		Total of all Areas of Safety (Max.=30)	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
1	4	4	3	2	3	4	10	10
2	2	3	2	3	3	5	7	11
3	1	5	3	1	4	2	8	8
4	2	3	3	2	2	1	7	6
5	0	4	2	3	1	1	3	8
6	3	3	1	3	0	4	4	10
7	2	2	2	1	4	1	8	4
8	2	2	1	4	3	4	6	10
9	3	2	3	3	3	4	9	9
10	2	5	2	3	8	6	12	14
11	3	7	3	3	1	3	7	13
12	2	4	2	1	2	4	6	9
13	3	5	3	4	4	2	10	11
14	2	5	2	4	2	3	6	12
15	2	3	1	3	3	5	6	11
16	2	5	3	4	1	3	6	12
17	5	3	5	4	3	5	13	12
18	2	5	4	5	1	5	7	15
19	2	3	3	3	2	4	7	10

Post-program questionnaire & result outcomes- After the safety education program, to all workers of the selected construction sites, another set of post- program questionnaires were issued to the workers. This questionnaire set consisted of completely new questions covering the discussed three modules of safety. There are three sub-divisions for each module with ten questions for each sub-division, totaling to 120 questions. These were also „yes" or no" type questions and had provisions for providing remarks. Even in this, all questions have to be answered and each question carried 0.25 point. Then, average of points of all workers for each sub-division was calculated. The score obtained by all workers after the education program is shown in Table 5.2. Site 1 refers to small-scale workers and site 2 refers to medium-scale workers.

Table 5.2 Points obtained by workers after training

Sl. No.	General worker safety (Max.=10)		Inspection and operation of MHE (Max.=10)		Safety of MHE environment (Max.=10)		Total of all Areas of Safety (Max.=30)	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
1	4	4	3	2	3	4	15	16
2	2	3	2	3	3	5	16	16
3	1	5	3	1	4	2	22	15
4	2	3	3	2	2	1	14	18
5	0	4	2	3	1	1	18	18
6	3	3	1	3	0	4	4	10
7	2	2	2	1	4	1	16	8
8	2	2	1	4	3	4	12	20
9	3	2	3	3	3	4	17	17
10	2	5	2	3	8	6	16	24
11	3	7	3	3	1	3	17	18
12	2	4	2	1	2	4	12	18
13	3	5	3	4	4	2	20	22
14	2	5	2	4	2	3	17	20
15	2	3	1	3	3	5	12	22
16	2	5	3	4	1	3	9	15
17	5	3	5	4	3	5	16	15
18	2	5	4	5	1	5	20	19
19	2	3	3	3	2	4	13	22

Major findings of HIRA study- The HIRA study was conducted for the MHE utilized in 28 small- scale and 28 medium-scale construction sites with specific focus on inculcating engineering controls and safety education among construction workers. Major findings of the HIRA study of MHE are given as follows.

i. No provision is done for machine guarding to the power transmission systems, including electrical motors, spindles, shaft, gear box, belt drives and clutch plates.

ii. Lack of fencing to the safe operating area of MHE. Thereby the working personnel of the sites are injured due to the accidents.

iii. The operators, supervisors and engineers are not properly trained for safety management with MHE.

iv. Lack of personnel protective equipment usage in the construction sites and irregular maintenance of MHE.

v. Improperly laid and unsafe access roads for MHE movement.

vi. Unsafe supports and maneuvering of MHE.

vii. Non display of safe working load and at times exceeding permitted safe weight limit values.

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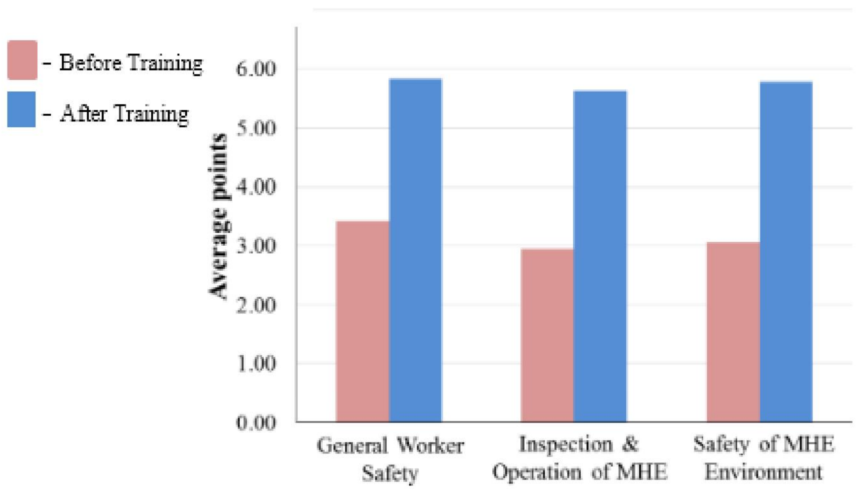
viii. Contractor's safety management system not followed, as most of the MHE used in construction sites are owned by contractors.

ix. Non-compliance to standards and lack of detailed examination of MHE, thus compromising its structural and mechanical integrity.

Analysis of worker safety knowledge level-On assessing usefulness of the conducted safety education program on MHE, the results achieved were considerably good as the knowledge level of safety showed major improvement in the concentrated areas. The shortcomings in safety procedures at the two types of construction sites were approached carefully in order to improve the workers safety consciousness. Also, results for the questionnaire showed definite improvements in the average points obtained by workers of each construction site after the program. The results of the education program were better than the work. The Figure 5.1 and figure 5.2 show the average of the total points obtained before and after the program by small-and-medium-scale sites respectively.

Figure 5.1 Points obtained by workers of small-scale site



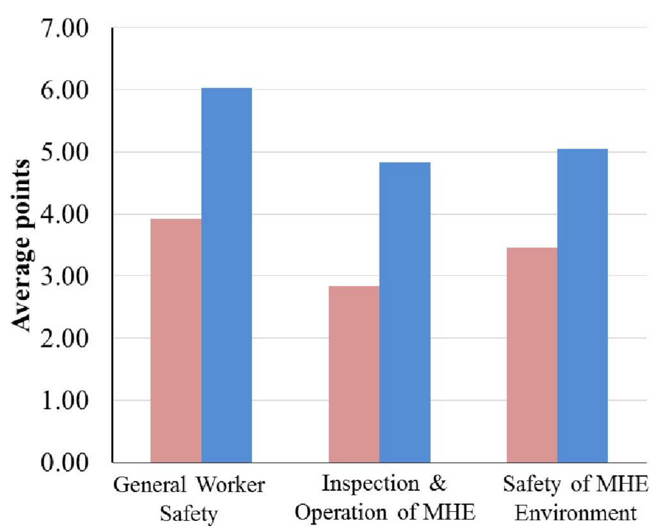


Figure 5.2 Points obtained by workers of medium-scale site

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The training modules stressed upon the importance of safety in workplace by touching on areas most relevant to daily workers‟ activities as well as inculcating engineering and administrative controls measures for avoiding hazards. This method of education has had its expectations satisfied as the positive correlation coefficient values of 0.53 and 0.56 for small- and medium-scale sites, respectively proved increase in the safety awareness of workers in both sites.

An increase in mean value from 7.46 to 13.61 for small-scale site and that of 10.21 to 15.92 are a definite improvement. Also, the standard deviation has reduced from 2.45 to 1.85 for small-scale and 2.62 to 1.85 for medium-scale sites. On comparing the small- and medium-scale sites, the mean increase is slightly better for medium-scale site although the percentage increase is the same for both sites.

Significance Analysis- Finally, to find out the significance in knowledge improvement of the workers of all the small- and medium-scale construction sites, a two-tailed t-test analysis was performed. The value for small-scale site is 8.79 and that of the medium-scale site is 7.74 for a 0.05 significance level. Also, the t-test value for small-scale sites is well-above the critical value of 2.0596 for 0.05 significance level. In the medium-scale sites, for a significance level of 0.05, the t-test value is well-above the critical value of 2.0484. The Table 5.3 shows the overall mean, standard deviation and the t-test values for both the small- and medium-scale construction sites.

Table 5.3 Result analysis of the safety education program

Small- scale sites	Mean	Before training	7.46
		After training	13.61
	Standard deviation	Before training	2.45
		After training	1.85
	Correlation	0.53	
	T test value	8.79	
Medium- scale sites	Mean	Before training	10.21
		After training	15.92
	Standard deviation	Before training	2.62
		After training	1.85
	Correlation	0.56	
	T test value	7.74	

From the above tests and analysis, it is clear that the education of workers about safety with the MHE at many areas and has been effectively approached. The safety education program proved to be successful in overcoming the knowledge deficit of workers at the 56 selected construction sites and would effectively prevent any accidents in future while operating with MHE.

V. CONCLUSION

The safety management system and engineering interventions are the two cornerstones of sites for their effective functioning. These management systems are essential because of the increased risk in sites coupled with public education and cost towards compensation against damages. There are large-scale improvements in the understanding of safety management system and engineering controls globally, in particular, in western countries. It becomes imperative on Indian sites irrespective of the size to adopt the safety management system elements and engineering interventions as a measure towards social commitment, legal compliance for meeting supplier and end-user requirements. It is also equally important that both systems should go together, hand-in-hand, in a harmonious manner to achieve the objective of safer sites with minimal risk to the society at large. At present, the adoption of safety management system and engineering controls have become a self-compliance measure to show the capability of organizations in ensuring their functioning in a safe manner. The corporate social responsibility, self-compliance activities, audit mechanism and standards codes and practices are some of the available measures in ensuring the management elements on safety education building among all the stakeholders such as employees, employer and government are essential for the

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successful implementation of the safety education program. Also, the management commitment is a pre-requisite for the success of the implementation of the safety management system and engineering controls in sites, which is further propelled by the social accountability and corporate ethics.

Hence, the safety management system should be adopted in a complete manner by providing all the required inputs such as finance, man- power, infra-structure, soft- and hard-skill, expertise and experience. The standards, codes and practices, which are available, will further assist sites to adopt effective and efficient adoption of safety and security management system. The Indian sites should avail all these inputs for enhancing their safety and security standard to the global level, thus paving way for safe living of human beings and inhabitants and thereby imposing less damage to the environment.

VI. RESEARCH OUTCOME

The final outcome of this research reveals that both small- and medium-scale construction sites have lesser equipped safety systems. Implementation of effective safety measures and improved engineering controls is necessary on a continual basis at the construction sites for enhancing the safety system and to prevent any accidents or injuries to the workers. Engineering intervention programs should be implemented to prevent and control the hazards and also periodically reviewed on a continual basis such that both unsafe acts and conditions of MHE are addressed on a holistic basis. The implementation of the designed safety modules results in better safety standards. The safety education program, if implemented continuously, will result in successful construction sites with enhanced safety and productivity by reducing injuries, ill-health and fatalities. Although, the self-instructional modules were used for the safety education program, its success was mainly due to workers effort and their motivation to acquire knowledge. A highlight point observed during this

research is mainly the management commitment which was lacking in many sites. Therefore, further carrying forward, this work is to be extended with more elements covering potential areas of health and safety that will also include management teams.

VII. RECOMMENDATIONS

The drawbacks observed in the safety management system of small-and medium-scale sites can be rectified through few improvements in the current policies and procedures. Though the safety levels of both the considered site types are below the par level and that their levels are more or less equal, the small-scale sites should concentrate more on improving and enhancing the safety of MHE at the construction sites. Few other recommendations for improving safety levels are discussed further.

i. The deployment processes of the mechanical facilities in general must follow the steps as: analyze problems, identify objectives, preparation and analysis, program selection, program implementation.

ii. The usage of machinery and equipment must be consistent with construction standards.

iii. Machinery and equipment deployment must be conducive to the construction for improving the overall efficiency.

iv. Increased level of mechanization of construction would lead to enhanced economic efficiency.

v. The preparation of mechanical equipment must adapt to the changing characteristics of construction projects with certain resilience.

vi. Appropriate heavy machinery should be arranged to handle the adequate workload and its safety must be ensured prior to its operation.

vii. The tools used should be reliable and have good mechanical properties.

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