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Study of Hazard, Risk Assessment and Mitigation Measure of Lifting Equipment at Cement Plant Construction Site

Bhaskardyuti Gangopadhyay[1], Prof. Abhilash Trivedi [2] and Prof. Manish Kumar Mishra[3]

[1] M.Tech scholar, Bhilai Institute of Technology, Raipur, CG.

[2] Assistant Professor, Bhilai Institute of Technology, Raipur, CG.

[3] Assistant Professor, Bhilai Institute of Technology, Raipur, CG.

ABSTRACT

The construction industry is the second most populous occupation in India after the agricultural sector. The dynamic and versatile nature of the construction sector and the variety of hazards associated within it make this sector a major stake of the accidents that had occurred in the past.

The lifting equipment as used in the construction sector are a major contributor of all the accidents/incidents that had occurred in the past. Also the operator and workmen associated with this sector are also not educated up to the mark and many lack technical knowledge as required in the sector.

There are various hazards and risk associated with the operation of the lifting equipment which may be physical, occupational, chemical and others. The major contributing factors for crane related accident/incident are mechanical failure and human based error.

The paper illustrates the various mechanical and human based error resulting in the failure of lifting equipment and also suggest the recommended action to avert the incidents.

Keywords: Behaviour based safety, Hazard identification and risk assessment, Job safety analysis, cost impact analysis, safety audits and safety surveys.

Introduction:

Construction industry is one of the most versatile occupation in India and rest of the world. After the 18th Century, construction of the most iconic high rise and complex structures took place. But with the advent of time, as the socio economic condition of the countries developed newer methods of construction came into the scene. Most developed countries as well as India seen a boom in the construction sector to cope up the customer demands, to fulfil the economic aspect of the country and to take the society into a new zenith.

In developing countries like India, agriculture sector stands backbone of the economy and is the sector which employed more than 40 million workers.

The construction sector is the second most sector employing more than 25 million workers. The majority of the workers in the construction sector are daily wage earners. Before the enactment of the Building and other construction workers Act in 1996, there was hardly any enactments in the legislation for the construction sector. But though there are BOCW Act, 1996 enacted in India, still there are many loopholes in the legislations. After BOCW, 1996 there are many amendments to the base act, but still there is long way go in the construction sector especially regarding implementation.

As India sees a boom in the construction sector, the cement production and allied infrastructure needs to be increased to fulfil the requirements and thus it became necessary to expand the existing production unit and to develop new production units.

But as the projects are executed, various accidents, catastrophic incidents, property damage, environmental pollution, etc. are common. The reason for those accidents/incidents are unsafe acts, unsafe working condition, behavioural issues and the most important lack of awareness and training to the engaged workmen. As most of the workmen engaged in construction sector are uneducated and lacking basic knowledge of the activity, safety is compromised resulting in incidents/accidents.

In the construction sector various heavy equipment/mobile equipment are engaged in the project from excavation to commissioning, and during the project construction phase accidents/incidents from the construction equipment are most common.

The main aim of this thesis work is figure out the hazards associated with the lifting equipment, assessing the risks, figure out the mitigation measures and implementation of the findings. The lifting equipment are a source of potential hazard in construction sites and their condition, lifting capacity and stability must be assessed before being deployed at site. If we can plan early about the lifting loads, ground condition, crane capacity, communication methods, etc. we can avert accidents. In this thesis

work discuss will be on about the main check points to consider while inspecting heavy lifting equipment. We will also look into the future scope of possible improvements in the existing equipment models.

Literature review:

A literature review is done to gain an understanding on the existing research and modelling that are being done at different parts of the globe and to incorporate the important findings in the research papers. A brief account is as :

1.Vivian W.Y Tam and Ivan W.H Fung et al. in their research paper-"Tower crane safety in the construction industry: A Hong Kong study" 02 highlighted the following issue:

- This paper investigates tower crane safety in related to the understanding and degree of executing statutory requirements and non-statutory guidelines for the use of tower cranes.
- Inadequate training and fatigue of operators are one of the main reasons causing unsafe practices of tower crane operations.
- Indolent performance of requirements or responsibilities of operators in tower crane operations is found.
- It is found that human factors are attributed to tower crane failures and incidents.

2. Mohammad KamarulArifin Mohamad Ali and Mohamad Ibrahim Mohamad et al. in their paper[15] "Crane Failure and Accident in Construction" identifies safe practices to be implemented forcrane machine in order to reduce hazards in constructions. The paper highlights that cranes are machines with high risk and should be operated with safety management and strong communication between crane operator and signalman.

The paper highlights about the human factors which are responsible for incidents/accidents at site are mainly due to lack in communication, crane being operated by incompetent person, poor work supervision, operator carelessness, etc.

3. Devdatt P Purohit, Dr.N A Siddiqui, Abhishek Nandan&Dr.Bikarama P Yadav et al.(2018) in their paper entitled [13] "Hazard Identification and Risk Assessment in Construction Industry" emphasizes on the hazards and risk analysis is to identify and analyze hazards, the event sequences leading to hazards and the risk associated with hazardous events. Various hazard identification techniques like

fault tree analysis, FMEA, HAZOP, QRA, etc .are studied. Thus the use of multiple hazard analysis techniques is recommended because each has its own purpose, strengths, and weaknesses.

The type of operations/activities carried out in a construction site are many and vary from site to site. Some of the routine work/operations carried out in construction sites are excavation work, scaffolding work , crane operations, hoisting operations ,material handling and electrical works.

In order to avert incidents/accidents proper risk assessment and hazard identification must be done by competent person.

Research Methodology

The research methodology will be based on the field study which will be consisting of site observations, site safety audits, interviews and site specific accident/incident case studies and document review. Field survey and studies of the site will assess the site specific hazards and contributing factors like human error or mechanical failure for failure of lifting equipment.

The field study will be conducted on two construction site both managed by the same multinational organization and following same management system. Both the sites are expected to handle lifting equipment but the capacity may vary according to the site condition.

It is expected to provide a detailed summary of the mechanical causes for equipment failure as of lifting operation is concerned.

The second factor that is considered for lifting equipment failure is human error or behavioural based error. This factor will be identified during HIRA and supported by past data and other open sources with expert advice.

The site observations are then compared and contrasted with the safe practices as envisaged in the legislation and/ or site safety manual and corrective actions are suggested for implementation. This comparison will highlight the similarities and differences between the actual vs site conditions and will be incorporated during HIRA.

Selection of technique for hazard analysis:

A number of techniques are available to conduct hazard identification at site like HIRA, HAZOP, JSA,FMEA. Hazard identification and risk assessment in short HIRA is a quantitative risk assessment method where a job or task is taken; identification and analysis of hazards are done and risk rating done and based on the rating control measures are implemented.

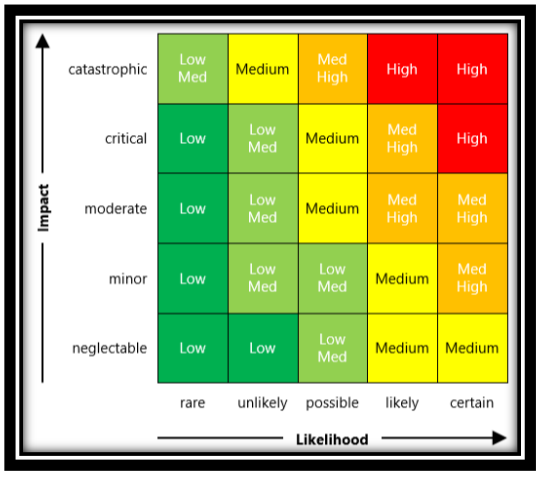

Table- 1 5x5 Risk matrix

Risk assessment steps:

The steps followed here in conducting the risk assessment are as follows:

- **Step 1**- Identify the hazards: Here the hazards are identified by using various methods like site survey, safety audit, etc.
- **Step 2**- Decide who might be harmed and how: Here the consequence analysis are done to find out who might be harmed and how the equipment can harm.
- **Step 3** – Evaluate risk and propose control actions- This step helps to evaluate the risk in the risk matrix and based on the outcome suitable mitigation measures are proposed. The control measures are implemented till the risk comes to an acceptable level.
- **Step 4**- Record the finding and implementation- The proposed action must be implemented immediately and the records are kept for future reference and audits.
- **Step 5**- Monitoring and review- The proposed actions must be monitored by the management for its effective implementation and review of the system must be done to incorporate any update.

Drawing of Pie chart and Bar chart from data analysis:

Based on the available data of the surveys, expert advice and case studies the bar chart and pie chart are drawn. The type of chart are selected as per suitability. The percentage shown in the chart are based on feedback from the respondents and previous case studies. The bar chart and pie chart are used for the following purposes:

- Easy representation of the data in a compact manner.
- Less time consuming to discuss in meetings.
- Summarizes a large data in visual and easy interpretable form.

Based on the finding of the feedback surveys, case studies, etc. both type of charts are prepared and the percentage are shown in the chart as per the analysis of the data.

$$\textbf{Percentage in chart} = \frac{\textbf{Similarity in observation/feedback x 100}}{\textbf{Number of respondents}}$$

Once the hazards are identified and risk assessment are done, it is important to prepare and implement the proposed mitigation measures immediately. The control measures must be based on the advice from the experts, manufacturer of the equipment and top management. The site management are responsible for effective implementation of the proposed control measures. The top management must ensure that the control measures are implemented and effectively followed at site level.

Result and Discussion

Now a days, in every construction sites, the use of lifting equipment are indispensable. But same time there are various hazards associated with those equipment which may be the followings:

1. Fall of material
2. Collapse of crane
3. Work near electrical line.
4. Work near excavation.
5. Overturn due to poor ground stability.
6. Ergonomic hazard.
7. Overloading of crane beyond SWL.
8. Environmental hazard.

Based on the findings of the site surveys, safety audits, past accident analysis and other open sources the probable mechanical causes and human based errors are discussed.

Behavioural cause for accident/incident:

Various analysis of accident root causes depicts that the following unsafe behavioural acts during operating crane are major causative factors:

- Using mobile while operating crane.
- Operating crane under influence of alcohol/drugs.
- PTW and SOP violation.
- Unauthorized person like crane helper operating the crane.
- Working under poor visibility and improper communication.

- Crane kept unattended in loading condition.
- Bypass of safety devices/overload limit switches.
- Operating extra duty hours leading to mental and physical stress.

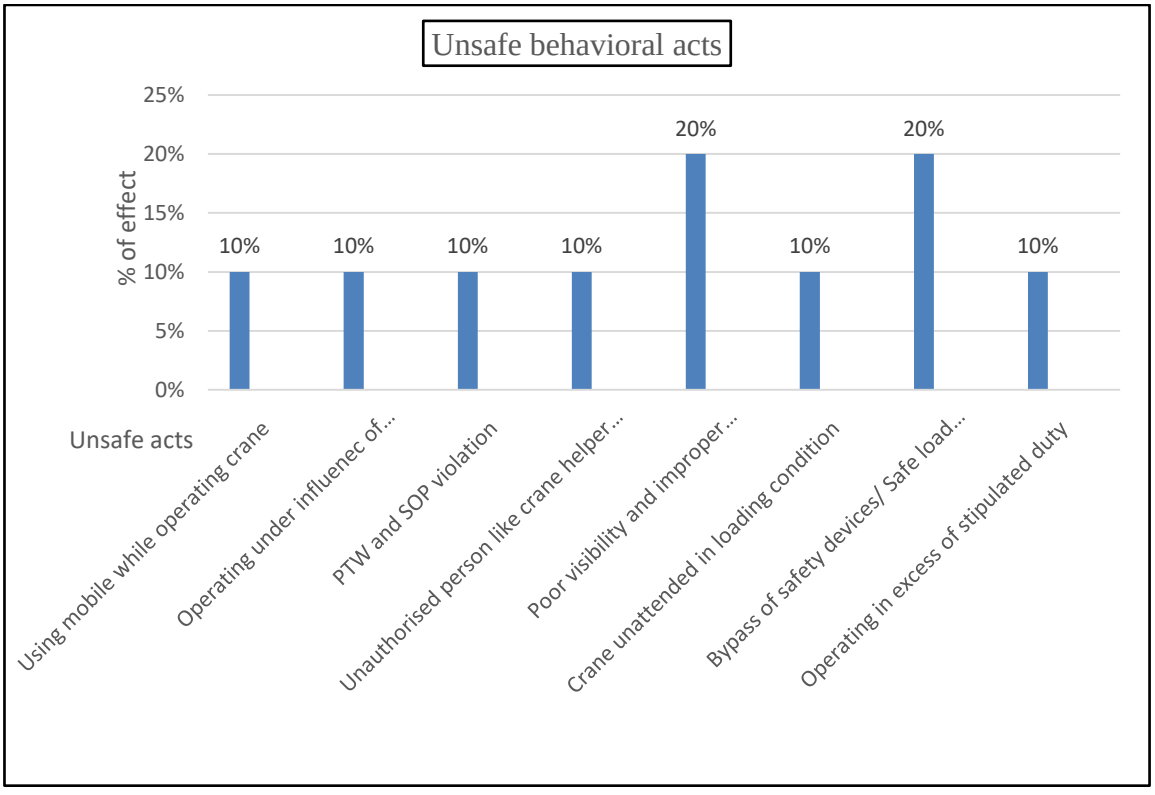

Chart 1- Human errors and factors for accidents

Mechanical factors for crane accident/incident:

The underlying mechanical factors which can lead to accidents can be categorized as:

- Failure of boom/jib section.
- Failure of hydraulic system.
- Failure in control system.
- Failure in safety system and SLI malfunctioning.
- Sudden shearing of wire rope.
- Sudden jerk in crane due to overload.

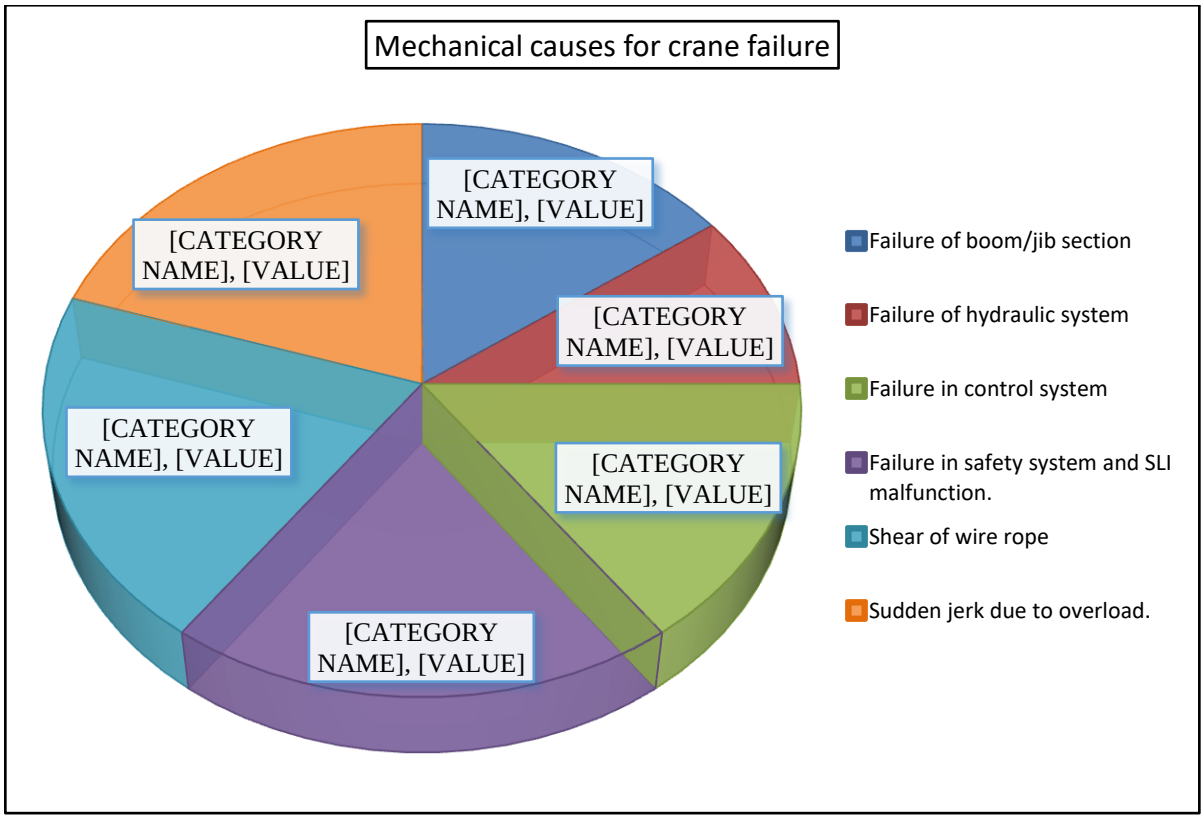

Chart 2- Mechanical causes for lifting equipment accidents.

Cost impact analysis

The impact of crane failure or accidents may have the following implications:

- Catastrophic damage/multiple fatality.
- Permanent disabling injury.
- Compensation cost.
- Hospitalization cost
- Damage to crane.
- Asset/structural damage.
- Delay in project schedule.
- Negative Company's reputation leading to contract loss.

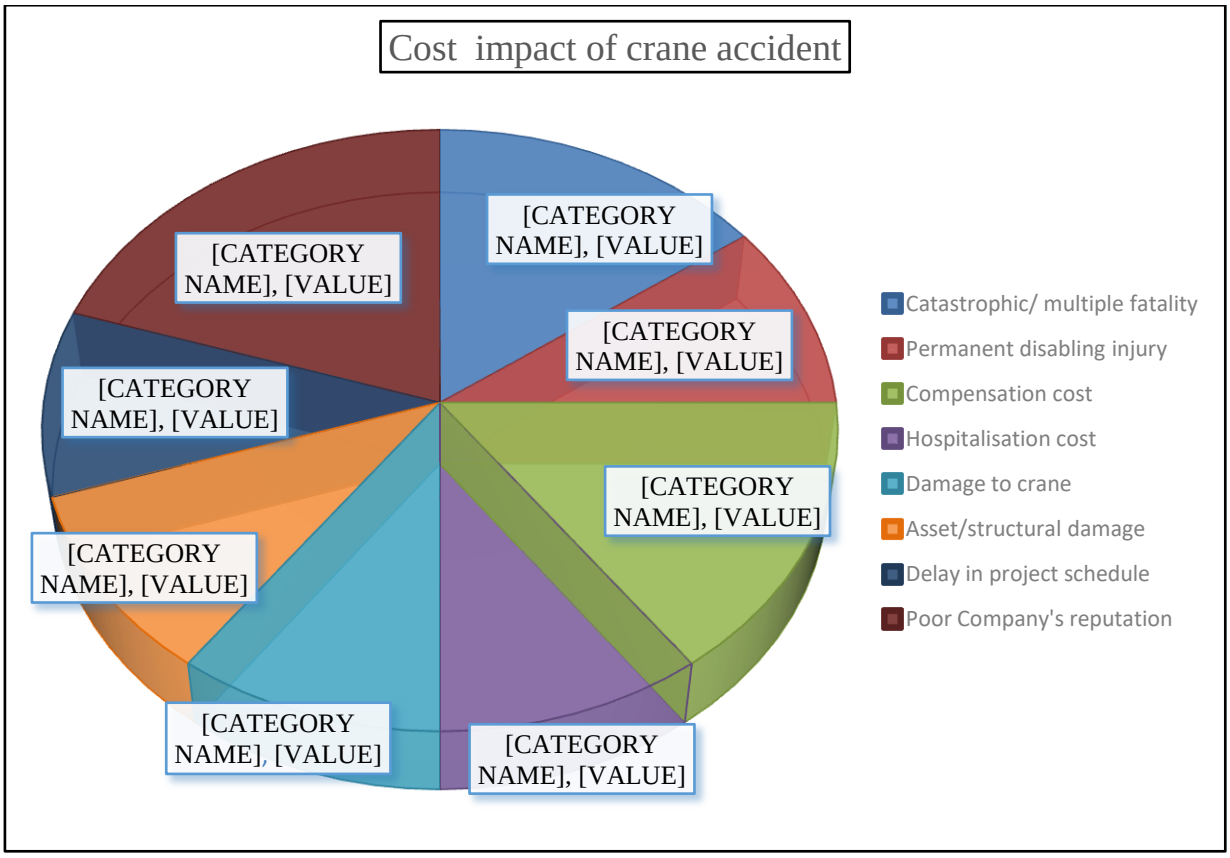

Chart 3- Cost impact analysis

Mitigation measures

Thus from the above HIRA and data analysis it should be borne in mind that unsafe acts or unsafe conditions are prerequisites for any accident/incident.

Based on LOLER regulations, Government acts, Company's HSE manual and subject expert advice the following safety rules to be followed at site:

- Through inspection of crane before deploying at site (using pre-approved checklist).
- Competent and experienced operator having valid HMV license with pre- employment medical check-up and trade test.
- Permit to work and Standard operating principle to be followed.
- Proper ground stability to check before crane positioning.
- Lifting plan, tested tools and tackles are checked prior to lifting activities.
- Biweekly and daily inspection checklist for crane to be done.
- Safety devices and Safe load indicator are must and SWL be visibly marked on crane.
- Hook latch and color code is must for crane.

- ROPS/FOPS are must to be installed.
- Proper signaling and communication system during lifting must be ensured.
- No live HT cable be near swing area, and if HT cable is there take LOTO prior to lifting operation.
- No crane must be placed near excavated area unless properly shored.
- Awareness and refresher training must be given for operator.
- Swing area to be barricaded.
- Only authorized and certified riggers to be engaged in lifting operation.
- Based on manufacturing date, the Safe work load (SWL) capacity must be de-rated as ascertained by competent person.
- Annually the crane must be certified by competent person as per BOCW Act1996 and a certificate in approved format must be documented as required.
- No use of mobile phone at site by operator and rigging team.

Safety inspection

These are some of the safety measures to be followed at site while working with mobile crane to avoid accident/incident.

During safety inspection of the mobile crane some of the points to take care are:

- Proper functioning of Safe load indicator.
- Any sign of oil leakage.
- Any abnormal sound while operating.
- All control system and safety system are integrated.
- Any damage in wire rope like cuts, kinks, bird cage etc.
- Hook latch integrity.
- Leakage in outrigger and availability of wooden logs/MS plate for outrigger placement.
- Fog light, reverse horn, rear camera, rear lights, boom lights etc. are in working condition.
- All vehicle documents are available and date validated.
- Wire rope termination are done with three U-bolt clamps as per standard.

Findings and scope of further improvement

The paper being developed based on the site related hazards and risks which are encountered commonly at project sites mainly related to the lifting equipment. The major focused area in this thesis paper are:

- Root causes for the accident/incident related to the lifting equipment where various roots causes and immediate causes are discussed.
- Mechanical factors as cause for lifting equipment incident where various mechanical factors are identified which may be the causative factor for crane failures.
- Human based error are discussed where various behavioral issues are highlighted.
- The cost- impacts analysis as discussed points the direct and indirect losses from the failure of lifting equipment.
- Hazard identification and Risk assessment is developed with mitigation measures so as to control the hazard to an acceptance level.
- And finally, various safety measures to be implemented at project level to avert lifting equipment related accident/incident are discussed.

The findings of the thesis paper throws light on the need of the safe work place and safe work equipment so as to be part of sustainable development. The commitment of the management in ensuring workplace safety is the essence of sustainability which in turn progresses towards the socio-economic development of the nation.

A number of limitations were observed while preparing and conducting the field surveys at site level, in the standard operating procedures and the risk assessment already in function at site level and in the legislation. These limitations could be reduced by conducting further analysis on a number of areas that could furtherstrengthen the research findings.

- Behavioral based safety
- Ergonomic and aesthetic operator cabin
- Electrical sensor at hook block for mobile equipment
- Competency mapping for operator

Conclusion

The paper achieved its intended goal of identifying the mechanical and behavioral causes for failure of lifting equipment and also recommended the corrective and preventive measures to be followed. To further improve safety, there is the need of a more integrated approach, where design safety and safety in the use fields are considered as one entity and with more attention being paid to behaviour based safety issues. And finally it is the duty of everyone to ensure safe place to work for attaining sustainable development and to conduct uninterrupted business to take the nation to its zenith.

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