



## **HAZARDS ASSOCIATED WITH HEIGHT WORK AT CONSTRUCTION SITES AND THEIR CONTROL MEASURES: A CASE STUDY AT THE NUMALIGARH REFINERY EXPANSION PROJECT, ASSAM**

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### **Abstract**

Construction works at height are among the major occupational hazards throughout the world, especially in mega industrial projects including NRL(Project) in the state of Assam. This study aims at identifying the risk factors of working at height and evaluating the effectiveness of the control measures currently practiced at NRL. The principal risks that have been identified are; working at height, hand tools falling, incorrect use of plant, environment, and human error. The paper reports NRL's safety measures, PPE, scaffolding codes, supervision and emergency practice to illustrate that with forward planning and compliance of standard safety measure, incidents and accidents can be minimised in the workplace. Such results may influence safety measures in similar industrial construction sites.

**Keywords:** Hazards, Height, Work, Construction, Sites, Numaligarh, Refinery, Assam.

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### **1. INTRODUCTION**

construction environment is one of the most dangerous working sectors and the work-at-height was determined to be a major cause of the workplace accidents and deaths. Particularly in hazardous environments such as refinery expansion work, employees are often subjected to such hazards as falls, unsecured structures, and heavy machinery operation at great heights.

The Numaligarh Refinery Expansion Project (NRL) in Assam makes for a good example for the study of these hazards, as it pertains to the massive structural works and machinery erection work wherein height safety measures are absolutely necessary.

This paper discusses how NRL recognizes, assesses, and controls hazards associated with height work. Emerging priority is given to technical safety measures as well as the introduction of a more safe consciousness at the workplace is for us. The research demonstrates the need for hazard evaluation, risk analysis, and inspection of equipment as well as personnel training.

The construction sector is a cornerstone for infrastructure projects in the world and one of the most hazardous working environments. Of the many hazards construction workers face, working at an elevated height is one of the greatest sources of accidents and fatalities. There is an inherent risk associated with work at heights-whether at home, on a commercial building, on an industrial project. However, according to international safety data and labour reports, falls from height form a considerable proportion of construction accidents, many of which are fatal or permanently disabling.

### **1.1. Significance of Height Work Safety in Industrial Construction**

The hazards of working at height are amplified in industrial construction environments and for refineries in particular where hazardous operations are carried out, often using heavy equipment in steel works and on high platforms just to name a few. The complexity of its structure, the temporal nature of its projects and the rough conditions in which its projects are built only compound these safety challenges. Mishap Prevention in a High Risk Environment Effective safety management in these types of environments involves more than simply adherence to regulations Poor safety culture and a proactive approach to hazard mitigation are also essential reasons that can affect mishap prevention efforts.

### **1.2 Case Context: Numaligarh Refinery Expansion Project (NRL), Assam**

The Numaligarh Refinery Limitation (NRL) expansion project in Assam is a noteworthy project of infrastructure in Indian industry. This is a part of the strategic objective of the country to augment its refining capacity and energy security in the North Eastern part of India. The NRL enlargement includes significant civil, structural and mechanical construction

activity, some of which is performed at great elevations. The size and complexity of the project and number of employees working at heights; make this a fundamental case to consider both the risk and controlling of working at heights.

### **1.3 Height Work Hazards at Construction Sites**

Typical hazards associated with working at height relate to the risk of falling from scaffolding, ladders, roofs and temporary platforms caused by misuse, lack of suitable fall prevention or equipment malfunctioning. Overturning of vehicles, debris, communication infrastructure and power lines, derailment or collision of trains may also present risks. Unfavourable environmental conditions (wet, windy), lack of supervision, worker fatigue, and a lack of training, are also external factors that increase risk. An all too frequent finding in numerous accidents is failing to follow the safety procedures and guidelines, either because the worker didn't know, wasn't made aware, or ignored those procedures and guidelines.

### **1.4 Safety Management at NRL Site**

At Safety is not compromised at the NRL construction site." The project has an effective safety management system in place which is as per the national norms (BOCW Act etc) and international standards (OSHA). Risks associated with work at height are generally managed using a mix of engineering controls (such as scaffolds, guardrails, safety nets), administrative controls (e.g., Job Safety Analysis, training, permit-to-work systems), and personal protective equipment (PPE). The safety emphasis is further supported through routine safety audits, safety officers being appointed (who take safety as priority) and the encouragement of "safety-first" attitudes among the workforce.

### **1.5 Purpose of the Study**

The present study was designed to investigate the risks peculiar to height work that are faced by workers at the NRL tuneable facility construction site as well as the effectiveness of measures undertaken to reduce this occupational risk. This study offers valuable information on the safety of height work by analyzing practices on the ground, safety plans and interventions in real time. It also seeks to make recommendations that can assist in improving

safety performance, not only in NRL, but also in construction of projects of a similar large magnitude in India and other developing countries.

### **1.6.Research Objective**

The objectives of the study are:

- To identify the hazards associated with height work at the NRL construction site.
- To assess the effectiveness of safety and control measures implemented to reduce height-related risks.
- To analyze real-time practices and safety protocols to identify common issues and preventive strategies.
- To propose recommendations for occupational safety improvement in large-scale industrial construction projects.
- To examine the roles of proactive planning, continuous supervision, and safety compliance.

## **2. LITERATURE REVIEW**

Building and construction are also considered as the most dangerous industries to work in, globally, with working at height being the largest contributor to serious injuries and fatalities. A significant percentage of occupational accidents are due to falling from heights. The dangers become even greater on such industrial projects as work on high rises normally have a very large amount of structural and mechanical work at height. Risks include: failure to prevent falls from open edges, unsafe scaffolds, improper PPE use, inclement weather and lack of training. Objects and tools being dropped, heavy equipment, high voltage lines and temporary construction also significantly increase the risk.

There are many regulatory bodies, including the Health and Safety Executive (HSE), and industry bodies which have produced a variety of standards that ensure all risks associated with working at height are appropriately managed. These rules are not the safest but are simply the

lowest acceptable safety standards. Safe tool, thorough training, PPE from employers “Employers are crucial to creating a safe environment through investment in PPE, a safe tool and training,” Nelson said. Workers must comply procedures, be conscious, and report hazard. The increasing effectiveness of high-tech safety —such as today’s safety locks on the latest scaffold systems, along with guardrails, non-skid platforms, workers’ wearables plus digital tools to spot and report potential hazards —is making a dramatic difference in risk management.

### **3. METHODOLOGY**

Multimethod research was performed for a comprehensive measurement of risk factors associated with Working at Heights and effectiveness of the control measures at the Numaligarh Refinery Expansion Project (NRL). This approach combined qualitative and quantitative techniques to develop a complete picture of the safety measures used at the yard. To achieve this approach, the authors implemented a literature review, a primary research using surveys and inspections, and analysis in an effort to interpret the results. The subsequent subsections elaborate on all parts of the research design:

#### **3.1.Problem Identification**

The first phase of the study was designed to explore the fundamental issues of high-elevation work. This entailed identifying the different kinds of falls that commonly occur on construction sites, as well as getting a sense of what exactly causes them. By means of observation, site visits, and interviews of safety personnel, repetitive hazards such as falls from scaffolds, ladders and elevated platforms were noted. This initial process was fundamental to the delimitation and guidance of data collection and analysis across the following stages.

#### **3.2.Data Collection**

In the second stage, the primary data was collected from the NRL site. This process included gaining an understanding of the safety procedures, protocols and challenges specific to each site. Structured questionnaire and field observation approaches were employed to garner insights from site engineers, safety officers and workmen. Questionnaires concerned workers’ knowledge of safety regulations, training undertaken, PPE use, and adherence to scaffolding

standards. Field visits also were made to observe height work being performed and to record the presence of control measures such as guardrails, safety harnesses, and access equipment

### **3.3.Risk Assessment**

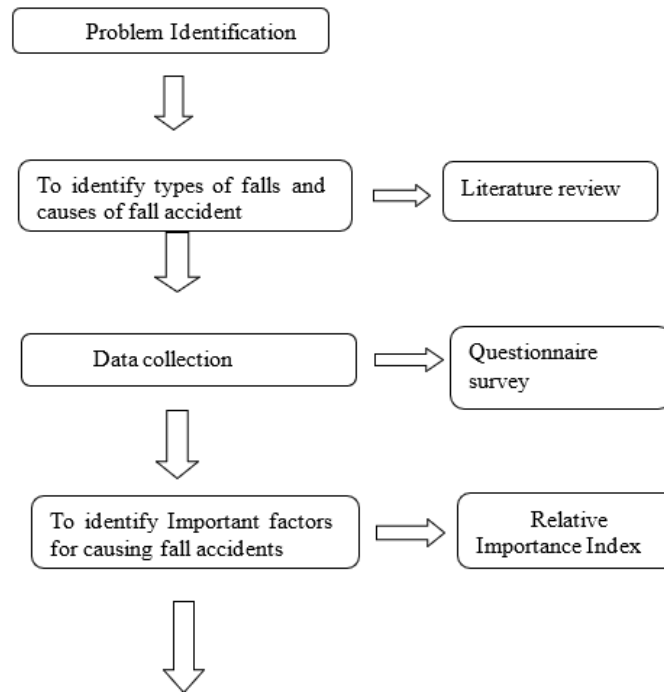
A key part of the approach was the use of JHA and PTW systems for the assessment of risks for each of the work-at-height operations. JHA was based on systematically creating a job, deconstructing all the activities that it contains in separate steps, pinpointing hazards faced during the individual steps and suggesting how to control them. The PTW system was examined in relation to governing access to hazardous zones, with only experienced and competent personnel being able to conduct height work. These instruments facilitated the comprehension of how administrative and procedural interventions contribute to accident prevention.

### **3.4.Relative Importance Index (RII)**

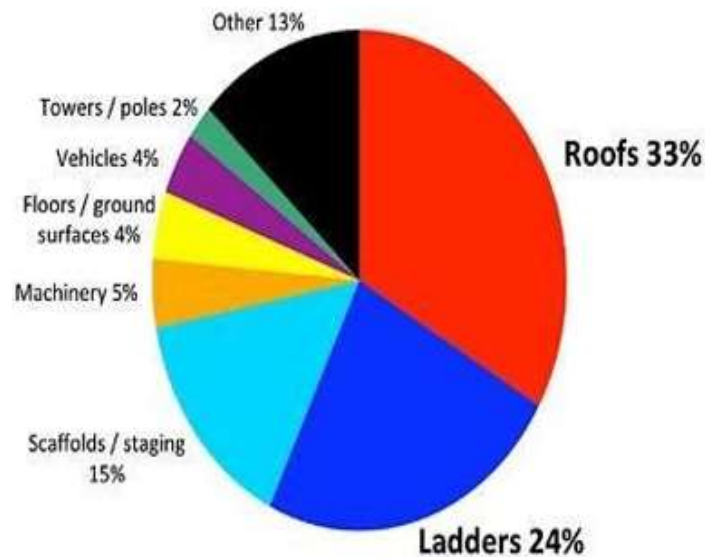
The Relative Importance Index (RII) method was used to assess the severity of various height-related hazards. It was employed to rank the risk factors based on contribution from the questionnaire response. Three-point Likert scales were used by participants to rank each of the hazards in terms of its potential impact, and RII were computed to ascertain their perceived ranking. This allowed ranking of the hazards according to likelihood and severity, which gave a useful indication as to which control measures to place emphasis.

### **3.5.Scaffolding and PPE Inspection:**

As part of the field assessment, safety inspection cards (refer to Tables 1 and 2 in the dissertation) were used to assess the condition and conformity of use of scaffolding and PPE. This checklist contained items like scaffold stability, condition of the platform, guardrail was installed and whether safety harnesses had been used. Intervals between inspections were defined and the inspections were performed by qualified employees to find signs of non-compliance, potential risks, and measures that should be taken. Such checklists proved to be a useful instrument for assessing in real time safety and compliance with pre-defined safety conditions.



**Figures :1**



**Figure :2**

Figures 1 and 2 illustrate the step-by-step methodological flow from risk identification to data interpretation.

#### 4. HEIGHT WORK HAZARDS

Risk of working at height There is a series of serious hazards which can necessarily arise if proper identification and mitigation have not been made. At the NRLP in Assam, structural and mechanical works are executed at heights on a regular basis and thus, the risk profile is particularly complicated. In the light of the findings of the on-site inspections and analysis of safety, a number of important height related hazards were found to be more common. All of the above is considered further below:

- **Falls from Elevated Surfaces:** Falls from elevation is the most severe and common hazard of construction sites. Experiences At the NRL site, such accidents commonly result from:
  - Unprotected edges
  - Poor or unstable scaffolding/ar access
  - Unsafe use of ladders or access systems.

These falls can occur because of missing guardrails, lack of maintenance to platforms which are damaged or slick with fat or other contaminants, or employees who step out of designated safety areas. Another factor known to contribute is the inability to keep three-points of contact while climbing up or down ladders. These conditions are exacerbated by missing or improper use of fall arrest devices including safety harnesses with lifelines. Due to the height and intricacy of the NRL buildings, a fall from those heights can be life-threatening.

- **Falling Tools and Debris:** Another major risk are falling objects like tools, materials for construction, or wreckage which also poses a danger for workers at the top and those working below. Such accidents are usually brought about by incorrectly securing tools or poor housekeeping. For example, loose screws, simple hand tools, or welding equipment not properly secured on high work locations are prone to fall if upset by vibration, standard movement, or wind. There are ways to help reduce the risk, including through the use of toe boards and debris nets, along with attaching tools with lanyards, however this is often overlooked, or poorly implemented. On a busy work site such as NRL, when multiple teams are working separately at different heights, the risk of objects falling and injuring someone is significantly increased.

- **Structural Collapse of Platforms:** Very dangerous the collapse of decks, scaffolds and work platforms. This can happen when one of these structures is overloaded, not properly assembled, or is built on unstable ground. In addition, inferior materials or devilry in erection and the like can weaken the strength of a scaffold. At NRL structures, the load for which the scaffold is designed can severely vary by the movement of personnel and materials for storage locations and construction work, leading to potential structural failures. An accident involving a down fabrication center not only jeopardizes the lives of those on the scaffold but also may cause a ripple effect of potential catastrophe for the immediate vicinity, such as falling debris and the threat of secondary injuries.
- **Electrocution:** During extended work at heights there is also a danger of electrocution from electrical installations and overhead power lines. If extra clearance and insulation are not available, employees using aerial lifts and metal scaffolding around energized wires are in serious danger. This risk is greatest when welding, laying cables, or assembling structures close to energized systems. Insufficient detection of electrical hazards or non-insulated tools often adds to this risk. Electrocution hazards are to be guarded against by: —providing clear signs or physical barriers —using help-grounding systems and specially designed personal protective equipment (PPE) to safeguard from electrical dangers.
- **Weather Hazards:** Adverse Inclement weather is a powerful and frequently overlooked risk in working at elevation in construction. Rain, fog, high winds, and even lightning all pose hazards to the stability of workers and equipment and reduce visibility. Slippery surfaces are more likely to cause a slip-and-fall and high winds can cause platforms, ladders and equipment that is hanging to become unstable. These weather conditions are extremely hazardous on the high steel structures found in refinery construction, as wind loads can alter the position of materials or men to an unsafe position. At NRL, early-warning systems and work rescheduling measures are among those tools used to manage the risk, but the success of both are predicated on proper use and immediate response.

- **Human Factors:** Lastly human factors, fatigue, over-confidence, complacency and poor training are significant contributors to falls from height. Long working hours, inadequate breaks, and the repetition of high-risk tasks can compromise decision-making and reflexes. Workers may become conditioned to the dangers or cut corners to shave a few seconds off a task. Additionally, new and inexperienced workers may not be familiar with site specific hazards with the correct utilization of PPE and fall arrest systems. In an effort to mitigate these risks, NRL has introduced safety induction training, frequent refresher training and behavior-based safety programs designed to re-enforce an alertness and procedural compliance.

## 5. PREVENTIVE MEASURES AND SAFETY SYSTEMS

The NRL site has introduced strong preventive measures and safety systems for the safety of workers, especially those engaged in high-risk elevated activities. These actions are not just best practices in the industry, but a clear statement about how we can, and will, prevent incidents at work through clear, enforceable procedures. The important elements of the NRL safety framework are described further below:

- Onboard Safe Skilled NRL only utilises tagged and certifiable scaffolding, and has regular maintenance and periodic inspections. All five-point scaffolds are provided with guard rails, mid-rails, and toe-boards to prevent falls and to protect workmen below from workmen dropping tools or objects. Reference appearances and technical characteristics can provide a basis for establishing and monitoring scaffold safety standards locally.
- Personal Protective Equipment (PPE): PPE must be worn and compliance with its use will be strictly monitored throughout the NRL project. Height operators are to wear safety full body harness double lanyard-constant anchorage. Other PPE includes hard hats to protect against head injuries, and anti-slip industrial shoes to avoid slipping and tripping on metal or on scaffolding surfaces.
- Training and Awareness Programs: that has created a safety culture through all-encompassing training programs. These comprise coach meetings daily to reveal task-related vulnerabilities, inductions (of new recruits) in an effort to provide them with

awareness in safety, and mock drills whereby response capabilities are tested and readiness in live situations is made.

- **Technology Infusion:** Sophisticated technologies have been infused with the safety infrastructure. Implementation of real-time monitoring using CCTV surveillance systems Real time monitoring of hot spots of vulnerability is possible with a robust system of CCTVs manned round the clock. Wearable safety technology also monitors the location and movement of workers, as well as vital signs, providing another level of protection and the ability to respond quickly to emergencies.
- **(PTW) System:** A formal Permit to Work (PTW) system for all working at height activities. This ensures that such works are not carried out unless full authorisation, risk assessment and control can be implemented. PTW provides accountability, procedural discipline and risk communication for every participant.
- **Emergency Response:** In order to respond quickly to any eventualities, NRL keeps a complete emergency response set up including fall rescue plan explaining step by step recovery processes. The first aid preparedness is maintained in the form of trained personnel as well as first aid kits available in different places in the site. In addition, hazard communication systems such as signs, horns, and loud speakers are in place, and actual verbal job briefings are conducted to inform and warn employees of site-specific dangers.

## **6. SCAFFOLDING AND ACCESS SAFETY NORMS**

Scaffolds are critical for elevated work. The following types and systems are used:

- Tube and Coupler Scaffolds



Figure: 3

- Tubular Welded Frame Scaffolds

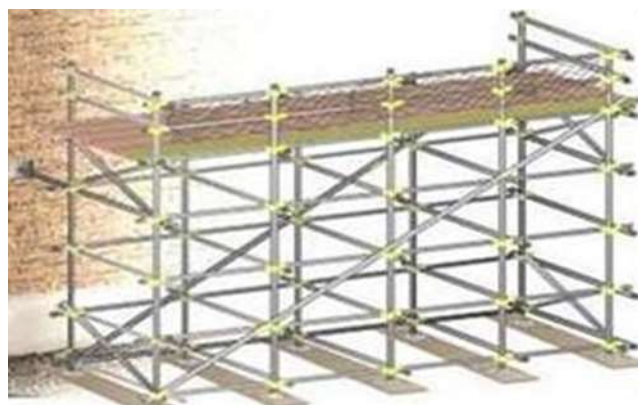


Figure :4

- Mobile Scaffolds with Lockable Casters
- Travel Restraint and Fall Arrest Systems for motion control and impact reduction.

Tables and checklists in the report provide detailed inspection guidelines to ensure that every scaffolding system is installed, used, and dismantled as per safety protocols.

## 7. RESULTS AND DISCUSSION

A positive aspect of safety measures at NRL is apparent in the decreased incidence. Key findings include:

- Meaningful exposure by following the scaffolding and PPE regimen reduces the time spent in falls.
- Worker training is an effective way to increase safety knowledge and compliance practices.
- Ongoing auditing and oversight keeps these conditions from being allowed to fester.
- Technology (wearables, real-time surveillance) allows an easy integration for monitoring.

These findings support the utility of a layered safety strategy and proactive leadership in addressing the height work risk.

## 8. CONCLUSION

Height work remains the inherent risk factor of construction work, more complex and large scale construction such as encountered in the project of Numaligarh Refinery Limited(NRL). The hazardous nature of work at heights places employees in danger of falling, the collapse of structures, and contact with overhead hazards. These challenges can be mitigated effectively, as evidenced by the present study, which is based on comprehensive planning, mandatory curricula, intensive supervision, and consistent adherence to widely accepted safety protocols. At NRL, the initiation of these initiatives have gone a long way towards lowering the incidence rate and making the workplace a safer place. Structured planning includes risk evaluations, planned task order, and the use of resources in a calculated manner to reduce risk exposure. (Training guarantees that all staff, regardless of their role, are armed with the knowledge and techniques to recognise, avoid and deal with working at height hazards. Monitoring is an important barrier to enforcing safe practices and preventing or responding to unsafe ones. The NRL case study also highlights the value of cultivating a safety-first culture – one in which



safety is not considered an obligation but a component of every operational decision. In addition to which the mediation between conventional safety practices (scaffolding check, use of personal protective equipment (PPE)) and digital tools (sensor-based fall detection systems, drones-supported controls, digital monitoring platforms) has increased the capacity of risk protection. These collaborative efforts at NRL represent a practical and cost-effective safety model worthy as best practice for all infrastructure work in the country – proving that through a combination of the right planning, education, enforcement and innovation, the number of hazards working at height can be vastly reduced.

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