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Case Study of Twin Tunnel in Western Ghats apropos Safety

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ABSTRACT: The New Khambataki Twin Tunnel is a significant infrastructure project aimed at enhancing transportation connectivity in a critical region. This research paper provides a detailed analysis of the construction and safety aspects of the New Khambataki Twin Tunnel project. The paper examines the design considerations, construction techniques, geotechnical challenges, safety protocols, and risk mitigation measures implemented during the tunnel's construction. Additionally, it explores the integration of advanced technologies and innovative safety solutions to ensure the safe and successful completion of the project. Through the examination of the New Khambataki Twin Tunnel case study, this research paper aims to provide valuable insights for the development of future tunnel projects with a strong focus on construction quality and safety.

Road safety is a critical concern worldwide due to the significant number of fatalities and injuries caused by road accidents. Road safety audits (RSAs) have emerged as a proactive approach to identifying potential hazards and improving road infrastructure to minimize the occurrence of accidents. This research paper provides a comprehensive review of road safety and road safety audits, exploring their significance, methodologies, effectiveness, challenges, and future prospects. The paper aims to contribute to the understanding of road safety measures and the role of RSAs in creating safer transportation systems.

This research paper examines the significant benefits of safety audits in tunnel construction projects. Safety audits play a critical role in identifying potential hazards, evaluating existing safety measures, and ensuring regulatory compliance. The paper explores the various types of safety audits commonly conducted in tunnel construction and highlights their positive impact on accident prevention, worker protection, and overall project success. Through the analysis of case studies and relevant literature, this research aims to emphasize the value of safety audits as a proactive approach towards improving safety in tunnel construction projects.

Tunnel construction is a complex and high-risk endeavour that poses numerous safety challenges for workers, engineers, and project stakeholders. This research paper aims to explore the safety problems encountered during the construction of tunnels, identify their root causes, and propose effective mitigation strategies. The paper provides an in-depth analysis of common safety hazards, including geological risks, ventilation issues, confined spaces, fire and explosion hazards, and construction site accidents. By understanding these challenges and implementing best practices, construction industry professionals can enhance safety protocols and reduce the occurrence of accidents in tunnel construction projects.

I. INTRODUCTION

Road defects play a significant role in the occurrence of accidents worldwide, resulting in fatalities, injuries, and damage to property. This research paper presents a comprehensive analysis of road defects and their contribution to accidents. It explores various types of road defects, their causes, and their impact on road safety. Additionally, the paper examines the interaction between road defects and other factors, such as driver behavior and weather conditions, that contribute to accidents. The findings of this study aim to enhance our understanding of the relationship between road Road defects and accidents, and provide insights for developing effective strategies to improve road safety.

Twin tunnels have gained popularity in transportation infrastructure projects due to their ability to increase capacity and improve operational efficiency. This research paper focuses on the design and safety considerations specific to twin tunnel projects. The paper explores various aspects of twin tunnel design, including alignment optimization, structural

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elements, ventilation systems, emergency egress provisions, and fire protection measures. Additionally, it addresses the safety challenges associated with twin tunnels and presents strategies to mitigate risks and enhance safety. By emphasizing the importance of sound design principles and effective safety measures, this study aims to contribute to the successful implementation of twin tunnel projects

Background and Purpose of the Study

Project consists of construction of tunnel in Khambataki ghat section including approaches on Pune – Satara section of NH-4 in the state of Maharashtra. Khambataki Ghat is located in Pune – Satara section of NH -4 from Km 771.730 to Km 782.000 in Satara District, Maharashtra. This section is a part of the Six Laning of Pune- Satara Section of NH-4 from Km 725.000 to Km 865.350 (Length-140.350 km). The project stretch constitute of 6 lane flexible pavement with paved & earthen shoulders. The general terrain along the road is mountainous with intermittent stretches falling under rolling terrain. The existing pavement is entirely of flexible type with varying width from 10.5m to 13.5m in 3 lane, 7m in tunnel section, paved shoulder width varies from 1.0m to 3m. The height of the embankment varies between 0.5m to 5m. There are no junctions along the project stretch.

Objectives of the Research Paper

The scope of this study is to understand the design of twin tunnels in Western Ghats considering the safety during construction of tunnels and during the operation phase of tunnels. For the purpose of same, case study on tunnel in Khambataki Ghat with respect of its design methodology, need of twin tunnel and safety considerations is carried out in this dissertation report to understand the basic construction methodology of tunnelling apropos design and safety aspect in India.

The project stretch serve a purpose of connecting two very important metropolitan cities namely Mumbai and Bangalore. Also the project stretch is used by a number of tourist passenger visiting a very famous hill station i.e. Mahabaleshwar. The tunnel section of NH-4 is a one way route used by commuters traveling from Satara towards Pune and comprise of 3 lane carriage way with paved shoulder outside the tunnel portion and two lane carriageway inside the tunnel. The commuters traveling from Pune to Satara have an existing 3 lane Ghat road, which is around 9 km in length. The two-lane tunnel is going to become a bottleneck as the traffic volumes increase. The geometric improvements for the Ghat section is not going to address all the geometric deficiencies in the alignment. Some of the issue in the Ghat section of existing highway is the slope instability, length wise long route, geometric deficiencies, high precipitation and seismic zone. Therefore, there is the need for construction of alternative route for the smooth and safe movement of traffic.

Project Overview

Considering the issues arising during operation of existing Pune Satara highway, new Greenfield alignment was proposed consist of twin tunnel and its approaches.

Further for the study of subject dissertation work, the case study of twin tunnel in Khambataki Ghat which is in Western Ghats has been carried out.

The Khambataki Ghat is the part of NH-4 originating from Mumbai and passes through several districts of Maharashtra and Karnataka like Thane, Pune, Satara, Kolhapur, Belgam, Chitradurga and terminates at Bangalore.

The project section starts near Vele (Km 771.730 on NH 4) and ends near Pargaon Khandala (Km 782.000 on NH 4).

II. LITERATURE REVIEW

1. Tunneling in Various Countries

R.K. Goel[14] made a sensitivity analysis on Status of tunnelling and underground construction activities and technologies in India. He studied that, A considerable amount of tunnelling work has been going on in India for hydroelectric, irrigation, roads and railways projects. Most of these projects are located away from urban areas. The use of tunnelling for urban utilities, such as water supply, sewerage disposal and metro rail has recently begun. A few projects have been completed and some are under construction in metropolises such as Mumbai, Calcutta and Delhi. The present status of tunnelling and its future potential in India is highlighted in the paper with emphasis on tunnelling

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projects for hydro-power developments, as this sector presently has maximum underground construction activity in India. The tunnelling technologies for planning, design and construction have also been presented in this paper.

Md Shariful Islam, Magued Iskander[8] studied Twin tunnelling induced ground settlements: A review. They observed that, In the past few decades, the number of tunnels constructed next to an existing tunnel has been gradually increasing in order to accommodate infrastructure needs in congested urban cities. When a new tunnel is constructed adjacent to an existing tunnel, both the relative position of the tunnels and the construction sequence affect the ground settlement and internal forces in the linings of both tunnels. Therefore, it is important to study the influence of these factors and their relationship to tunnel construction. A review of twin tunnelling induced ground settlement is presented in this paper. A wide range of data is collected, summarized, and compared with each other to infer interaction phenomenon related to ground settlement. This data is gathered from published field observations, laboratory tests, and finite element analyses. The paper begins with an overview of single tunnelling induced settlements, volume losses, and factors which can affect twin tunnelling induced ground settlements. Next, a summary of the effects of construction sequence, pillar width, and cover depth, among other influencing factors, has been presented for four twin tunnelling configurations including (i) side-by-side, (ii) piggyback, (iii) perpendicularly crossing, and (iv) offset arrangement twin tunnelling. The paper also presents a summary of available techniques to calculate ground settlements induced by a new tunnel excavation in the presence of an existing tunnel. Finally, the paper summarizes available knowledge on ground settlement induced by various twin tunneling arrangements and identifies known unknowns.

Xue-tao Wang et. al.[17] investigates Prediction of ground settlements induced by twin shield tunnelling in rock and soil – A case study. In which he stated that, Ground movements caused by the construction of tunnels and excavation are inevitable. Estimation of such movements is a very important for risk management in tunnel design. This paper presents a case study of ground settlements induced by twin shield tunnelling in Copenhagen using analytical and numerical methods and their predictions. The predictions are compared with the monitored settlements. The comparison shows that the predictions are sufficiently conservative.

Yao Hu et. al [19] investigates Ground movement induced by triple stacked tunneling with different construction sequences by. tried to explore the ground movement induced by triple stacked tunneling (TST) with different construction sequences. A case study in Tianjin, China was used to investigate the ground movement during the TST (upper tunneling (UT)). For this, a modified Peck formula was proposed to predict the surface settlement induced by TST. Next, three sets of finite element analyses (FEA) were used to compare the effects of construction sequences (i.e. UT, middle tunneling (MT), and lower tunneling (LT)) on vertical and lateral ground displacements. The results of Tianjin case and UT reveal that compared to a Gaussian distribution for a single tunnel, the surface settlement curve of triple stacked tunnels is a bimodal distribution. It seems that the proposed modified Peck formula can effectively predict the surface settlement induced by TST. The results of the three sets of FEA demonstrate that the construction sequence has a significant influence on the ground movement. Among the three construction sequences, the largest lateral displacement is observed in the MT and the smallest one in UT. The existing tunnel has an inhibitory effect on the vertical displacement. The maximum value of the lateral displacement occurs at the depth of the new tunnel in each construction sequence.

2. Design & Construction Of Tunnel

Katsushi Miura[6] studied Design and construction of mountain tunnels in Japan by made a sensitivity analysis on the state of technologies of the mountain tunnelling method in Japan. In addition to the review of the design and construction technologies, the paper focuses on the development of technologies for tunnels with large cross-sections, urban tunnels in non-cemented soil ground, and applications of TBMs, which are technically evolving nowadays.

Aliakbar Golshani et. al.[1] studied Innovative design modification during construction of a twin tunnel using real-time field data. They observed that, Tunnels are vital substructures that are strongly influenced by the surrounding soil, especially when using the New Austrian Tunneling Method (NATM) in which the soil surrounding the tunnel displaces under part of the applied load and the remaining load is borne by the tunnel initial lining. Displacement monitoring is of

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great importance in this method and designers should monitor data during construction in addition to a choosing an initial design based on primary soil parameters. The method should be a performance-based approach that is required to meet a target. This paper reports on a case study on an urban twin tunnel constructed using NATM. The construction method is compatible with existing geological conditions and space constraints caused by the high traffic congestion on Valiasr Street in Tehran. The twin tunnel is composed of asymmetric sections and has an overburden of about 12.5 m, height of 8 m and width of 18.3 m with three lanes. In other words, it is composed of a two-lane and a one-lane tunnel with connected initial linings and separate final linings. The numerical modeling was based on a 2D finite element program (PLAXIS version 8). Performance was evaluated by inducing settlement during and after excavation and initial and final stabilization. The model was analyzed statically. During construction, limiting settlement to the regulation values required strategies such as reducing the length of excavation, partial construction of the final lining on one side and reinforcement with micropiles and compensation grouting. The numerical results show that the length of excavation resulted in low efficiency of about 13%, but the micropile elements reduced the resultant surface settlement 30% and the induced total strain 46% over the critical value. In other words, the displacement trend line decreased with a dip of 30%. In comparison with field observations and field data, the numerically estimated settlement at the ground surface was approximately twice that of the measured value and, interestingly, the recorded convergence was fixed during tunneling, suggesting that unknown conditions like a cavity or deep soil with filling material exists above the tunnel. Comparison of the back-analyzed results with the field data showed a decrease in the real values of the geotechnical parameters for the soil layer of more than 20%. This confirms that the existence of local unknown conditions can cause a difference of up to 50% in surface settlement. It was found that the loose soil properties decreased the efficiency of soil improvement to less than 15%.

Pietro Lunardi[7] had done a sensitive study on Evolution of design and construction approaches in the field of tunnelling: the results of applying ADECO-RS when constructing large underground works in urban areas & observed that, In the last 25 years in Italy, over 1000 km of tunnels have been constructed in urban and extra-urban areas. Despite being constructed in very complex and difficult grounds; generally these were completed (from the design stage to the construction and actual opening of activity) with industrial methods, and within the technical times and costs foreseen by the design laid out by the tenders. This extraordinary result has been made possible since the public administrations have adopted modern design and construction approaches in their contract specifications, based on strictly scientific criteria and which leave nothing to the typical vagueness of those design and construction systems from the twentieth century, which remedied cavity instability solely by means of partitioning the excavation face. Today we know that full-face advancement is all the more necessary the more difficult the excavation conditions are. Memory serves to illustrate the criteria that helped define modern design and construction concepts and an example of their application for constructing a great twin tunnel (258 m2 + 258 m2 in section) in the urban area of Rome.

Minh Ngan Vu & Wout Broerea[10] observed that, Structural design model for tunnels in soft soils: From construction stages to the long-term, In bored tunnel design, most recent structural design models for tunnel linings concentrate on the behaviour of the tunnel lining in the long-term. The load on the tunnel lining in these models is derived from the original soil stresses, often simplified for a single homogeneous layer. Field observations show that higher loads may occur in the initial hours after the assembly, that might effect the tunnel lining and that soil layers with different stiffnesses may have a negative impact on the internal forces of the tunnel lining. This paper proposes a new model for these early construction stages and also includes a more accurate model which explicitly models the impact of multilayered soils. The change of internal forces in the tunnel lining from the initial construction time to the long-term is investigated with this model. Validations with field observations and other analysis results at time of construction and the long-term confirm that the new structural analysis models can accurately predict internal forces in the tunnel lining. The analysis results also show that internal forces in the tunnel lining have an increasing trend in time and become stable in the long-term and accord with field observations.

Zuliang Zhong et. al.[20] estimated Analysis of ground surface settlement induced by the construction of mechanized twin tunnels in soil-rock mass mixed ground. In this study, the said The ground surfaces induced by the subway tunnel excavation has been an issue of great concern in the engineering field. When building subway tunnels in rugged

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mountainous cities, settlement problems are inevitable for shallow buried sections. Therefore, this paper analyzes the influence of some major tunnelling parameters on the surface settlement during excavation by creating a fine 3D FE model for the shallow-buried section of the Chongqing Metro Circle Line. Due to the lack of construction experience in the project area, the thrust force, backfilling pressure, backfill gravels and backfilling density of the right tunnel were suggested changeless as 6500 kN, 0.3 MPa and 85% separately based on similar engineering case. Simulations show that the settlement can meet the construction control requirements (<20 mm) then the construction parameters of the left tunnel were studied in detail under the condition of right tunnel excavated. The numerical computation results reveal that a tunnelling thrust of about 5000 kN and an average backfill gravels density of 89% of left tunnel corresponded to the minimum cumulative surface settlement. Finally, both the numerical prediction and field data show that the shape of surface settlement curves in the study area still follows the Gaussian distribution, which can provide a reference for other metro construction projects in this region.

III. METHODOLOGY

Safety Problems faced during the construction of New Khambataki Twin Tunnel

- Fire protection systems: Incorporation of fire-resistant materials, fire detection systems, and fire suppression measures to enhance tunnel safety.
- Emergency exits and escape routes: Designing and locating emergency exits and evacuation routes at regular intervals to ensure safe evacuation during emergencies.
- Tunnel monitoring systems: Implementation of monitoring systems to continuously assess the structural integrity, ventilation, and environmental conditions within the tunnel.

Root Causes of Safety Problems:

During the construction of twin tunnels, there are several safety problems that can arise. Some of the common safety issues include:

1. Cave-ins and collapses: One of the primary risks during tunnel construction is the possibility of cave-ins and collapses. This can occur due to unstable soil or rock formations, inadequate support systems, or improper excavation techniques.

2. Underground water or gas leaks: Tunnels are often constructed in areas where underground water or gas pipelines exist. Care must be taken to avoid damaging these pipelines, as it can lead to floods or explosions.
3. Fire hazards: Construction activities involving welding, cutting, and the use of machinery can pose a fire hazard in the confined space of a tunnel. Precautions such as fire-resistant materials and adequate ventilation must be in place to minimize these risks.
4. Hazardous materials exposure: Construction sites often involve the use of hazardous materials like chemicals, solvents, or asbestos. Workers must be trained on their proper handling, storage, and disposal to prevent exposure and related health risks.
5. Falling objects: There is a risk of falling objects during construction, especially if workers are not properly secured or if materials are not adequately contained. This can lead to injuries or fatalities if workers or equipment are struck by these objects.
6. Poor air quality: Tunnel construction generates dust, fumes, and other airborne pollutants, which can impact the air quality within the tunnel. Workers may be exposed to respiratory hazards if proper ventilation systems or personal protective equipment (PPE) are not provided.
7. Equipment accidents: The use of heavy machinery and equipment during tunnel construction can increase the risk of accidents, such as collisions, equipment failures, or entrapment. Adequate training, regular maintenance, and adherence to safety protocols are necessary to minimize these risks.
8. Access and egress issues: Entrances and exits to the construction site must be properly designed and maintained to ensure safe access and egress for workers. Failure to provide adequate access or emergency exits can lead to delays during evacuations or increased risks during emergencies.

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To ensure safety during the construction of twin tunnels, strict adherence to safety protocols, adequate training, regular inspections, and effective communication among workers and supervisors are essential. Additionally, the implementation of safety measures such as proper excavation techniques, effective support systems, proper ventilation, and the use of personal protective equipment are crucial to minimizing the risks associated with tunnel construction.

Road Safety and Road Safety Audits

Road safety is the practice of preventing accidents and injuries on the road by implementing measures and strategies to reduce risks for all road users. It involves various aspects, including designing safer road infrastructure, enforcing traffic rules and regulations, educating the public about safe driving behaviors, and conducting road safety audits.

A road safety audit is a systematic evaluation of an existing or proposed road infrastructure to identify potential hazards and recommend appropriate safety measures. It involves a thorough examination of the road design, layout, traffic control devices, signage, and other features that may contribute to accidents or injuries.

During a road safety audit, traffic experts and engineers review the road infrastructure from different perspectives, including drivers, pedestrians, cyclists, and other vulnerable road users. They analyze factors such as visibility, road surface conditions, signage effectiveness, intersection design, and traffic flow patterns. Based on their findings, they provide recommendations to enhance road safety.

The main objective of road safety audits is to identify areas of improvement and implement preventive measures to reduce the likelihood of accidents. These audits can be conducted at various stages, including during the planning, design, construction, and operation phases of a road project. The recommendations from road safety audits help in optimizing road design, improving road user behavior, and reducing the number and severity of accidents.

Some common recommendations that may arise from road safety audits include improving signage visibility, enhancing pedestrian crossings, providing adequate lighting, implementing traffic calming measures, modifying intersection layouts, and optimizing traffic signal timings. These measures aim to improve road safety by reducing the potential for collisions and creating a safer environment for all road users.

In summary, road safety is a crucial aspect of ensuring the well-being of all road users. Road safety audits play a significant role in identifying potential hazards and suggesting appropriate safety measures. By implementing the recommendations from road safety audits, authorities can enhance road infrastructure to reduce the risk of accidents and promote safer behaviors on the road.

Road Safety Audit Methodologies used in construction of New Khambataki Twin Tunnel:

Data Collection and Analysis
Road Safety Audit Checklist
On-Site Safety Inspection
Post-Audit Reporting and Recommendations

Safety Training Programs taken for New Khambataki Twin Tunnel Workers

Safety training programs for tunnel workers are crucial to avoid the risk of construction accidents and promote a culture of safety on-site. These programs should be comprehensive and cover various aspects related to tunnel construction hazards and proper safety practices. Here are some key components that should be included in safety training programs for tunnel workers:

1. Hazard identification and risk assessment: Workers are trained to identify potential hazards associated with tunnel construction, such as collapsing of tunnel walls, falling objects, electrical hazards, hazardous materials, and working in confined spaces. They should also learn how to assess and mitigate these risks effectively.
2. Proper use of personal protective equipment (PPE): Training programs educated workers on the proper selection, fitting, and usage of PPE. This includes wearing hard hats, safety goggles, ear protection, respiratory masks, gloves, and high-visibility clothing. Workers are trained on the importance of using PPE consistently and correctly to minimize the risk of injury.

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3. Safe operation of machinery and equipment: Training provided on the safe operation of all machinery and equipment used in tunnel construction, including tunnel boring machines, excavators, drilling rigs, and conveyor systems. Workers are now familiar with equipment controls, emergency shut-offs, and safe operating practices to prevent accidents.
4. Electrical safety: Tunnel construction often involves working with electrical equipment and wiring. Training programs covered electrical safety protocols, including proper lockout/tagout procedures, identifying exposed wires or damaged cables, and maintaining a safe distance from power sources.
5. Working at height safety: When working on elevated platforms or scaffolding within the tunnel, workers must be trained on fall prevention measures, including the correct use of fall protection equipment like harnesses, lanyards, and anchor points. They learned proper ladder usage and understand the importance of maintaining stable footing.
6. Emergency response and evacuation procedures: Workers received training on emergency response protocols, including evacuation routes, emergency rendezvous points, and reporting procedures. They are now prepared for potential incidents like fires, cave-ins, gas leaks, and medical emergencies. Regular drills are conducted to practice these procedures.
7. Communication and coordination: Effective communication is crucial for maintaining a safe working environment in tunnels. Workers are trained on clear and concise communication techniques, use of hand signals, and understanding specific site communication protocols. This promoted better coordination and reduces the risk of accidents.
8. Health and hygiene practices: Training programs addressed health and hygiene practices specific to tunnel construction, such as proper handling and disposal of hazardous materials, awareness of dust and air quality, prevention of musculoskeletal injuries, and importance of maintaining good personal hygiene to prevent the spread of infections and diseases.
9. Regular refresher training: As tunnel construction projects can span over a considerable period, regular refresher training sessions are going to be conducted to reinforce safety practices, update workers on new regulations or equipment, and address any emerging safety concerns.
By implementing a comprehensive safety training program, tunnel workers can develop the necessary skills and knowledge to identify hazards, adhere to safety protocols, and respond effectively to emergency situations. This helps create a safer working environment, reduces the likelihood of accidents, and protects the well-being of all individuals involved in tunnel construction.

Road Safety Measures and Interventions

To avoid accidents during the construction of a tunnel, several measures are taken to promote a safe working environment. These measures include:
1. Personal protective equipment (PPE): Workers are provided with and required to wear appropriate PPE, such as hard hats, safety goggles, high-visibility clothing, gloves, and steel-toe boots. PPE helped to protect workers from potential hazards like falling objects, debris, and chemical exposures.
2. Adequate signage and warnings: Clear and visible signage are placed at appropriate locations to indicate potential hazards, restricted areas, and safety procedures by using respective IRC standards. Warning signs regarding potential risks, electrical hazards, overhead construction, and excavation work are prominently displayed.
3. Regular inspections and maintenance: Frequent inspections of equipment, machinery, and tunnel structures are conducted to identify and address any potential safety issues or equipment malfunction. Regular maintenance performed to ensure the safe and reliable operation of all machinery and equipment.
4. Good communication and coordination: Effective communication among all workers, including contractors, engineers, supervisors, and laborers, is vital for maintaining a safe construction site. Regular safety meetings and open lines of communication help ensure everyone is aware of safety protocols and can report any hazards or concerns.
5. Traffic control and pedestrian safety: The construction site of New Khambataki Twin tunnel is close to public roads & pedestrian areas, so proper traffic control measures are implemented to ensure the safety of workers and the public. Barricades, fencing, and warning signs are used to guide traffic and pedestrians away from hazardous areas.
6. Emergency preparedness: A comprehensive emergency response plan is in place, detailing procedures for accidents, injuries, fires, or other emergencies. This plan included evacuation routes, emergency contact numbers, and the location of emergency equipment like fire extinguishers and first aid kits. Regular drills are conducted to ensure that all workers are familiar with emergency procedures.

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7. Regular safety audits: Conducting regular safety audits of the construction site helped to identify potential hazards and areas for improvement. These audits are performed by me with safety professionals & internal safety team to ensure compliance with safety regulations and best practices.

By implementing these measures consistently, we minimized the risk of accidents and created a safe working environment for all workers involved in New Khambataki atwin tunnel construction. Safety should always be a top priority to protect the well-being of individuals and prevent costly accidents and delays

IV. RESULTS & RECCOMONDATIONS

1. Near Tunnel Approach

Site Photographs-

Safety Concerns & Audit Findings-

a. Non Standard warning & work zone (Work in Progress, Men at Work, Keep left and Deep Excavation) signs observed at approaching of construction of tunnel location.

b. Solar Blinker has been missing at approaching of diversion location.

Recommendations

a. Provide Standard Warning Signs & Work Zone signs with good reflectivity as per IRC: SP: 55-2014.

b. Provide the Solar Blinker at approaching of diversion location to warn the road users during the night time.

2. Under Tunnel Alignment

Site Photographs-

Safety Concerns & Audit Findings-

a. Safety Consultants inspected the site along with AE and EPC Contractor representatives through the Tunnel (Starting to Ending).

Recommendations

a. Good Practice

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3. Tunnel Alignment (Ending)

Safety Concerns & Audit Findings-

a. Continuous Spring posts and drums with reflective sheets provided from tunnel alignment (ending) to approach of viaduct.

Recommendations

a. Good Practice

4. Viaduct Location

Site Photographs-

Safety Concerns & Audit Findings-

a. Deep Excavation for Pier foundation has been observed without any standard barricading at Viaduct location, vehicles may enter into work zone area and fall into the trenches and it may leads to severe accidents.

b. Traffic marshal/ flagmen provided to warn the drivers of construction vehicles at work zone area. – Good Practice

Recommendations

a. Provide stronger standard continuous barricading like water filled/ new jersey barrier/Type 3 and 4 standard barricades between the carriageway and adjacent deep excavation work zone as per the IRC: SP: 55-2014.

5. VUP

Site Photographs-

Safety Concerns & Audit Findings-

a. At VUP location, non-standard Diversion ahead & speed limit signs has been observed.

b. Galvanized sheets with drums have been provided as safety barricading at work zone area. This safety barricading not compliance with IRC: SP: 55-2014.

Recommendations

a. Provide the standard diversion ahead and speed limit signs as per IRC: SP: 55-2014.

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b. Provide standard continuous barricading at work zone area as per the IRC: SP: 55-2014

6. KM: 772+200

Site Photographs-

Safety Concerns & Audit Findings-

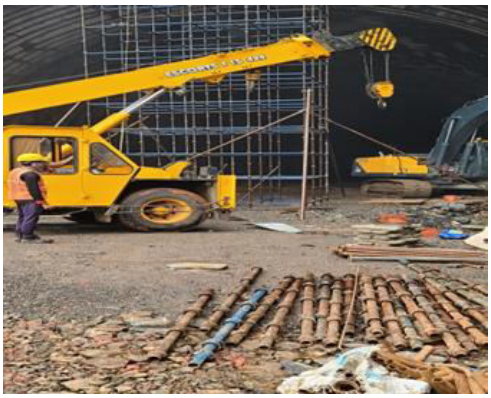
a. Safety barricading provided along the work zone area along with all work zone signs.
b. Traffic marshal/ flagmen provided to warn the road users about diversion

Recommendations

a. Good Practices.

7. KM: 772+680

Site Photographs-



Safety Concerns & Audit Findings-

a. Tunnel false portal work is in progress at LHS of Tunnel. False work material stacked on ground at work zone area. Workers may get injured by tripping during night time.

.**Recommendations**

a. False work materials which are being used at site should be stacked properly at allocated storage areas only and away from the working areas and should be cover with safety delineators.

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8. KM: 776+300

Site Photographs-


Safety Concerns & Audit Findings-

a. Diversion boards are installed alone at diversion location, which is also not compliance with IRC: SP: 55-2014.

b. Curve ahead sign provided but chevron signs has been missing along the curve location.

c. Nonstandard traffic signs and work zone sign boards installed at diversion/work zone area and also not compliance to IRC: SP: 55-2014.

d. Solar blinker/ LED blinker missing at approach of diversion location.

.**Recommendations**

a. The diversion boards should be compliant with IRC:SP:55-2014 and NHAI Work Zone Safety Manual.

b. Provide the chevron signs along the curve location to warn the road users.

c. Provide standard traffic and work zone (Men at work, Road works ahead, Traffic diversion ahead, No overtaking, Speed limit) signs as per IRC: SP: 55-2014.

d. Provide the solar blinker/ LED blinker at approach of diversion location.

9. KM: 776+650

Site Photographs-



Safety Concerns & Audit Findings-

a. Nonstandard traffic signs and damaged signs has been observed between work zone area & existing carriageway.

b. Continuous safety barricading missing along the LHS of existing carriageway.

Recommendations

a. Provide standard traffic and work zone (Men at work, Road works ahead, Traffic diversion ahead, No overtaking, Speed limit) signs as per IRC: SP: 55-2014.

b. Provide the continuous safety barricading along the LHS of existing carriageway.

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10. KM: 777+200

Site Photographs-

Safety Concerns & Audit Findings-

a. The details about Project corridor has been missing at ending of the project stretch.

.Recommendations

a. Provide the details about Project corridor at ending of the project stretch

V. CONCLUSION

This research paper provides an in-depth analysis of road safety and road safety audits. It explores the various aspects of road safety, the importance of road safety audits, their methodologies, effectiveness, challenges, and future directions. By highlighting the significance of road safety audits in improving road infrastructure and reducing accidents, this paper aims to contribute to the ongoing efforts to create safer and more sustainable transportation systems.

This research paper gives a comprehensive analysis of the results and effectiveness of safety measures implemented during the construction of twin tunnels. The paper explored the importance of prioritizing safety in tunnel construction projects and reviews various safety measures commonly employed. It assesses the outcomes of these measures in terms of accident prevention, worker protection, and overall project success. Case studies and statistical data from a range of twin tunnel projects worldwide are analyzed to provide insights into the performance and impact of different safety measures. The research contributed valuable knowledge to the ongoing efforts of improving safety practices and establishing best practices in twin tunnel construction.

Impact of Safety Measures on Project Cost and Schedule

a. Analysis of the influence of safety measures on construction timelines
b. Examination of the financial implications of safety measures
c. Assessment of the value of safety investment in terms of project outcomes and reputational benefits

Improvement Strategies and Best Practices

a. Identifying areas for improvement in safety measures
b. Encouraging collaborative efforts to enhance safety culture
c. Incorporating technological advancements and innovation for improved safety outcomes

Challenges and Future Directions

a. Addressing cultural barriers and mindset towards safety in tunnel construction
b. Embracing emerging safety technologies and practices
c. Potential impacts of external factors such as pandemics (e.g., COVID-19) on safety measures

Statistical Analysis of Safety Performance in Twin Tunnel Construction

a. Overview of available data and statistical analysis methods
b. Examination of accident rates, incidents, and injuries in twin tunnel projects
c. Comparison of safety performance across different projects and regions

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d. Identification of trends and patterns in safety performance

Evaluating the Effectiveness of Safety Measures

a. Assessment of accident/incident rates before and after implementing safety measures
b. Worker feedback and satisfaction surveys on safety provisions
c. Comparative analysis of safety measures using performance indicators (e.g., near misses, safety audits)
d. A review of lessons learned and recommendations for future projects

Challenges and Limitations of Safety Audits

a. Resistance to change and cultural barriers
b. Resource constraints and time limitations
c. Ensuring objectivity and impartiality during auditing

Future Directions and Emerging Trends

a. Incorporating technology in safety audits (e.g., drones, sensors, data analytics)
b. Integration of safety audits with BIM (Building Information Modeling) technology
c. Global harmonization of safety audit standards and practices

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