

# Job Safety Analysis during Tunnel Construction

Anjay Kumar Mishra\*, & P. S. Aithal\*\*

\*Post Doctoral Research Scholar, Srinivas University, India and Associate Professor, Madan Bhandari Memorial Academy Nepal, Uurlabari 3, Morang, Nepal  
OrcidID: 0000-0003-2803-4918; Email: [anjaymishra2000@gmail.com](mailto:anjaymishra2000@gmail.com)

\*\*Professor, College of Management & Commerce, Srinivas University, Mangalore, India  
OrcidID: 0000-0002-4691-8736; E-mail: [psaithal@gmail.com](mailto:psaithal@gmail.com)

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\*\*Professor, College of Management & Commerce, Srinivas University, Mangalore, India

OrcidID: 0000-0002-4691-8736; E-mail: [psaithal@gmail.com](mailto:psaithal@gmail.com)

### ABSTRACT

**Purpose:** *There are many tunnels under construction in Nepal as its mountainous country. Road, water supply, hydropower, and irrigation projects are under construction in Nepal through the tunnel. "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. A single person alone cannot do it alone. A team including safety professionals to concentrate on health, safety, and environmental concerns shall be involved to ensure that safety environment will be maintained in the construction site. OSH is the relation between man and man, man and machine and man and environment. The paper aims to analyze the job safety of major selected construction activities during tunneling.*

**Design/Methodology/Approach:** *Site Observation, Key Informant Interview (KII), and Study of Methods of Statement were done as main data collection tools. Job safety analysis and identification of activity with high risk level involved should be determined so that proper prevention and control mechanism could be determined and implemented. Drilling, excavation, blasting, mocking, scaling and shotcutting were major activities whose hazards, prevention mechanism and the responsible party were identified.*

**Findings/Result:** *The study reveals that the main occupational hazards were mechanical and chemical hazards. Rockfall and landslide were noted as the major mechanical hazard whereas toxic gas and cement dust were the main chemical hazards. Similarly, noise and vibration were the main physical hazards and untimely payment of wages and leave were psychological hazards. It was reported that the major accident occurred at sites where the leg struck on steps of boomer while pulling a worker to save him from falling of boomer, penetration by fine grinding wheel material into the eye while carrying out grind cutting of drum and faint due to oxygen deficiency inside the tunnel. Some minor accidents were road traffic accidents, cut by sharp tools, fall/hit to/hit by objects, splashing of acids, burning caught by fire, etc. and the fatal accidents was one of the mechanics blown away by the erupted boomer tyres while filling up air into the same and one of the workers lost his life due to truck accident inside the work premise. The families of the demised had been compensated by the company. For safe construction requires the teamwork of sincere and coordinated effort of all stakeholders. Lack of regular inspection and monitoring at the site was the main cause of improper implementation of prevailing health and safety regulations.*

**Originality/Value:** *The study is highly significant for working engineers to perform the task without any misfortune inside the tunnel.*

**Paper Type:** *Project Management Action Research.*

**Keywords:** Activities, Hazards, Risk Control Measures, Responsible party

### 1. INTRODUCTION :

Safety determines site performance. Lingard & Rowlinson (2005) [1] through their study concluded that execution at the site is always prone to these workers being exposed to various risks associated with construction works and other work-related diseases/ health hazards that physically and mentally affect the employees. The projects are delayed as a result of this because of the loss of working hours

and legal hassles associated while mitigating the adversaries. Safety management can ensure the improvement of occupational safety at the construction site.

Nepal being a developing country, tunnel construction and safety practices in tunnel construction are a new topic. Accident related with the ignorance of safety leads to death of the worker. The cost associated with the safety can be huge be it direct cost or indirect cost. Tunneling is very dangerous engineering work as there are many hazards present as it is a risky underground construction so more preventive measures should be adopted. Currently, lots of tunneling works are going on in Nepal therefore it is necessary to understand safety related provisions and measures in Tunnel construction. it will also provide the framework for Job Safety Analysis of major activities of tunnel construction.

## 2. OBJECTIVES :

The focus of the research is to analyze the job safety of major activities during tunnel construction within Nepal.

## 3. LITERATURE REVIEW :

### 3.1 Job Safety Analysis:

Job Safety Analysis is one of the most effective tools to control accidents through proactive approaches which increases work productivity and project performance (Mishra & Aithal, 2021) [2]. It is a widely accepted approach of the construction industry for safe site management throughout the project.

### 3.2 Process of JSA:

According to Mishra and Aithal (2021) [2], JSA confides in the following steps.

1. Specify the job and break it into tasks for knowing possible hazards.
2. Assign the relative level of Risks of those specified hazards.
3. Perform elimination, substitution, Engineering Control, Administrative control, and Provide proper and suitable personal protective equipment.

### 3.3 Activities in Tunnel Construction: (based on a study by Lama et al, 2019 [3])

- a. Drill: During drilling assure rock quality, use of holes and its drilling through effective pick-up track and jumbo forward and backward velocity, Geological application to sketch the tunnel face, and very importantly workmanship for drilling.
- b. Blast: During blasting charging the holes, blast followed by ventilation where pick-up track both direction velocity, workmanship and timing are to be maintained.
- c. Muck: Removal of loosened rock pieces, loading and hauling the debris out of the tunnel which needs effective excavation velocity, workmanship, loader velocity, and truck velocity.
- d. Primary Support: Proper use of shotcrete using wire mesh, arch profile and rock bolts based on topographic assessment with careful shotcrete pump velocity management, Mixer both directional velocity, workmanship for spraying concrete, pick-up track movement, wire mesh installation skill, survey engineering skill for setting steel arc profile, loader movement, and workmanship for drilling rock bolts, installing steel arch profile and all.

## 4. RESEARCH METHODOLOGY :

### 4.1 Study Area: Melamchi Tunnel:

The total length of the water tunnel was 27,584m of which excavated length of the water tunnel at Ambathan downstream was about 3549.4m out of 4321m, at Gyalthum Downstream was about 3730.8m out of 3751m and at Sindhu Upstream 3280.5m out of 3698m. Excavation at Ambathan Upstream, Gyalthum Upstream, Sindhu downstream and sundarijal were completed. In addition to water tunnel, there were 3 already excavated adit tunnels namely Ambathan adit tunnel with total length 298m, Gyalthum adit tunnel with total length 331m and Sindhu Adit Tunnel with 752m. To sum up this, the total excavated length of the water tunnel till 9th of January, 2018 was about 27,078.9m. The cross-sectional area of the tunnel was 12.7sqm with D-shaped cross section. The tunnel was being constructed by drill and blast method. The design discharge of the tunnel was 6 cumec to bring 51 Crore lpd. The tunnel was supported by shotcreting and rock bolting permanently [4] & [5].

**4.2 Data Collection:**

**4.2.1 Primary data**

Primary data were the main data for the analysis and interpretation of result for this research work. Primary data was collected in three ways:

**Site visit:**

Site observation was done of four adits which had been used as one of the data collection method. So, it was used to identify occupational hazards, risks and accident as well as it was used to analyze the job safety practices.

**Focus Group Discussion:**

Focus group discussions (FGD) were done to find out the effective implementation of safety measures and regulations as per contract document. The subject of focus group discussion was limited to:

- Identify various occupational hazards, risks and accident presents in the tunnel.
- Investigate various safety measures adopted and practiced by workers.

**Key Informant Interview:**

KII regarding safety was performed on various key personnel from Employer, Engineer and Contractor for different safety practices adopted and could have been adopted at Tunnel construction.

**4.2.2 Literature Review**

These include safety related books, notes, journals, articles, published data from Government agencies, papers, thesis reports, websites, and safety related documents of the Melamchi project.

**4.3 Data Analysis:**

After the collection of primary and secondary data, all these data were used for job safety analysis tables.

**4.4 Research Matrix:**

As summarized in the table below for the research matrix, the information was collected from the different stakeholders to evaluate their knowledge and information regarding the implementation of safety practices and regulations in Melamchi Tunnel. KII and focus group discussion along with direct observation was the main tools used for the data collection.

**Table1:** Research matrix

Objective	Information required	Data source	Methodology	Output
To analyze the job safety of major activities of tunnel construction.	Various stages of specific jobs, Relative level of risk, Different measures taken to reduce or eliminate the risk.	Work Breakdown Structure, Risk Assessment Chart, Checklist, Standard Formats.	Site Observation, KII Study of Methods of Statement	Job Safety Analysis of major activities of Melamchi Tunnel.

**5. RESULTS AND DISCUSSION :**

**Job Safety Analysis of Major Activities:**

The main health problems faced due to hazards were wrist pain, back pain as well as being faint and deaf. The riskiest activities during tunnel construction were drilling and blasting. The Key Informant stated that 50% workers, 17% client, 17% Contractor, 25% consultant and 8% government were responsible for accident at site. About 48 % employers and 40% workers responded that preventive measures are effective 0in tunnel during construction phase. It clearly indicates that proper safety plan and implementation is still remaining to do to enhance productivity and to ensure the workers that they are safe.

Use of PPEs, administrative control and Engineering Control were the control measures adopted for tunnel construction. Elimination and substitution were generally not adopted though these are the best control measures for hazard control. It was observed that the medical clinic was established and clinical services at each site were functioning well. The clinics were well equipped with sufficient medicines.

Two medical staffs were appointed in each clinic to carry out assign duties each during day and night shift, respectively.

The issues of OSH in Nepal are still in infant stage. Despite of several efforts, so many things still remained to establish sound OSH environment. The assurance of effectively OSH in implementation as investment not expenditure with a hope of safe, productive and healthy work culture is not easy task. It depends on teamwork of sincere and coordinated effort of all stakeholders. Lack of regular inspection and monitoring at site was the main cause of improper implementation of prevailing health and safety regulations (Mishra and Joshi, 2021 [6]; Mishra and Sharestha, 2017 [7]). JSA of major activities in tunnel construction like excavation, loading and blasting, drilling, mucking, scaling and primary supports as shotcreting/ sprayed concreting can be presented as follow:

**Table 2:** Job Safety Analysis of Tunnel Excavation

Company Name	Melamchi Diversion Scheme		
Site Name	GYALTHUM		
Contractor	CMC DI RAVENNA		
Activity	TUNNEL EXCAVATION		
Activities List in Sequence of Performance	Hazards Identification	Proactive Approaches for controlling Risk Measure	Responsible Professional
Survey and Geological mapping	i) Dust and Solvent. ii) Ladder, Fall, Slip	i) Mask and filter mask. ii) Support, Good housekeeping	i) Survey In charge ii) Tunnel supervisor
Drilling and Charging	i) Boomer, Noise, Rock fall ii) Explosives, Detonators	i) PPE and Support system. ii) Safe method of work	i) Site In-charge ii) Supervisor
Blasting and Mucking work	i) Post Blasting fume and gaseous ii) Rock-mass, low visibility	i) Defuming, PPE ii) Support work, Inspection	i) Site In charge ii) Blaster
Support Work	i) Shotcreting/ Wiremess ii) Rock Bolt/ Lattice Girder	i) Safe Method of work ii) PPE	i) Site In-charge

**Table 3:** Job Safety Analysis of Loading and Blasting

Company Name	Melamchi Diversion Scheme		
Site Name	AMBATHAN		
Contractor	CMC DI RAVENNA		
Activity	LOADING AND BLASTING		
Activities List in Sequence of Performance	Hazards Identification	Proactive Approaches for controlling Risk Measure	Responsible Professional
Blasting material is taken out from Army Barrack.	May blast during transporting	Detonator and Explosive should be carried differently.	Blaster and Army
Blasting material is send inside the tunnel.	May blast during transporting inside the tunnel	Two vehicles should be used to carry those explosive material	Blaster
Blasting material is loaded to the drilled holes.	Misfire	Properly (Carefully) charged	Blaster

All the holes are connected by wires.	Misfire	Only Blasters having registered license of blasting should be hired and allowed to do this work.	Blaster
Then move away around 200m-300m down.	i) Misfire ii) Can be Injured by Blast material (rocks)	Do not Panic	Blaster
Then Blasting	Misfired due to wrong wiring	Keep distance and reach to safe place	Blaster

**Table 4:** Job Safety Analysis of Drilling

Company Name	Melamchi Diversion Scheme		
Site Name	AMBATHAN		
Contractor	CMC DI RAVENNA		
Activity	DRILLING		
<b>Activities List in sequence</b>	<b>Hazards identification</b>	<b>Preventive Measures</b>	<b>Responsible Professional</b>
Boomer (equipment) operation	Mechanical	Should be operated only by expert	Boomer operator
Boomer moved to the drilling face	No	-	Boomer operator
Boomer connected with electricity	Electricity	Strong enforcement of Code of Practice: i) preparing for electrical risks ii) standard operating procedure of equipment before application	Boomer operator team
Boomer connect with water and drill rod	Loose rock falling	Careful walk down through tunnel frequently and scaling where needed -mechanically scaling and bolting -installing ground support: immediately applying overhead protection in case of manual-changing ground support methods	Foreman/Supervisor
Drilling started by boomer	No	Use ear plugs	Operator
Around 80-100 holes is been drilled of around 2 m to 2.8 m long	No	-	Operator
Rod / Pipe is installed inside the drill hole to clean the hole before charging	No	Lift the rod/pipe carefully	Operator /Contractor
Detonator/Explosive material is been installed in holes	Misfire	Explosive material should be handled carefully	Detonator installer/contractor
Connect all the wires of detonator	Misfire	Only Blasters having registered license of blasting should be hired and allowed to do this work.	Blaster
Fire	Rock falls or tunnel collapse	Do not Panic and move to safest distance	Blaster

**Table 5:** Job Safety Analysis of Mucking

Company Name	Melamchi Diversion Scheme		
Site Name	AMBATHAN		
Contractor	CMC DI RAVENNA		
Activity	MUCKING – (After an hour of blasting)		
Activities List in sequence	Hazards identification	Preventive Measures	Responsible professional
After 1 to 1 ½ hours for defuming	Harmful chemical produced	Good quality mask to be used, good lighting to work area	Driver
Then haul loader / tipper is transported to the mucking site	Rock fall	Driver have to be careful while entering to the site	Driver
Mucking started	Truck is loaded so break fail or mechanical break down and also chances of collision, dust and noise	Truck should be fully serviced and maintain	Driver
Muck is loaded and transported away from the face or worksite	Being struck or crushed	Vehicle should be well serviced, other people do not enter into loading area	Driver
Muck removal using conveyance system or a muck bucket, muck box, muck cart, or muck car.	Chemical hazard, Falling material	Musk equipment should be handled with care and should be used properly	Labor / driver
muck transported to the surface using the conveyor via horizontal, inclined, vertical or combination of horizontal and vertical route to its final destination	Tripping and falling	Keep running surface in good condition	Driver
The final destination is a stock pile where the muck is dumped and also can be re used from the disposal place.	Overturn and fall of vehicle while dumping, tripping and falling	Should take care while dumping and one person should be there on back side of vehicle	Driver

**Table 6:** Job Safety Analysis of Scaling

Company Name	Melamchi Diversion Scheme		
Site Name	AMBATHAN		
Contractor	CMC DI RAVENNA		
Activity	SCALING		
Activities List in sequence	Hazards identification	Preventive Control Measures	Professional Responsibility
The detached rock in the crown should be removed from crown by using scaling stick on the other vehicle	Rock can fall on the human or worker.	Proper scaling should be carried out	Foreman/supervisor
	Rock fall	Use machine for rock scaling	
	Collapse as result from instability of exposed	enter only after scaling is done in risky zone	

	rock surface		
		Sufficient Lighting	
Manual Scaling	Falling from heights	Use working platforms	
	Being crushed	Only work from a safe area	
		Area should be lightened.	

**Table 7: Job Safety Analysis of Shotcreting or Sprayed Concrete**

Company Name	Melamchi Diversion Scheme		
Site Name	AMBATHAN		
Contractor	CMC DI RAVENNA		
Activity	SHOTCRETING OR SPRAYED CONCRETE		
Activities List in sequence	Hazards identification	Preventive Control Measures.	Responsible professional
Shotcrete is a commonly used term for sprayed concrete. Shotcrete is mortar or concrete conveyed through a hose and pneumatically projected at high velocity onto a surface.	Cement dust, ammonia and chemical accelerating compounds.		
Transporting concrete in large plant, usually in confined spaces with poor lighting	cement or chemical additives	i) providing: a. exclusion zones and traffic management planning b. lighting on the plant and at the work face c. plant reversing alarms ii) using suitable PPE including high-visibility protective clothing	Operator
Transferring the concrete to the conveyor	Cement dust, rebound	i) providing guarding to prevent entry to the conveyor unit ii) using suitable PPE including splash protection for eyes	Operator
Conveying the concrete	Plant electrical supply	i) providing: a. regular servicing of the plant according to the maintenance plan including checking conveyor tubes and hoses b. relevant training to plant operators and mechanics	Operator
Applying concrete	Direct Eye or skin	i) providing exclusion	Operator

	contact which causes chemical burns, poisoning and other toxic effects, Burst of concrete hose	zones and restricting entry to only workers involved in the concrete application ii) using suitable PPE including impact-resistant goggles, helmet, gloves, breathing apparatus, hearing protection, safety boots and full body clothing	
After applying concrete	Slips, trips and falls	i) ensuring no entry to unprotected, unestablished freshly sprayed areas	security

A proper linear responsibility chart (LRC) and checklist, work permit facility should be strongly enforced. The LRC assures a complete responsibility of professional involved and checklist assures task to be performed and approval process will reconfirm emergency plans to facilities and overall check. The effectiveness of safety measures has been assessed by Mishra et al, 2019 [8] in tunnel construction with proper advice for improvement which might increase the performance of industry resulting in productivity of the industry as Chilawal and Mishra, 2017 [9] have highlighted the need of hydropower project improvement. Every project should be properly implemented based on OSHA [10] rules and effective tunneling engineering [11] application would be highly effective before construction.

### 7. CONCLUSION :

The assurance of Occupational Safety and Health in Nepal needs overall revision. Despite of several efforts, so many things still remained to establish a sound OSH environment. The task of enforcing OSH investment as an investment for a safe and healthy work environment is necessary. It should have teamwork of sincere and coordinated effort of all stakeholders. Lack of regular inspection and monitoring at the site was the main cause of improper implementation of prevailing health and safety regulations. Job safety analysis and identification of activity with high risk level involved should be determined so that proper prevention and control mechanism could be determined and implemented. Drilling, excavation, blasting, mocking, scaling and shotcutting were major activities whose hazards, prevention mechanism and responsible party were identified. Management should review job safety plans in the interval of a fixed time for improvement and conduct safety training to workers frequently to reduce the rate of near-miss and mishap accidents at the construction sites.

### 8. RECOMMENDATIONS :

#### Government:

Following recommendations could be made to Government:

- Effective implementation of existing Labor Laws on OSH
- Separate policies should be formulated based on the type of construction and geographical area of the construction site. The risk and the protective measures to be implemented vary from one sector to another.

#### Employers:

The role of the Employer is to monitor the OSH conditions of the site and provide required back up to Engineers. Following recommendations could be made to Employers:

- Cooperate to coordinate with concerned stakeholders and agencies to conduct OSH training.
- Regularly monitor whether PPEs have been used properly by workers or not and whether the mitigation measures have been implemented or not at construction site.
- Provide necessary comments and suggestions for further improvement, if required, regarding the OSH issues of the construction site.

**Engineers:**

Engineers should play a vital role to maintain the proper safe and healthy working environment of construction site to prevent from occupational hazards. Following recommendations could be made to Engineers:

- Regular monitor whether PPEs have been effectively used by workers or not and make mandatory to use PPEs. If PPEs have not been suitably and properly used, the Contractor shall be instructed to provide required PPEs to workers.
- Regular monitor whether the protective measures have been implemented or not. If not, the Engineer should instruct the Contractor for proper implementation of protective measures.
- Regular monitoring of the record keeping system of accidents maintained by Contractor, whether regular checkup of workers done or not.
- Regular monitor whether pure drinking water has been provided to workers or not and whether proper sanitation and drainage system has been maintained or not.
- Regularly monitor whether regular maintenance of equipment has been done or not.
- Instruct the Contractor if any improvements to be made and regularly follow up whether the instruction has been followed or not.
- Facilitate the Contractor to conduct the regular OSH training and meeting with workers.

**Contractor:**

It is often blamed that the Contractor is not serious enough regarding OSH issues means they usually ignore the OSH issues. Hence it is the duty of Contractor to maintain the construction site safe and healthy and the following recommendations could be made to Contractors:

- Installation of warning sign boards and isolation of the construction site by barricading it and prevent entry of unauthorized personnel at site.
- Encourage the workers to maintain the healthy and safe working environment by providing rewards.
- Contractor should appoint safety personnel with relevant and necessary expertise.
- Manage proper electric wiring in order to ensure that not any unwanted accidents will occur at construction site due to electric shock or leakage.
- Maintain proper first aid treatment facilities, manage regular health checkup of workers and staffs at construction site.
- Maintain medical and accident insurance of all workers.
- Make necessary arrangements for medical treatment at nearby hospitals.
- Maintain the systematic record keeping system of any accidents whether minor injury or major injury including death of person and report it to Engineers and Employers.
- Manage necessary arrangement to ensure safety against fire.
- Maintain a reasonable mechanism of compensation to workers.
- Provide pure drinking water to workers and maintain proper sanitation and drainage system to ensure hygienic environment at the construction site.
- Provide non-hazardous work to pregnant women workers and maternity leave and facilities as mentioned in Labor Act.
- Provide a separate smoking zone.

**Workers:**

- Share the knowledge among co-workers.
- Inform the management if any improvement to be made regarding health and safety condition of the site.
- Workers should be made aware of their rights mentioned in the Labor Act.
- Avoid child labor at the construction sites.

The requirements of Occupational Safety and Health issues shall be clearly indicated in the Contract Documents and should be agreed and compulsorily implemented at the time of execution of the project. The budget should be allocated for OSH issues so that they could be effectively implemented during construction.

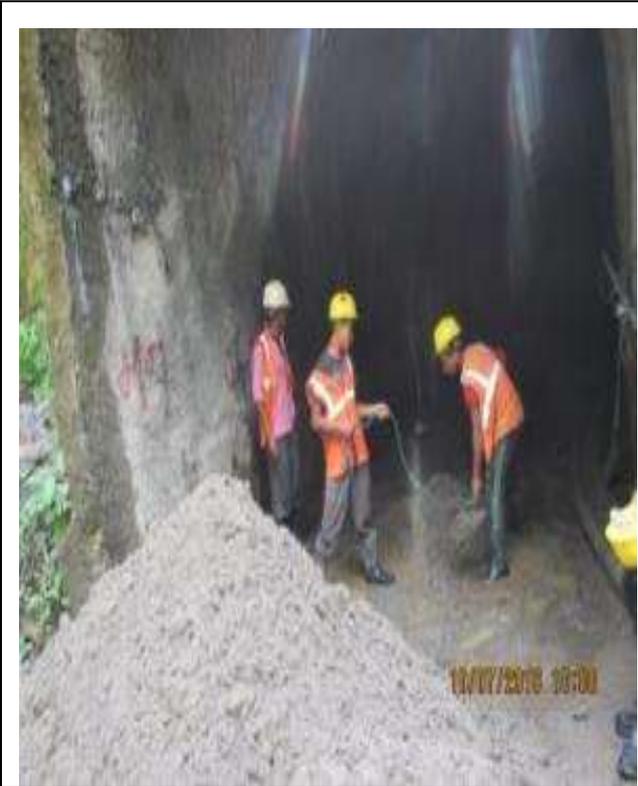
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**Appendix**



**Dewatering diversion Tunnel**



**Mucking using a dump truck**



**Ventilation repairs**



**Water Accumulation**



**Fire extinguishers placed at DG set**



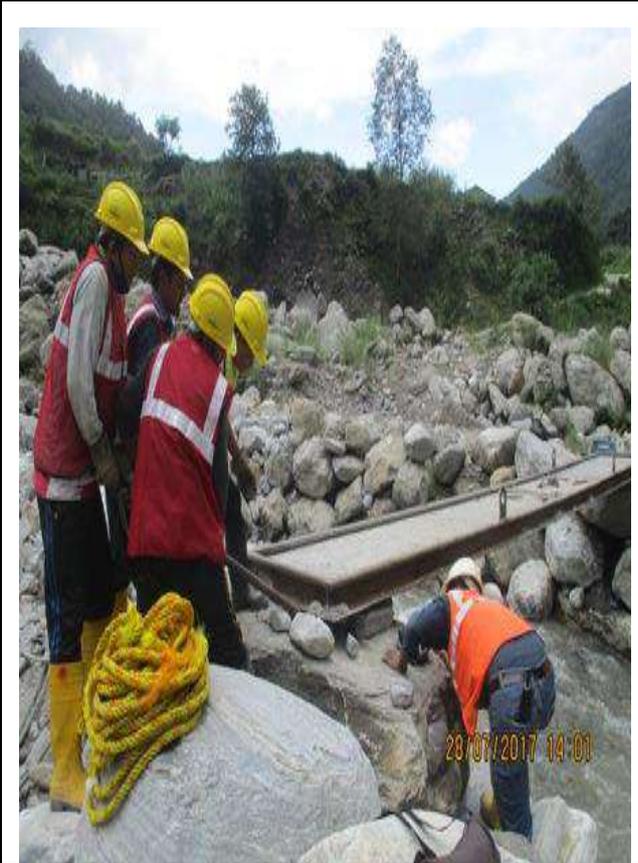
**Clinic**



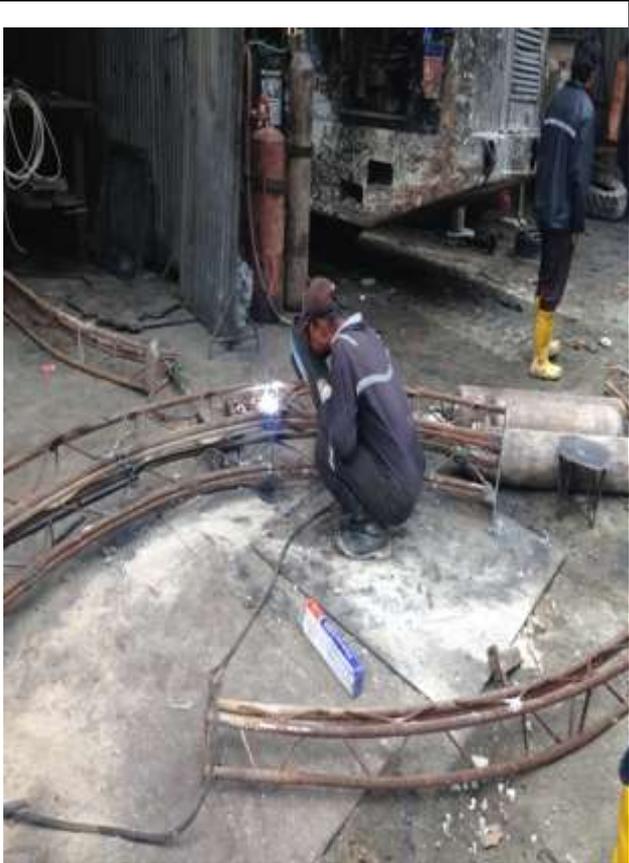
**First Aid Box inside the tunnel**



**Spoil Disposal**



**Maintenance of Access Road**



**Fabrication of girder**



**Installation of Primary Support**



**Preparation for Shotcreting**



**Shotcreting**



**Rock Mass Fall**



**A dragger X-am 5600 gas detection meter**



**Equipment used for Mucking**



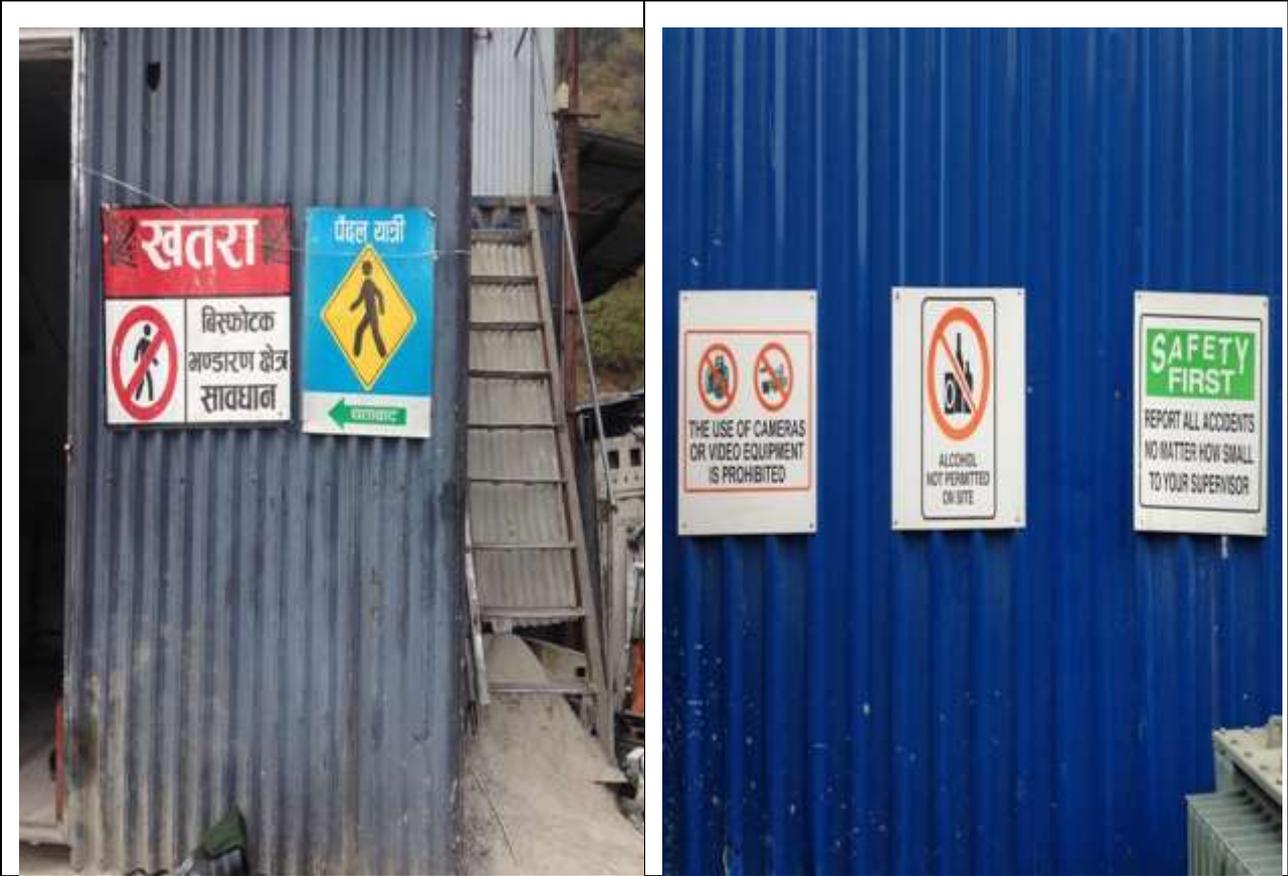
**Standby Ambulance**



**Safety signs at Workshop Area**



**Safety signs at Fuel Storage Area**



Safety signs and Signal at Work Premises