Effectiveness of Mechanical Material Handling Equipment Safety in Construction Sites for Operation Safety and Environmental Health

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Abstract

Safety management systems require highly qualified management and professionals who have sound knowledge in safety procedures. Improper safety measures lead to accidents which are, uncontrollable occurrences that result in minor or major injury and damage. The construction sites are considered to be a common place of more hazards because of the higher incidence of fatal accidents. To curtail these occurrences, various elements need to be incorporated in the modern construction machinery such as equipment, resource allocation, and overall management. This paper studies and analyses safety management in the construction sites through means of safety survey, interviews with different level of employees and accident data analysis with specific reference to the mechanical material handling equipment and recommendations are suggested for enhancing the overall safety in the construction sites. The results are then statistically tested for significance through a ‘t’ test analysis.

Keywords: safety, material handling, construction safety, safety management system.

1. INTRODUCTION

The implementation of safety management systems and its procedures should be done in the supervision of people having deep knowledge about the safety requirements of the work site. Accidents, which occur due to improper safety measures is an

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unforeseen and unplanned event or circumstance, often with lack of intention or necessity. Some of the key elements for the occurrence of accidents are lack of management control, basic personal and task factors, sub-standard acts and conditions. Any unplanned incident leading to death, injury or property damage which stems from inadequate control of work processes causes an accident. But, these can be prevented through an established framework of safety activities.

1.1. Accidents and safety

Accidents affect the health of workers, creating disability and in some cases, fatality. It affects smooth functioning of the organization resulting in production loss; damage of property and lag in delivery schedules. According to Heinrich,[1] accidents create disaster, either major or minor injury and even casualties. Hence, it is important to implement strict measures to prevent accidents for the sake of both workmen and management.

Accident investigation is necessary to know the causes of accidents. Before any precautionary measures is taken, careful investigation is required as the most trivial case can also be a cause of accidents. Itasca [2] discusses the reasons for accident investigation as to:

- Study the causes for accidents in order to prevent similar type of accidents in future.
- Determine the deviation that produced an error, resulting in an accident.
- Publicize the particular hazard among employees and direct their attentions to accidents prevention.

Safety is the condition of being protected against physical and mental distresses which could be considered as non-desirable. According to Purify [3], safety is to control the recognized hazards around us in order to achieve an acceptable level of risk from being protected in the event of exposure to conditions leading to health and economic losses. Anderson [4] discussed seven factors which cause the major safety issues in the construction industries.

1.2. Safety management system

A safety management system provides a systematic way to identify hazards and control risks while maintaining assurance that these risk controls are effective. Florio, Stafford and Allies, [5] expressed that it needs a systematic, explicit and comprehensive process for managing safety risks. As with other systems, safety management system at construction sites provides for a goal setting, planning, and measuring performance while it is combined with the routine activities of the organization.
1.2.1. Safety at construction industries

Safety in construction industries deals with various areas such as excavation, scaffolding, work at height and manual and mechanical material handling equipment (MMHE). Construction safety covers all safety aspects in a construction industry. MMHE safety is a science under research in the field of construction machineries, during operation or while assembly and disassembly. The accident rate in India’s construction sites is serious despite the overall downward trend of accidents in recent years, [6]. This paper deals with the safety management of the MMHE’s in the construction industries in India, highlighting the drawbacks and necessary action required to improve the present condition.

1.2.2. Mechanical material handling equipment

Construction machineries and MMHE form the basis for majority of construction tasks and hence, safety management with these materials forms an important necessity. The construction equipment cover a variety of machineries such as hydraulic excavators, wheel loaders, backhoe loaders, bull dozers, dump trucks, tippers, graders, pavers, asphalt mix plants, vibratory compactors, cranes, forklifts, dozers, off-highway dumpers, drills, scrapers, motor graders, rope shovels etc. When it comes to handling these equipment, each tool requires a safety procedure and a method of operation. These procedures, on an overall is known as the safety management system at the construction industries.

This paper consists of seven sections. Section two discusses the available literature on safety at construction industries, section three details the safety procedures of MMHE, section four describes the methodology of the research, sections five and six gives the observations and recommendations respectively and the conclusion is given in section seven.

2. LITERATURE REVIEW

A number of research works and studies have been carried out by different authors regarding the safety at worksites and material handling techniques. The physical hazards of UV/EB technology was discussed in [7], 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. Piquet, Punnett, Buchholz, [8] 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-reutilized work.

In addition to these works, papers have been published in [9 - 16] on safety with material handling equipments. The materials handled were categorized as heavy and little heavy based on their weight and evaluated for their usage by different work
forces. Neitzel, Seixas and Ren,[17] pointed that the complex, dynamic, and continually changing nature of construction work is a major contributor to the high rates of injuries and fatalities in the industry. Especially, cranes contribute to a large fraction of construction deaths; estimating to about to one-third of all construction and maintenance fatalities. A metallurgical failure analysis was performed in [18] on carbon steel gantry crane wheels to improve its operation safety, in which excessive damage to the central tread surfaces was observed.

Fonseca, Uppal and Greene, [19] developed a knowledge based method for the material handling processes in a conveyor based system. And a case study was presented in [20], 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.

3. SAFETY MANAGEMENT OF MMHE

MMHE at work safety covers the assembly, disassembly, testing, transportation and other associated activities which could result in the operator injury. Elangovan, Mohammed and Mohan [21], implemented a safety improvement programme at two companies and studied the awareness of safety among the workers after improvement programme. Safety of machinery related to that of workers, businesses and properties, is an important component of sustainable development. India’s MMHE safety rates are good, despite the overall downward trend in recent years, but the situation is still serious and problems still prevail. Therefore, implementation and strengthening of the science of safety management of MMHE is a big challenge.

3.1. Analysis of safety management in equipment and machineries

With the increasing use of various types of MMHE in the construction industries, security issues become highly prominent causing problem that include; Imperfect safety management system, unable to strictly enforce the state and industry regulations, existence of long-term and outdated safety supervision administration, poor management of MMHE operators, imperfect MMHE technical file, mismanagement of equipment and machineries at the construction site, appalling conditions of equipment and machineries.

3.2. Reforms for safety management in MMHE

Several issues regarding safety in constructions sites need strict reformations so as to overcome the disadvantages of the present system. We propose few suggestions for improving the current norms and regulations for the MMHE at construction sites.
3.2.1. Suggestions for improvements in norms and regulations

To establish critical on-site safety procedures of equipment and machineries, the construction sites must strictly implement the following suggestions along with the existing standards and norms. In the field, machine management should develop an effective on-site management system which;

a) The construction site has be equipped with all the equipment, materials and tools required for construction site safety management.

b) Strict safety management regulations should be established and followed for each machinery and equipment being used at the site.

c) The implementation of statutory measures for the machinery and equipment, and personnel, will be the responsibility the management of the construction site.

d) The mechanical, electrical and construction equipment operation should be well maintained and in good operating condition.

e) Proper use of equipment and machineries is necessary for safe operation of equipment and machine overloads must be strictly prohibited.

f) With the progress of building at construction site, the various classes of MMHE used should be dynamically tracked for performance.

g) Technical files of the process safety management procedures should be updated from time to time in order to establish the complete safety of MMHE.

4. METHODOLOGY

The safety of MMHE that are being used in construction sites require continuous and extensive studies to improve its operation safeness. Each equipment has several in-built safety features differing from one manufacturer to the other. Further, the numbers of violations of safety procedures are in the increase due to lack of knowledge, defective operation and irregular maintenance procedures. Human factors also play a vital role in the accidents caused with mechanical handling equipment. Industries are of three types, classified as small scale, medium scale and large scale industry. Each of these industry types has a unique safety management system peculiar to their own construction sites. But, each of these industry types have few drawbacks in their safety procedures. The main reasons for this lack of safety systems are largely attributed to the economic, social and manpower qualification constraints. This research work has been carried out considering two segments of the construction industry, small and medium scale, based on the number of workers. The construction sites employing less than 50 workers are termed as small scale industries and those which employ between 50 and 100 workers are termed as medium scale industries. Since large scale construction industries follow the best practices in safety and well established safety measures, it has been excluded from this research.
4.1. Elements of safety

A research method has been prepared after conducting extensive study of the MMHE for small and medium scale construction industries. This research method has been categorized into two types of systems, namely; management and technical system and each system has several elements being considered which are shown in table 1. The system, method and elements have been checked and validated by field experts and their suggestions have been incorporated in the elements for more effective and efficient results.

A questionnaire has been created for each system with ten questions for each element, totaling to hundred questions for the management system and ninety questions for the technical system. This questionnaire was sent to forty small scale construction sites and forty medium scale construction sites.

4.2 T-test analysis of collected data

The data that was received in response to the questionnaire were tabulated and analyzed for correlation coefficient and significance values through a T-test procedure. The answers for the questions were either a ‘yes’ or ‘no’ and the number of questions which were answered ‘yes’ were counted and the count was considered for the T-test analysis. A sample data from ten companies out of the entire collection is shown in table 2 for elaboration.

In a similar way, the data was collected and sorted for about forty organizations both in the small scale and medium scale construction sites and tested for their significance in safety procedures at the work sites. Then, the sorted out data is used to calculate the standard deviation, variance, correlation coefficient and significance values. The results obtained after the calculation is shown in table 4.

5. NOTABLE OBSERVATIONS

The results of the T-test and the correlation coefficient values indicate the present safety conditions that exist in the small and medium scale industries. The health and safety policy, education about safety and its allied training, general working conditions including hazard identification and risk assessment and fire protection are more or less in the same rate when compared between small and medium scale construction industries. In addition to this, few other observations were;

- The level of safety, health, industrial hygiene, and usage of personal protective equipment (PPE) is much higher in medium scale industries than small scale construction industries.
- The safety of MMHE at both the small and medium scale construction industries is less than the standard level.
- There is no specific focus of the industries on target related safety education and training to prevent and control hazards.
• Overall safety enhancement measures in both the small and medium scale construction industries are inadequate.

• Lack of qualified safety personnel leading to increasing safety failures, resulting in more accidents.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Management System</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 Total</td>
</tr>
<tr>
<td>1</td>
<td>5 7 5 6 5 6 6 5 5 6 56</td>
</tr>
<tr>
<td>2</td>
<td>5 5 6 7 5 8 5 5 5 8 58</td>
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</tr>
<tr>
<td>10</td>
<td>3 6 6 5 6 7 6 6 6 6 57</td>
</tr>
</tbody>
</table>

6. RECOMMENDATIONS FOR ENHANCED SAFETY SYSTEMS

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

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

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

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

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

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

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

### Table 3: Sample data for technical system collected from small scale industries

<table>
<thead>
<tr>
<th>Organization</th>
<th>Technical System</th>
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<td>9</td>
<td>6</td>
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<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

### 6.2. Suggestions for prevention of accidents

Although, safety procedures are being implemented and followed at the construction sites. Unexpected and unprecedented activities may lead to accidents which may result in major or minor injuries and in certain cases would result in casualties. Accidents can be prevented by following the rules and regulations, abiding to the standards, regular inspection of machine safety and personnel with required educational qualifications. Few other accident prevention measures with the MMHE in construction sites are discussed below:
Table 4: Calculation of correlation and significance values

<table>
<thead>
<tr>
<th>Organization</th>
<th>Standard deviation</th>
<th>Variance</th>
<th>Correlation coefficient</th>
<th>T-Test values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>0.82</td>
<td>0.20</td>
<td>0.08</td>
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<td>1.08</td>
<td>0.02</td>
<td>0.13</td>
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<td>1.04</td>
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<td>4</td>
<td>0.99</td>
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<td>-0.34</td>
<td>0.09</td>
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<td>5</td>
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<td>1.15</td>
<td>-0.53</td>
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<tr>
<td>6</td>
<td>1.41</td>
<td>1.18</td>
<td>-0.21</td>
<td>0.13</td>
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<tr>
<td>7</td>
<td>1.09</td>
<td>1.04</td>
<td>0.09</td>
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<tr>
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<td>1.02</td>
<td>-0.51</td>
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<td>9</td>
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<tr>
<td>10</td>
<td>0.80</td>
<td>0.89</td>
<td>0.02</td>
<td>0.50</td>
</tr>
</tbody>
</table>

a) *Regulations:* The legal requirements for the material handling equipment should be complied regulations.

b) *Inspection and standardization:* Construction machineries must be inspected regularly and the operating conditions should abide with all the applicable national and international standards.

c) *Mechanical safety:* Proper machine guarding, wheel guards, testing of lifting machines and lifting tackle, safe lifting and rigging procedures should be maintained.

d) *PPE:* Approved PPE’s such as shoes, hard hats, gloves have to be used and replaced from time to time as they may worn out while working with the construction machineries.

e) *Education and training:* Teaching and instructing the construction workers on safety with material handling equipment will enhance safety management in the sites. Training is a continuous effort aimed at preventing accidents and also improving safety awareness.

f) *Persuasion and insurance:* The employment of various methods to create publicity among people and appeal to develop safety mindedness and create provisions for financial incentives to promote accident prevention.

g) *Proper housekeeping:* Considerable number of accidents are likely to be avoided, if things are placed order with proper housekeeping all over the plant. The factors contributing to housekeeping include, clean passageways with white line marking, proper storage of materials etc.
h) **Working clothes:** Working clothes must be selected, taking into consideration the hazards to which the worker may be exposed to, and these clothes should not be loose, torn or ragged.

i) **Colours, notices, signs and labels:** Colours are used for a variety of purposes as a mark of safety. Suitable colour schemes can improve perception and visibility and also can have a good psychological effect. General safety colour codes are used to identify danger spots, fire protection equipment, first-aid equipment, traffic lanes and special colour codes are used to identify the contents of gas cylinders and piping.

j) **Lighting, noise, ventilation and temperature control:** Lighting is an important factor in the physical environment of the worker. Most lighting factors that contribute to accidents include direct glare, reflected glare and dark shadows. Adequate lighting should be setup, which are suitable to the type of work done will help to reduce the number of accidents drastically. Also, excessive noise makes communication between workers very difficult, which makes hearing of warning signals impossible, misunderstandings and also cause hearing loss. Further, ventilation and temperature control go hand in hand in terms of the safety standpoint. They are very much important if the work is carried out at indoor areas as the room has to be adequately ventilated and temperature controlled.

### 7. CONCLUSION

Material handling problems in construction sites contribute to the maximum number of accidents. And MMHE’s play a critical role for the safety management process in these construction sites. The selection and procurement of construction and material handling equipment is important and should be done carefully as it is the base for safer operation and easier maintenance. The outcome of this research reveals that small scale construction industries have lesser equipped safety systems when compared to that of medium construction industries. Hence, proper regularization needs to be done in the small scale industries. Further, the medium scale industries require technological improvement and up gradation of their safety management system. Implementation of effective safety measures is necessary on a continual basis for the construction sites, which will greatly enhance the safety system and protect the construction workers from injuries and fatalities.

### 8. ACKNOWLEDGMENTS

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REFERENCES


