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Ensuring Safety for the Construction Workers involved in Metro Tunnelling Projects

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Abstract - *The growth of Tunnel Construction industry made significant improvement over the past few decades. "Safety First" should be one of the main objectives of any construction projects mainly tunnel and shall be given high priority throughout the construction period. This many a times lead to the incompletion of these projects, and ultimately its cost overrun and time overrun. This study aims to bring out the safety measures taken by the management towards the construction workers involved in the tunnelling works. This research involves literature study through reviewing various journal papers and data collections regarding the tunnel workers safety and case studies on various metro tunnel projects and accidents happened during the construction. The outcome of this study is to come up with the proper managing tools for the safety managers towards the safety of the workers and identifying the risk factors in the construction phase and also suggesting some risk mitigation measures and techniques to avoid such accidents in future.*

Key Words: **Tunnelling, Safety Management, Hazards, Risk Management, Risk Identification, Accidents, Standards.**

1. INTRODUCTION

Tunnelling is commonly used in the construction of railways, roads, and irrigation systems. Tunnelling engineering specialisation is a major risk factor during project implementation. Tunnelling and subterranean construction projects entail risks to all parties concerned, including those who are not directly involved in the operation. The impact has been significant, particularly in residential areas. Influence the local population as well as neighbouring structures. Among the inherent threats are ground and groundwater concerns. There are also conditions, cost overruns, and major accidents. There is a risk that the tunnel project could cause public protest, which could have an impact on the project. Typically, these dangers are mitigated by employing appropriate risk assessment and mitigation measures. However, a lack of appropriate risk management approaches in our country has resulted in many project cost and time overruns. Implementing risk assessment and the need for management in the tunnel construction sector has grown over time as the complexity of tunnelling projects has increased, as has the rising pressure to reduce costs and shorten construction time.

2. AIM AND OBJECTIVES

The main objective is to assess and manage the risks associated with tunnelling projects in India, as well as to determine the probability and severity of risks involved in various phases of the project, analyze the risks, and offer risk mitigation methods for the principal hazards included in the project. Determine the primary internal and external risks that the tunnel construction industry's development is most vulnerable to risk assessment in order to rank them for effective risk management. The development of a risk management strategy that incorporates appropriate measures to reduce tunneling-related hazards.

3. METHODOLOGY

The first step will involve conducting a thorough review of relevant literature on metro tunnel projects, construction safety, and best practices in ensuring safety for construction workers in tunnel projects. This literature review will provide a comprehensive understanding of the current state of research on the topic, identify research gaps, and provide a foundation for the research.

The second step will involve conducting case studies of metro tunnel projects from different regions of the world to identify and compare different safety measures implemented in these projects. The case studies will include interviews with project managers, construction workers, and safety officers to gain insights into the various safety measures implemented and their effectiveness in ensuring worker safety.

The third step will involve conducting gathering data on the current safety measures being implemented in metro tunnel projects. This will be designed to gather information from construction workers, supervisors, and project managers involved in metro tunnel projects. This will focus on the types of safety hazards encountered in metro tunnel projects, the current safety measures being implemented, and the effectiveness of these measures in ensuring worker safety.

The fourth step will be to analyse the data gathered from the data gathered and case studies. The survey data will be evaluated statistically in order to detect trends and patterns in the data. Thematic analysis will be used to discover reoccurring themes and patterns in the data obtained from the case studies. The suggestions will be based on best practises discovered in the literature review as well as survey and case study data.

4. LITERATURE REVIEW

4.1 Hazards in tunnelling and Underground Works

The hazards involved in tunnelling and underground works arise due to the following operations:

I. Drilling

II. Explosives and blasting

III. Mucking plant and equipment.

IV. Supporting the excavation

4.2 Common Causes of Accidents in Excavation

Workers trapped and buried in an excavation after the sidewalls collapsed; Material falling into the excavation wounded and injured workers; Falling workers into the excavation; In the event of flooding, there are insufficient and unsafe entry points. Vehicles pushed into or dangerously close to the edge of an excavation, especially when reversing, causing the sides to collapse; Asphyxiation or poisoning induced by vapors heavier than air entering the excavation, such as diesel and petrol engine exhaust fumes..

4.3 Precautions Needed

Precautions that should be taken before any one is allowed in a trench or excavation.

I. What conditions can affect the stability of the sides of an excavation?

II. Why are a considerable number of the accidents in excavation work fatal?

III. If the sides of a trench collapse burying a fellow worker, what action would you take?

IV. What precautions are needed to be taken to avoid danger from underground services?

4.4 Safety Program

Safety Personnel - All operations inside the tunnel or shaft shall be carried out under the immediate charge of a competent foreman. A safety committee shall also be appointed in jobs where 100 or more persons are employed. It shall have at least three members - one each from workers, supervisors and management. This committee shall conduct its meeting at least once in 15 days and discuss safety problems on the work.

4.5 Medical and Other Facilities

Stretchers and other equipment required to transfer injured people must be available at all shifts and portals. Where there are more than 50 people working in a shift, appropriate artificial respiration systems with trained individuals capable of giving artificial respiration must be supplied.

4.6 On-Site Rules

At the entrances to these places, 1 × 1.5 m sign boards with the following language must be installed. Unless the worksite is within 500 meters of the tunnel's portal, sanitation facilities must be nearby. Unless it is impractical, dry closets, water closets or closet cars shall be provided in the tunnel at a scale of one unit for every fifty men in the shift.

Up to 100 m of tunnel length, just one of the above-mentioned systems shall be provided, however tunnels longer than 100 m shall have at least two systems installed, with wires running along opposite sides of the tunnel, if practical. In front of switchboards, a corridor no less than 60 cm wide must be maintained. All subterranean electric lines carrying voltages of 440 and above must be insulated, lead-covered cables that are well armored against abrasion and grounded.

They must have a 45 cm free area between the explosive and detonator compartments, and nothing may be carried in that gap. Insulated containers used to transport explosives or detonators must be made of finished wood that is at least 5 cm thick, plastic that is at least 6 mm thick, or pressed fibre that is at least 10 mm thick. There must be no metal parts, including nails, screws, bolts, and so on, and it must be watertight and have a top. Located at least 170 meters away from the operating area.

Other than clay sticks 25 mm dia and 10 cm long, no other substance shall be used for blinding and sealing the holes after charging. Before use, each electric detonator must be examined for a positive test with an ohm-meter.

5. NET CASE STUDIES

5.1 Delhi Metro Rail Project

On July 12, 2009, an accident occurred in the Badarpur - Secretariat section close to P-67 while lifting superstructure segments as part of the construction of Delhi Metro Rail Project's Phase II. The pier cap of pier P-67 collapsed, which led to the subsequent collapse of : the erected and pre-stressed Launching Girder, the span between P-66 and P-67,

and segments of the superstructure for the span between P-67 and P-68.

Six people died and many others were hurt in the incident. Initially the support system for viaduct was designed as portal pier till the casting of the pier was over. The shop owners in the nearby area put up resistance against casting of the other leg of the portal and it was subsequently decided by DMRC that this would be changed to a cantilever pier, similar to P-68. The top reinforcement of the cantilever beam did not have any development length into pier concrete. As learned from the sources, the top reinforcement of the cantilever beam had an "L" bend of 500 mm only.

Fig -1: Delhi Metro Project Accident on July 12 2009

On 13th July, 2009, while clearing the site of all debris, 4 cranes were deployed by DMRC for taking out the entrapped launching girder. Three out of four cranes failed during this operation. The boom of the crane, used for lifting the launching girder had failed in bending and showed a clear sign of overloading.

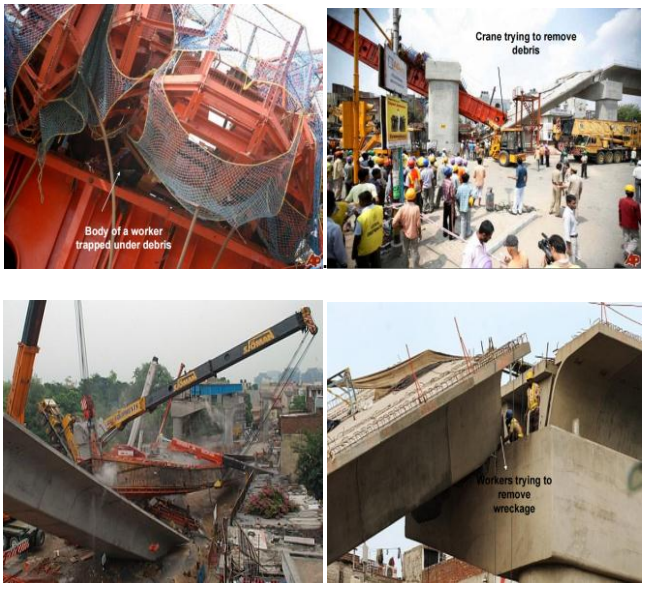

Fig -2: Delhi Metro Project Accident on July 13 2009

The project was about two months behind schedule. According to nearby residents, cracks were obvious in the collapsed pillar, and work had been halted for approximately two months to 'repair' it. The phase 2 project, which includes a 121-kilometer line and 81 metro stations, was approved in 2005, with a completion date of October 2010. Phase I began on October 1, 1998, and ended in November of 2006. The project's total length was 65 kilometers. The total time limit for phase 1 was 8 years, whereas the time limit for phase 2 is 5 years, despite the fact that the project's length is nearly double. Work was moving at a rapid rate due to the restricted time frame.

According to experts because to the limited time frame, several concessions were made with the construction work and safety standards. The contractor's performance is also being scrutinized. If the project is delayed, the contractor will be fined heavily, according to the contract terms and conditions.

As a result, in order to complete the project on time, which had already been delayed, the contractor disobeyed the safety regulations, resulting in the accident.

5.2 Pune Metro Rail Project

A 19-year-old worker, Mulchandrakumar Sitaram from Fatehpur. Sitaram fell from a height of 50 Feet at the Metro Crashed construction site near Vanaz. He was taken immediately to a nearby hospital as he was seriously injured, but he succumbed to his injuries on arrival at the hospital before he could be treated.

"Sitaram had worn safety gear, but he did not attach his hook to the rope while working at such a height. He suffered a grave and painful injury and subsequent death because of falling from such a height", said Senior police inspector Mahendra Jagtap of Kothrud Police station.

Fig -3: Pune Metro Rail - TBM tunnelling process

The priority model can be used to evaluate risks. This will be useful for reducing risk and monitoring it. Further research is needed to assess risk. According to this study, design and technology selection delays are a significant risk factor for project delays in the majority of infrastructure projects. It is advised to research these dangers using risk assessment methods.

Risk control is the process used to identify, develop, implement and continually review all practicable measures for eliminating or reducing the likelihood of an injury, illness or diseases in the workplace.

The phase of risk identification is essential, because it establishes the bases of the risk analysis. Indeed, the data of risk identification will be the input of the evaluation and/or hierarchization phases. Therefore, it is necessary to make an identification phase in an exhaustive way to get the best results.

5.3 Shanghai Metro Rail Project

Beijing, June 2 2019 (IANS) Five workers, trapped in a collapse at an under-construction Metro tunnel site in Qingdao, China's Shandong Province, have been confirmed dead, according to the project management company. With the problems of existing safety standards, safety accidents often occur in construction projects. According to the statistics of the Ministry of Housing and Urban (Ministry of Housing and Urban Rural Development of People's Republic of China, 2017), nearly 80 accidents took place from 2011 to 2016 during metro construction, including high falling and other types of accidents. Among them, the high falling, collapse and object strike were the most frequent types of accidents, accounting for up to 66% of the total accidents; vehicle injury, electric shock and lifting injury respectively took an identical proportion of about 6% which was slightly lower than that of mechanical injury, 7%. Wuhan, Beijing and Shenzhen ranked the top three.

Fig -4: Shanghai Metro Rail Accident on June 2019

The results of this instrumentation program show that the EPB shield at the Shanghai Metro Tunnel-line 2 project performed successfully. Ground movements were held within limits which were typically much smaller than what would be expected with a conventional shield. The advance of the EPB shield at the instrumentation site led to initial outward movements from the shield, movements that were largely lateral and confined to the soil immediately to the side and in front of the shield.

This result indicates that the special provisions of balancing the earth pressure at the cutting face and the compensation tail grouting technique adopted by the EPB shield are able to effectively reduce the potential shear stress development induced by the tunnel excavation process.

However, the overburden pressure developed at the tunnel crown and the weight of the tunnel lining will be eventually transferred to the bottom of the tunnel lining.

5.4 Comparative Analysis

Due to the short time frame, some concessions were made with the building work and safety standards. In order to complete the job on schedule, which had already been delayed, the contractor violated safety regulations, resulting in the accident. The Delhi metro has been praised for its superior safety standards and more efficient building procedure. Construction businesses' safety departments should compile basic safety regulations, technological requirements, and other safety knowledge into safety behavior standards. Employees can learn safety knowledge and eliminate unsafe behaviors by using the standards to train them.

When hazards are identified and their likelihood of occurrence is quantified, it is anticipated that they will operate as intended in the absence of unforeseen events (component and material failure, human mistake, external event, process unknown) that may change process behaviour. Each measure must have a designated person and a deadline for control implementation. This guarantees that all necessary safety precautions are taken.

6. LIVE CASE STUDY

6.1 Chennai Metro Rail Project: Phase II

Phase II extension is proposed for a 118.9 km network with 128 stations. Corridor -3 connects Madhavaram to SIPCOT (45.8 kilometers), Corridor -4 connects Lighthouse to Poonamalle Bypass (26.1 kilometers), and Corridor-5 connects Madhavaram to Sholinganallur (47 km).

L&T | TATA provides structural consulting services. The project's projected cost is Rs. 63246/- Cr (Rupees Sixty-three thousand two hundred and forty-six only) (including IDC). This plan is in the works and is expected to be finished by the end of 2026.

6.1.1 Stretch I – Kellys to Ayanavaram

Stretch Name: Ayanavaram to Kellys

Main Station: Purasaiwakkam

Sub-stations: Otteri, Pattalam, Perambur Barracks Road, Dovetown

Length of the tunnel: 2.8kms Approx.

Start Date: June 21 2021

Completion Date: Expected 48 months from the start date

Project Cost: 200 - 225 crores

Current Status: Excavation, drilling, De-walling

Total Number of Workers: 150 - 180 workers per Shift

Number of Shifts: 02 [8am to 8pm & 8pm to 8am] (with 2hours break)

Type of the Tunnel: Twin - Bored Tunnel

Structural Consultants: TATA PROJECTS

Tunnel Details: Inner dia. 5.8m, Outer dia. 7.05m

Insurance Consultants: TATA ZeTo Group Insurance

Main Contractor: TATA PROJECTS LIMITED

Sub - Contractor: NKAB



Fig -5: Chennai Metro Rail Works (Purasaiwakkam)

First aid room is provided for the workers in case of any emergencies. PPE equipment were not followed by some workers on the site. There are no safety persons present on the site and there is no proper monitoring of the works and workers. Many places did not have any proper security and the workers were not present there so that anyone can access the place and also to some equipment. Workers does not seem to be productive as there is no proper supervision in the site. Fire evacuation place for the site was not provided by the safety management. No proper space for workers training.

6.1.2 Stretch II – Kellys to Greenways Road

Stretch Name: Kellys to Greenways Road

Main Station: Chetpet

Sub-stations: Thousand lights, Royapettah

Length of the tunnel: 6kms Approx.

Start Date: July 15 2021

Completion Date: Expected: 43 months from the start date

Project Cost: 370 - 400 crores

Current Status: Excavation, drilling, De-walling

Total Number of Workers: 200 - 220 workers per Shift

Number of Shifts: 02 8am to 8pm & 8pm to 8am (with 2hours break)

Type of the Tunnel: Twin - Bored Tunnel

Structural Consultants: Larsen Taubro

Tunnel Details: Inner dia. 5.8m & Outer dia. 7.05m

Insurance Consultants: BAUER Group Insurance

Main Contractor: Larsen Taubro

Sub - Contractor: NKAB | BAUER

Fig -6 : Chennai Metro Rail Works (Chetpet)

First aid room is provided for the workers in case of any emergencies. All the workers in the site were strictly following their rules by wearing PPE equipment (helmets, jackets, boots, gloves, etc.). All the workers in the site were found productive in their work. The safety monitoring persons were present at the site Fire Evacuation Plan was clearly marked and provided at the site.

A 45-year-old contract worker died following a cave-in while working underground for laying sewage pipeline for the Chennai Metro Rail project near Medavakkam.

The pipelines were moved and re-laid a few meters away at a depth of 10 feet in order to allow soil testing in the centre of the road," said a senior police officer. Around 1 am, Ravi entered the 10-feet pit without any protection and was involved in laying the pipe, when the soil caved-in.

7. FINDINGS FROM THE STUDY

Safety supervisors should be present on the job site to increase workplace efficiency while also monitoring worker and workplace safety. All workers must rigorously adhere to the safety regulations. These should be monitored by a supervisor, and any infractions should result in a punishment. Each zone should have a security guard and be monitored by the management. Access to certain areas and equipment should be controlled.

The administration should offer enough medical and other amenities for the personnel. According to IS regulations, safety sign boards should be placed on the job site. Emergency contact information should be posted on the site so that anybody there may transfer the information to the safety team in the event of an emergency.

According to the IS and BOCW Act, all workers must be equipped with appropriate safety and PPE equipment. A fire evacuation plan must be given at the site to save staff and guests in the event of an emergency. Workers and employees must have an Emergency Assemble Area that may be utilized to protect them in the event of an emergency.

Communication between employees and management is required and must be considered. To promote communication, many communication techniques can be given.

According to IS regulations, emergency exits must be provided every 30 metres. This is absent in both segments. This element must be considered in all tunnelling projects in order to promote worker wellbeing. Workers must be educated about the dangers linked with their jobs. Management should provide regular training in all elements of the job.

8. RESULTS AND DISCUSSIONS

Different techniques are used to stabilize the tunnel face depending on the soil and ground water conditions. One of them and the most efficient one is compressed air face support, but it is pricey. Under the beginning, a crew of workers would be sent underground in compressed air to dig and construct a tunnel, the TBM handles this currently.

Usually tunnelling happens 26m below the safe ground level. [4m below the ground - safe ground level] TBM Air lock accidents, while changing the gutter workers faces breathing suffocation and this is said as the serious issues by the workers.

Breathing Air: Air was supplied by electric compressors, and a sample was taken from each compressor and tested for purity. As a benchmark for air quality, IS 15879 (2002), an Indian standard for "Breathing air quality," was employed. Consequently, safety workers used handheld multigap monitors to check the air quality once every shift. Filters were incorporated on the air line as an additional safety.

Hazards of compressed air working: Barotrauma | Decompression sickness (DCS) | Dysbaric osteonecrosis.

Noise: TBM operator is well protected in a sound-proof cabin and all other persons are more than 100 m away. They should be provided with ear plugs.

Flood problems: This cannot be avoided in an underground tunnelling, as the electric wires Unpredictable accidents which cannot be avoided also a major reason. Workers gets injured by sharp pieces during the excavations. Landslides also a reason.

Post - Work Solutions: As the TBM hits an uneven surface, hard rocks becomes clay, this leads to the creation of sink holes in the upper layer. It is due to the loosening of soil. This can be prevented by back filling with concrete to

stabilize the ground hard to avoid collapse. Workers requires a regular monitoring and inspection of the workplace and workers health.

9. CONCLUSION

The need of suitable risk transfer procedures must be increased because external risks are the most important ones and cannot be controlled by the project. The implementation of a risk management plan should begin at the project's inception and continue throughout the duration of the project. Additionally, it's important to periodically identify secondary and residual concerns and update the risk register with them. The idea that the cost of reducing or avoiding a risk shouldn't be higher than the cost of the risk itself should be kept in mind when managing risks is another crucial idea.

A high level of transparency is necessary to be able to manage the risks involved in tunnelling. For the purpose of developing appropriate operational plans as soon as feasible, it is crucial for tunnel operators to quickly gather situational knowledge that can be acquired from previously occurring occurrences.

The type of incident, the number and location of individuals trapped, the infrastructure status, and the tunnel asset management condition are all part of the situation information. To management the risk effectively and efficiently, the contractor must understand risk responsibilities, risk event conditions, risk preference, and risk management capabilities.

In order to build a more effective risk management strategy based on their prior experience, the operators or authorities in charge should constantly refresh the operation and maintenance plan by adding all that information. And one of the most valuable pieces of knowledge that all tunnel operators need is all the general dangers that have been recognized and examined.

10. RECOMMENDATION

In order to prevent the risks, the usage of AI can be implemented with the safety management. As there are many technologies have been used in many countries, some of those may be adopted by knowing the level of usage in India.

A thermographic camera is a device that creates an image using infrared (IR) radiation, similar to a normal camera that forms an image using visible light. An Online safety management system helps prevent accidents and their human and financial consequences. Effective safety management reduces the costs associated with accidents and many hidden costs. Wearing a hearing protector is important if the noise or sound level at a workplace exceeds 85 decibels. By using a hearing protector, the risk of hearing loss can be reduced.

The inspection of the tunnel can be carried out by a fully autonomous system without endangering the security of the operators. Future systems must be able to perform maintenance and inspection with little to no oversight from humans, if not at all.

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