STUDY AND REVIEW OF EMERGENCY MANAGEMENT SYSTEM OF TUNNELS

Final year project report

Submitted by

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Under the guidance of

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BONAFIDE CERTIFICATE

Certified this titled study and review of emergency management system in tunnel" at pratibha industries Delhi Metro construction site is the bonafide work of **NIKITA SINGH (R107213012)** who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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This M. Tech. dissertation entitled **“STUDY AND REVIEW OF EMERGENCY MANAGEMENT SYSTEM OF TUNNELS”** prepared by Nikita Singh (Roll No.R10213012) is approved for submission for the degree of Master of Technology in Disaster Management at University of petroleum and energy studies, Dehradun.

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Declaration

This is to certify that Thesis/Report entitle" STUDY **AND REVIEW OF EMERGENCY MANAGEMENT SYSTEM OF TUNNELS**"which is submitted by me in particle fulfilment of the requirement for the award of degree M. Tech. in Disaster Management, University of Petroleum and Energy studies, Dehradun, only my original work and due acknowledgement has been made in the text to all other Material used.

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Abstract

"**STUDY AND REVIEW OF EMERGENCY MANAGEMENT SYSTEM OF TUNNELS** "this plan provides core guidance on actions necessary for all emergency situations with could cause hazard to life or property from accidental causes. Since The complexity of tunnelling work means there are often many people involved. Everyone involved in tunnelling work has health and safety duties when carrying out the work and more than one person often has the same duty. For example, contractors and subcontractors can have the duties of persons conducting a business or undertaking but they may also be workers. This Guide explains how to manage the risks associated with tunnelling work by following a systematic process which involves: identifying hazards – find out what could cause harm in tunnelling work assessing risks if necessary – understand the nature of the harm that could be caused by the hazard, how serious the harm could be and the likelihood of it happening controlling risks – implement the most effective control measures that are reasonably practicable in the circumstances, and reviewing control measures to ensure they are working as planned. Tunnels play a vital role in our way of life as it ease the method of transportation in urban cities in the world. Tunnelling works came in to being in eighteen century, the technology and the construction method had developed over time. The current technologies used in tunnels construction around the world are becoming greatly develop and very efficient. In recent years technology has introduced new sets of tunnelling technologies such as the tunnel boring machine (TBM). In this report various hazards and risks and their control measures of tunnelling are discussed.

Keywords: tunnel, tunnel boring machine, hazards and control.

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AIM AND OBJECTIVE OF THE PROJECT REPORT

OBJECTIVE-

- Promoting a positive work culture based on improving our SHE performance.
- To minimize safety hazards by ensuring a high degree of housekeeping is always maintained.
- Complying with all applicable SHE legislation as per SHE PLAN 22.12..07.C1
- Identifying and eliminating / controlling hazards and pollution that could cause accidents, illness or damage to environment.
- Providing need based training and resources for employees to maintain SHE systems.

AIM-

To review emergency management plan and recommending controls and to promote a safe culture in tunnel safety.

Chapter 1 - Introduction

1.1-About the company

PRATIBHA INDUSTRIES LIMITED (PIL), the flagship company of the Pratibha Group is dedicated and committed to providing the society at large with quality infrastructure in its field of expertise which currently include design, engineering and execution/construction of complex & integrated water transmission & distribution projects, water treatment plants, elevated and underground reservoirs, mass housing projects, commercial complexes, pre-cast design & construction, road construction and real estate. The company which started with pre-cast products in just over two decades has created a technical niche for itself graduating into a multifunctional construction and infrastructure development company of repute with annual turnover of INR 8060 million. Our rapid and consistent growth over the years bear testimony to our focus on dedication, quality of production and services through continuously evolving technologies along with timely execution of projects which has won us accolades and repeated business from our clientele.Pratibha Industries was established in 1982, by a dynamic young entrepreneur Mr. Ajit B. Kulkarni. The firm started its foray with manufacturing of SFRC manhole covers & frames, which were designed & introduced as a replacement to the conventional cast iron manholes cover & frames. Till the early ninety's the firm was focusing only on pre-cast products. In 1992, the firm decided to extend its presence in the civil construction industry and started participating in bids invited for such projects by Government / Semi- government Departments. In-depth technical knowledge and sound management ethics ensured that the company received its first major mass-housing project [INR125.00 million] from CIDCO of Maharashtra Limited in the same year. In 1994, the Company realized that water supply projects hold great potential. Till 2001, the operations of PIL were restricted to the State of Maharashtra alone. The next challenge for Pratibha was to consolidate and strengthen its engineering department to make its presence felt in more complex & integrated Water Supply projects, as also to form alliances with fellow contractors of repute to ensure fulfillment of this goal. The Company started working towards this by establishing a design department and bidding for projects of complex nature, which also involved designing, in Joint Venture with reputed contractors like Petron Civil Engineering (P). Limited and Unity Infra-projects Limited. The efforts bore fruits in 2003, when the company was awarded multi-million projects by Mumbai Municipal Corporation, Gujarat Water Supply & Sewerage Board, and Delhi Jal Board, along with other Governmental Agencies. It was during this period that the company also expanded the segments of operation by entering and receiving work orders for intra-city road projects. In 2007 & 2008 Pratibha Industries strengthened their Buildings Division and bagged many unique and the best Buildings in India. Building Divison has been working with the top most clients and the most renowned Architects and Consultants. Today Pratibha Group has specialised themselves with methodology and the concept of Tall buildings. As on date Pratibha Industries are constructing more than 6 skyscrapers in Mumbai and one of them being the tallest Structural steel commercial building in India with a height more than 195 Mts. The company over the next few years [2010-2011] on standalone basis or through Joint Ventures, strategic alliances & acquisitions [if a suitable opportunity arises] proposes to have strong presence in road, retail, urban, oil and gas transmission and power segments of the infrastructure sector, apart from water supply segment. It also proposes to be global player in pipe segment and market spill over capacities after accounting for in-house consumption. The said projects will be executed on both, EPC & PPP basis.

1.2-Project details

Project name- Delhi metro rail transport service phase 3- CC-23

Design and construction of tunnel between hauj khas station and kalkaji station by shield TBM, tunnel near chirag Delhi and kalkaji station and underground ramp beyond kalkaji station by cut and cover method, underground metro stations at panchsheel park, chirag delhi, G.K enclave-1, Nehru place and kalkaji by cut and cover method on janakpuri west botanical garden corridor of Delhi MRTS project of phase

✓ **Scope of work –**

- TBM bored tunnel having finished dia of 5.8 mts.
- NATM tunnel near kalkaji mandir station
- Cut and cover tunnel
- Panchsheel park,chirag delhi,GK-1,Nehru enclave and kalkaji mandir underground stations by cut and cover method.
- **Contractor**- FEMC pratibha J

✓ **Employer**-Delhi Metro Rail Corporation, metro bhawan, fire brigade lane, barakhamba road, New Delhi.

✓ **Date of commencement:**19/11/2012

✓ **Completion period of the project**-18/05/2016 (42 months)

✓ **Construction methodology-**

✓ CC-23 is an underground MRTS corridor package on the line -8 between hauj khas and kalkaji mandir. the whole package includes construction of 5 underground stations ,1 neutral zone and tunnel from hauj khas to kalkaji mandir connecting all the stations within the scope and on adjoining stretches i.e. CC-27 (beyond hauj khad) CC-15(beyond kalkaji mandir) with construction of an underground ramp into ground level.

1.3 Materials and Methods used at site-

Equipments used on site-

- Segment mould
- Batching plant
- Gantry Crane
- Stirrup machine
- Boiler
- Chilling plant
- Diesel generator
- Air compressor
- Welding machine
- Bar shearing machine
- Bar rolling machine
- Truck mounted crane
- Transit miller
- Loader
- Trailor truck
- Tractor
- Forklift
- Segment car-

1.4 Scope of this particular thesis is limited to these kind of activities-

- CC-23
- Station construction- top down and bottom up
- Neutral zone-top down & cut and cover

- Tunnel construction-Tbm,NATM,cut and cover
- Ramp-cut and cover/fill

1.5 WHAT IS TUNNELLING AND HOW IT IS DONE

Tunnel- A **tunnel** is an underground or underwater passageway, dug through the surrounding soil/earth/rock and enclosed except for entrance and exit, commonly at each end. A pipeline is not a **tunnel**, though some recent **tunnels** have used immersed tube construction techniques rather than traditional **tunnel** boring methods.

1.5.1 Tunnel construction

The construction of tunnels consists in two main phases: tunnel excavation (including construction of the tunnel support) and equipment of the tunnel with final installations (ventilation system, lighting and safety systems etc.). The latter is not discussed in this thesis.

Three main tunnelling technologies commonly utilized in present practice are briefly described in the sequel. A special attention is paid to the conventional tunnelling which is used in application examples later in this thesis

1.5.2 Tunnel construction methods:

- Classical methods
- Mechanical drilling/cutting
- Cut-and-cover
- Drill and blast
- Shields and tunnel boring machines (TBMs)
- New Austrian Tunnelling Method (NATM)

1.5.3 -Conventional tunnelling

According to definition of International Tunnelling Association (ITA, 2009), the conventional tunnelling technology is construction of underground openings of any shape with a cyclic construction process of excavation, by using the drill and blast methods or mechanical excavators (road headers, excavators with shovels, rippers, hydraulic breakers etc.) .mucking placement of the primary support elements such as steel ribs or lattice girders soil or rock bolts shot Crete , not reinforced or reinforced with wire mesh or fibres.

One cycle of the construction process is denoted as round and the length of the tunnel segment constructed within one round is denoted as round length. The final profile of the tunnel can be divided into smaller cells, which are excavated separately. The excavation method, round length, excavation sequencing and support measures (in sum denoted as the construction method in this thesis) are selected depending on the geotechnical conditions and cross-section area of the tunnel. The decisive factor for the selection is the stand-up time of the unsupported opening. To give an example, a tunnel constructed in very good ground conditions with long stability of unsupported opening can be excavated full face with round length of several meters and it requires only simple support. On the contrary, in difficult ground conditions, a finer sequencing, shorter round length and demanding support measures must be applied. In poor ground conditions, auxiliary construction measures can be used. These are for example jet grouting, ground freezing, pipe umbrellas or face bolts. Additionally, if the primary support is not sufficient for long-term stability of the tunnel, it must be supplemented by the construction of final (secondary) lining. The conventional tunnelling allows adjusting the construction process based on observations of the ground behaviour, which are continuously carried out during the construction. The technology is therefore especially suitable for tunnels with highly variable geotechnical conditions, tunnel with variable shapes of tunnel cross-sections and for short tunnels, where utilization of expensive TBM would not be economically justifiable. The geotechnical monitoring is an essential part of the construction process. It enables to check the structural behaviour with respect to the safety and serviceability criteria, to optimize the construction process and to control the impact of construction on the adjacent structures. The monitored parameters are usually the deformations (displacements, strains, changes in inclination or curvature), stresses and forces on structural elements, piezometric levels and temperatures.

1.5.4 Mechanized tunnelling

International Tunnelling Association defines mechanized tunnelling as tunnelling techniques, in which excavation is performed mechanically by means of teeth, picks or disks. The machinery used for the excavation is commonly called Tunnel Boring Machine (TBM).Diameter of the tunnel excavated with TBM can range from a metre (done with micro-TBMs) to 19.25 m to date.

The application of TBM has several advantages compare to conventional tunnelling methods. The excavation is generally faster, the deformations of the ground and surface is smaller, which is beneficial for the existing structures. However, the TBM can only excavate a round tube and must be thus in most cases combined with other construction methods for construction of access tunnels, technological rooms etc. It is also only suitable for longer tunnels, where the initial investment into the TBM purchase is reasonable.

- The essential parts of the machine include the following items (ITA, 2001):
- Rotary cutter head for cutting the ground
- Hydraulic jacks to maintain a forward pressure on the cutting head
- Muck discharging equipment to remove the excavated muck
- Segment election equipment at the rear of the machine
- Grouting equipment to fill the voids behind the segments, which is created by the over-excavation?

1.5.5 Cut & cover tunnelling

The cut & cover tunnels, unlike the previous bored tunnels, are constructed directly from the surface. The construction consists in excavating a trench or a cut, installing of temporary walls to support the sides of the excavation, roofing the tunnel and covering it with fill material. The costs of the excavation increase significantly with the depth of the tunnel, the method is thus suitable for construction of shallow tunnels. The method is often used for the construction of beginning and end parts of the bored tunnels .The major disadvantages of a cut & cover construction is its disturbing impact on the surroundings and the need of extensive traffic restrictions.

Tunnelling methods-

- NATM
- TBM

1.5.6 NATM-New Austrian Tunneling method

The New Austrian Tunneling method (NATM), also known as Sequential Excavation Method (SEM), describes a popular method of modern tunnel design and construction. This technique first gained attention in the 1960s based on the work of Ladislaus von Rabcewicz, Leopold Müller and Franz Pacher between 1957 and 1965 in Austria. The name NATM was intended to distinguish it from the old Austrian tunneling approach. The fundamental difference between these new methods of tunneling, as opposed to earlier methods, comes from the economic advantages made available by taking advantage of the inherent geological strength available in the surrounding rock mass to stabilize the tunnel.

Principle

The NATM integrates the principles of the behavior of rock masses under load and monitoring the performance of underground construction during construction. The NATM has often been referred to as a "design as you go" approach, by providing an optimized support based on observed ground conditions. More correctly it can be described as a "design as you monitor" approach, based on observed convergence and divergence in the lining and mapping of prevailing rock conditions. It is not a set of specific excavation and support techniques.

NATM has seven elements:

- Exploitation of the strength of native rock mass - Relies on the inherent strength of the surrounding rock mass being conserved as the main component of tunnel support. Primary support is directed to enable the rock to support itself.
- Shot Crete protection - Loosening and excessive rock deformation must be minimized. This is achieved by applying a thin layer of shot Crete immediately after face advance.
- Measurement and monitoring - Potential deformations of the excavation must be carefully monitored. NATM requires installation of sophisticated measurement instrumentation. It is embedded in lining, ground, and boreholes. In the event of observed movements, additional supports are installed only when needed, with a resultant overall economy to the total cost of the project.
- Flexible support - The primary lining is thin and reflects recent strata conditions. Active rather than passive support is used and the tunnel is strengthened by a flexible combination of rock bolts, wire mesh and steel ribs, not by a thicker concrete lining.
- Closing of the invert - Especially crucial in soft ground, the quick closing of the invert (the bottom portion of the tunnel) which creates a load-bearing ring is important, and has the advantage of engaging the inherent strength of the rock mass surrounding the tunnel.
- Contractual arrangements - Since the NATM is based on monitoring measurements, changes in support and construction method are possible, but only if the contractual system enables them.
- Rock mass classification, ranging from very hard to very soft, determines the minimum support measures required and avoids economic waste that comes from needlessly strong support measures. Support system designs exist for each of the main rock classes. These serve as the guidelines for tunnel reinforcement.

Based on the computation of the optimal cross section, only a thin shot Crete protection is necessary. It is applied immediately behind the tunnel boring machine, to create a natural load-bearing ring and minimize the rock's deformation. Geotechnical instruments are installed to measure the later deformation of excavation. Monitoring of the stress distribution within the rock is possible.

This monitoring makes the method very flexible, even if teams encounter unexpected changes in the geotechnical rock consistency, e.g. by crevices or pit water. Reinforcement is done by wired concrete that can be combined with steel ribs or lug bolts, not with thicker shot Crete, The measured rock properties suggest the appropriate tools for tunnel strengthening. Since the turn of the 21st century, NATM has been used for soft ground excavations and making tunnels in porous sediments. NATM enables immediate adjustments in the construction details, but requires a flexible contractual system to support such changes.

When NATM is seen as a construction method, the key features are:

- The tunnel is sequentially excavated and supported, and the excavation sequences can be varied to efficiently address the specific rock conditions being encountered.
- The initial ground support is provided by shot Crete in combination with fiber or welded-wire fabric reinforcement, steel arches (usually lattice girders), and sometimes ground reinforcement (e.g. soil nails, spilling).
- The permanent support is typically a cast-in-place concrete lining placed over a waterproofing membrane

1.5.7 TBM-tunnel boring machine

Tunnel boring machine (TBM) also known as a "mole", is a machine used to excavate tunnels with a circular cross section through a variety of soil and rock strata. They can bore through anything from hard rock to sand. Tunnel diameters can range from a meter (done with micro-TBMs) to 19.25 meters to date. Tunnels of less than a meter or so in diameter are typically done using trenchless construction methods or horizontal directional drilling rather than TBMs.

Tunnel boring machines are used as an alternative to drilling and blasting (D&B) methods in rock and conventional "hand mining" in soil. TBMs have the advantages of limiting the disturbance to the surrounding ground and producing a smooth tunnel wall. This significantly reduces the cost of lining the tunnel, and makes them suitable to use in heavily urbanized areas. The major disadvantage is the upfront cost. TBMs are expensive to construct, and can be difficult to transport. However, as modern tunnels become longer, the cost of tunnel boring machines versus drill and blast is actually less. This is because tunneling with TBMs is much more efficient and results in shortened completion times.

Hard rock TBMs

In hard rock, either shielded or open-type TBMs can be used. All types of hard rock TBMs excavate rock using disc cutters mounted in the cutter head. The disc cutters create compressive stress fractures in the rock, causing it to chip away from the rock in front of the machine, called the tunnel face. The excavated rock, known as muck, is transferred through openings in the cutter head to a belt conveyor, where it runs through the machine to a system of conveyors or muck cars for removal from the tunnel.

Open-type TBMs have no shield, leaving the area behind the cutter head open for rock support. To advance, the machine uses a gripper system that pushes against the side walls of the tunnel. Not all machines can be continuously steered while gripper shoes push on the side-walls, as in the case of a Wirth machine which will only steer while ungripped. The machine will then push forward off the grippers gaining thrust. At the end of a stroke, the rear legs of the machine are lowered, the grippers and propel cylinders are retracted. The retraction of the propel cylinders repositions the gripper assembly for the next boring cycle. The grippers are extended, the rear legs lifted, and boring begins again. The open-type, or Main Beam, TBM does not install concrete segments behind it as other machines do. Instead, the rock is held up using ground support methods such as ring beams, rock bolts, shot Crete, steel straps, Ring steel (Pat 2011) and wire mesh (Stack, 1995).

In fractured rock, shielded hard rock TBMs can be used, which erect concrete segments to support unstable tunnel walls behind the machine. Double Shield TBMs have two modes; in stable ground they can grip against the tunnel walls to advance. In unstable, fractured ground, the thrust is shifted to thrust cylinders that push off against the tunnel segments behind the machine. This keeps the significant thrust forces from impacting fragile tunnel walls. Single Shield TBMs operate in the same way, but are used only in fractured ground, as they can only push off against the concrete segments (Stack, 1995)

Soft ground TBMs

In soft ground, there are three main types of TBMs: Earth Pressure Balance Machines (EPB), Slurry Shield (SS) and open-face type. Both types of closed machines operate like Single Shield TBMs, using thrust cylinders to advance forward by pushing off against concrete segments. Earth Pressure Balance Machines are used in soft ground with less than 7 bar of pressure. The cutter head does not use disc cutters only, but instead a combination of tungsten carbide cutting bits, carbide disc cutters, and/or hard rock disc cutters. The EPB gets its name because it is capable of holding up soft ground by maintaining a balance between earth and pressure. The TBM operator and automated systems keep the rate of soil removal equal to the rate of machine advance. Thus, a stable environment is maintained. In addition, additives such as bentonite, polymers and foam are injected into the ground to further stabilize it.

In soft ground with very high water pressure and large amounts of ground water, Slurry Shield TBMs are needed. These machines offer a completely enclosed working environment. Soils are mixed with bentonite slurry, which must be removed from the tunnel through a system of slurry tubes that exit the tunnel. Large slurry separation plants are needed on the surface for this process, which separate the dirt from the slurry so it can be recycled back into the tunnel.

Open face TBMs in soft ground rely on the fact that the face of the ground being excavated will stand up with no support for a short period of time - this makes them suitable for use in rock types with strength of up to 10MPa or so, and with low water inflows. Face sizes in excess of 10 meters can be excavated in this manner. The face is excavated using a back actor arm or cutter head to within 150mm of the edge of the shield. The shield is jacked forwards and cutters on the front of the shield cut the remaining ground to the same circular shape. Ground support is provided by use of precast concrete, or occasionally SGI (Spheroidal Graphite Iron), segments that are bolted or supported until a full ring of support has been erected. A final segment, called the key, is wedge-shaped, and expands the ring until it is tight against the circular cut of the ground left behind by cutters on the TBM shield. Many variations of this type of TBM exist.

While the use of TBMs relieves the need for large numbers of workers at high pressures, a caisson system is sometimes formed at the cutting head for slurry shield TBMs Workers entering this space for inspection, maintenance and repair need to be medically cleared as "fit to dive" and trained in the operation of the locks

Back-up systems

Behind all types of tunnel boring machines, inside the finished part of the tunnel, are trailing support decks known as the back-up system. Support mechanisms located on the back-up can include: conveyors or other systems for muck removal, slurry pipelines if applicable, control rooms, electrical systems, dust removal, ventilation and mechanisms for transport of pre-cast segments.

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1.6 Safety aspects of PIL-

- Appointment of safety personnel for the project and the formation of safety committee on site.
- Review of specifications to identify appropriate safety standards and special safety conditions.
- Hazard analysis.
- Emergency and contingency plan for obtaining medical assistance, ambulance and direction for rescue operation.
- Safety induction training for every worker, to make them aware of the safety rules & procedures.
- Inspection, testing and certification of tools and equipment.
- Display of safety signage caution boards and awareness posters.
- Periodic safety inspection and compliance of observations.
- Accident reporting and investigations.
- Analysis of accidents.
- Safety audit and compliance.

1.7 -Emergency management system of tunnels

. This plan provides core guidance on actions necessary for all emergency situations with could cause hazard to life or property from accidental causes.

DEFINITION AND SCOPE

The major emergency is defined as one which may affect one or several areas of the site and may cause serious injuries, loss of containment or environmental impacts and may require the help of outside resources in addition to our own to handle it effectively.

"Emergency management" should be framed in such a manner so as to take immediate action by various groups to meet and control the critical situation within shortest period with minimum loss of Material, Machine and Property & also to minimize the loss of personnel injuries.

It is the responsibility of all the individuals in their respective areas to take the necessary safety measures to eliminate the possibility of the emergency and if at all it occurs limit its impact.

Purpose of this plan-

- This plan has the two fold purposes. One is to prepare for the emergency situations by means of Mock Drill Exercises & Other Training programs.
- The other purpose is to handle emergencies and effective use of all resources with complete liaison and coordination with outside agencies to minimize the effect of such a disaster / emergency.

The major functions of this plan are to:-

a) Prepare the associates for the emergency situations described above by Mock Drills & Other Safety Trainings.
b) Rescue the potential victims and treat them suitably.
c) Safeguard others (evacuating them where necessary).
d) Contain the incident and control it with minimum damages.
e) Identify the persons affected.
f) Inform relatives of the casualties / effected person.
g) To provide information to district or industry authority.
h) Preserve relevant records and equipment needed as evidence in any subsequent inquiry.
i) Rehabilitate the affected areas

1.7 primary emergency procedure of emergency management system in a tunnel- it is a must that everybody knows the actions that they must do. Hence in these cases, presence of mind is very important and the following shall be done as a minimum:

RAISING AN ALARM

This has to be done in cases where automated fire alarm system is not available and/or somebody has discovered a fire and fire alarm has not been heard yet. For most facilities, a manual fire alarm station is available which shall be operated to raise the alarm. In some cases that it is not available, the alarm to be raised shall be as per agreed procedure before the commencement of work to raise the alarm.

CALLING THE RELEVANT AUTHORITY

In case of fire or other emergencies) .Immediate call shall be made as per the posted emergency numbers. Generally, the number posted is the telephone numbers of the following: Safety Officer, Construction Manager, Client's Safety Representative, Fire Department, Ambulance Service, etc. When calling, it is imperative that brief and precise information is given to the call receiver i.e. assessment of fire size, exact location, actions that have been taken, etc.

EVACUATION

Upon hearing the emergency or fire alarm, everybody shall immediately but calmly proceed to the designated muster point. Nobody should stop to collect personal belongings. If it is safe to turn OFF equipments before leaving i.e. somebody is close to it when the when the alarm is heard, do so with necessary precautions. A roll call shall be made to ensure that nobody is left. Nobody shall be allowed to return to the area unless declared that it is safe to do so

FIRE FIGHTING

In the event of fire event of fire, designated or trained Fire Fighters shall try to stop the fire if it is safe to do so. This shall be done by using suitable fire fighting equipments e.g. portable fire extinguisher, fire blanket, fire hose connected to the fire hydrant.

FIRST AID

injury of somebody, trained First Aider shall do the immediate treatment while waiting for the medical team to arrive. This is why a first aid kit is always required to be available to every work site especially if the ambulance service is quite far. The company is sending competent individuals to training on First Aid.

REPORTING AN INCIDENT OR ACCIDENT

- Work Site Supervisors are valuable in reporting an incident or accident since the witness or victim may likely be his subordinate that would report to him. With this, his total coordination and support with the Safety Officer and other Investigating Team during the investigation process is very much expected.

- Investigation and reporting shall be as per Kent standard procedure. The Safety Officer will be the one to prepare and submit the investigation and monthly injury report in a standard format. These reports (copies) will be submitted to the Project Manager and originals to be maintained and filed by the Safety Officer.
- With the report of the Safety Officer, the Project Manager will include this information in the safety statistics, which is a part of the monthly project report.

INCIDENT, ACCIDENT & FIRE DISASTER. HOW THEY AFFECT WORK, LIFE AND PROPERTY?

To summarize things up, all the necessary precautionary measures and preventive safety procedures are developed and strictly implemented to avoid the following negative consequences that will likely affect our work, life and property:

- Permanent disability or loss of body parts
- Loss of property e.g. equipment, facility, plant, office, vehicle, etc.
- Loss of important documents
- Unwanted cost for clearing the remains and re-construction
- Loss of Client's confidence
- Weakened market share
- Demoralized worker
- Loss of job or imprisonment if found that accident caused by intentional misconduct And most importantly, loss of own life or loved ones

RESPONSIBILITIES

The following describes the minimum specific responsibilities for safety at work sites:

- The Work Site Supervisor is responsible for ensuring everybody under his command is working to defined safety procedures and practices. In close coordination with the Safety Officer, he shall ensure that everybody is given the safety induction training and included in the weekly toolbox talk meetings as necessary. He shall ensure that proper housekeeping is observed at all times, fire and incident prevention is strictly followed and that all incidents are reported to him at the earliest possible time. The Quality Assurance Manager/delegate shall ensure the effective implementation of the safety procedures and practices by conducting a periodic surveillance and/or internal audits. Feedback of these surveillance and audits shall be properly conveyed to the Project/Construction Manager, Safety Officer and Supervisors such that necessary actions or plans may be done as necessary's

ORGANISATION TO CONTROL EMERGENCY

As the work progress for 24 hours a day. The following coordination plan is to be followed to control and limit the consequences of the emergency situation.

CO-ORDINATORS & THEIR DUTIES

EMERGENCY COORDINATOR

The Emergency Coordinator is Chief SHE Manager. In his absence Sr SHE Manager is the Emergency Coordinator. The Emergency Coordinator is responsible for ensuring that the Emergency management is maintained and all the requirements of the Emergency Management Plan are complied with.

The Emergency Coordinator is to oversee the emergency management (including evacuation of the whole Site or any particular area) with the help of Fire & Safety Coordinators.

EMERGENCY COORDINATOR 'S DUTIES

- Goes to the area where emergency is & keeps in touch with Safety & Fire Coordinator & assess the real situation.
- Staying in touch with Safety & Fire Coordinator, Plans for the rescue so that the fire is contained in the restricted area only.
- Makes sure that Safety & Fire Coordinator is in touch with Communication Coordinator to Ensure that the outside Fire Brigade is called (if required). This may be done using telephone from neighboring premises, cell phone, if safe to do so, (Clearly stating the NAME & ADDRESS OF THE SITE and the NATURE OF THE EMERGENCY (fire, chemical spill etc.).
- If the phone lines are not working, the Company vehicle can be sent to inform Fire Brigade.
- If Company vehicle is also not available, seeks help from the neighboring companies for help.
- Informs Chief Project Manager & Project Manager about the incident & for guidance.
- Shuts off appropriate machinery as required.

Chapter 2
Literature Survey

S.no.	Author and place	Year	topic	Methodology or work done	conclusion
1	Alan N. Beard' Civil Engineering Section, School of the Built Environment, Heriot-Watt University, Edinburgh, Scotland EH14 4AS, United Kingdom	2010	**Tunnel safety, risk assessment and decision-making**	This article gives a brief account of a project which was commissioned by the European Parliament. The author was requested to carry out a study of tunnel safety and make recommendations to be considered for possible application within the European Union. The background to the project was the large number of catastrophic tunnel fires which have taken place in Europe since 1995	Twenty five recommendations are made within the Report the purpose of which is to help to increase tunnel safety in the European Union and, primarily, to help to move towards a common system of tunnel safety decision-making and risk assessment.
2	Yasushi Oka[a], Graham T. Atkinson[b] [a] Department of Safety Engineering, Yokohama National University, 156 Tokiwadai, Hodogaya-ku, Yokohama 240, Japan [b] Health and	2000	**Control of smoke flow in tunnel fires**	concerns the specification of the longitudinal ventilation necessary to prevent upstream movement of combustion products in a tunnel fire. Experiments carried out in a model tunnel have revealed significant limitations on the utility of existing empirical	. The effects of changes in the shape, size and location of the fire on the critical velocity have been investigated

	Safety Laboratory, Health and Safety Executive, Harpur Hill, Buxton, Derbyshire SK17 9JN, UK			expressions for the critical velocity. Simple formulae with a wider range of applicability are presented. The method of scaling model results has been tested by comparison with large-scale test data	
3	Vytenis Babrauskas, Richard D. Peacock Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA	2003	**Heat release rate: The single most important variable in fire hazard**	To explain why heat release rate is, in fact, the single most important variable in characterizing the 'flammability' of products and their consequent fire hazard. Examples of typical fire histories are given which illustrate that even though fire deaths are primarily caused by toxic gases, the heat release rate is the best predictor of fire hazard	The delays in ignition time, as measured by various Bunsen burner type tests, also have only a minor effect on the development of fire hazard
4	Z.H. Ye[b], L.P. Li[a], Q.Q. Zhang[a], Z.H. Xu[a] [a] Geotechnical and Structural Engineering Research Center, Shandong University, Ji'nan 250061, Shandong, China	2015	**Comprehensive geophysical prediction and treatment measures of karst caves in deep buried tunnel**	• Engineering geological and hydrogeological conditions of the tunnel were investigated. • GPR method was integrated with Geological Drilling for karst cave prediction.	the treatment of the karst cave which situated under the tunnel floor

Chapter 3-Methodology

1. Site inspection (including station area , tunnel)-An inspection is, most generally, an organized examination or formal evaluation exercise. In engineering activities inspection involves the measurements, tests, and gauges applied to certain characteristics in regard to an object or activity. The results are usually compared to specified requirements and standards for determining whether the item or activity is in line with these targets, often with a Standard Inspection Procedure in place to ensure consistent checking. Inspections are usually non-destructive. Site inspection also includes observations records and checklists.

- Excavation checklist
- Dust control checklist
- Fire prevention
- Confined space
- Lifting operations
- Vibration

Some of the checklist are attached in annexures.

2. Knowing the processes- to know all the activities performed there and the hazards associated with it.

- Excavation
- Drilling
- Concrete production and transport
- Work at height
- Electrical system
- Working with hand tools
- Material lifting
- Shot Crete
- Confined space working
- Lifting

3. Hazard and risk identification- by walk through survey of the site (station and tunnel both)

4. Performing project start up checklist.eg-

- Noise control checklist
- Scaffolding
- Electricity
- Confined space
- Lifting operations etc.

5. Work permit-for eg-hot work and confined space.

6. Reviewing emergency management plan of company

An emergency plan must provide for:

- emergency procedures including an effective response to an emergency
- evacuation procedures
- notifying emergency service organisations at the earliest opportunity
- medical treatment and help
- effective communication between the person authorised by the person conducting the
- business or undertaking to co-ordinate the emergency response and people at the workplace
- testing emergency procedures including the frequency of testing, and

Information, training and instruction to relevant workers about implementing the emergency procedures

7. Recommendations

CHAPTER 4- WORK DONE

Observations-

4.1 Uncertainties in the tunnel projects

All phases of the tunnel project are influenced by numerous uncertainties. These can be categorized into two groups:

- Usual uncertainties in the course of tunnel design, construction and operation
- Occurrence of extraordinary events (failures) causing significant unplanned changes of the expected project development

Both types of uncertainties influence the stakeholders’ objectives, which can be expressed using performance parameters such as costs, time, quality etc. Examples of the uncertainties and performance parameters, in division to the project phases, are given in Table.

Examples of uncertainties and the influenced performance parameters in the tunnel projects

Planning phase	Construction phase	Operation phase
Usual uncertainties -quality of planning team -quality of designer -geotechnical survey -tendering	**Usual uncertainties** - geological + hydrological cond -performance of the technology -quality of organization and works - prices of materials, labour	**Usual uncertainties** -number of vehicles -quality of maintenance - durability of materials
Extraordinary events - Strong public aversion - Rejection of financing Legislative obstructions	**Extraordinary events** - Tunnel collapse or flooding - Unpredicted existing structures Extensive deformations	**Extraordinary events** - Vehicle accident - Tunnel collapse - fire
Performance parameters - Land acquisition time and costs - Design cost, time and quality -Time for acquisition of regulatory approvals and permits	**Performance parameters** Construction costs Construction time Quality financing	**Performance parameters** Income/availability M&O costs Environmental aspects Life time

4.2 - Managing health and safety risks by emergency management system in tunnel-

Identifying hazards – find out what could cause harm in tunnelling work

Assessing risks if necessary – understand the nature of the harm that could be caused by the hazard, how serious the harm could be and the likelihood of it happening

Controlling risks – implement the most effective control measures that are reasonably practicable in the circumstances, and „ reviewing control measures to ensure they are working as planned.

4.2.1- Planning and preparation-

Roles in design state-

1. The persons conducting a business or undertaking commissioning the tunnelling design or construction work are in key positions to influence the safe design, construction, use, maintenance and de-commissioning of the tunnel.
2. Many aspects of tunnel design influencing whether a tunnel is constructed safely, like tunnelling in rock or soft ground, are decided in the concept design stage.
3. During this phase duty holders should consult and plan to manage risks which may occur when constructing, using and maintaining the tunnel..
4. Not all hazards and risks associated with tunnelling work will be obvious during the concept design phase so there should be on-going consultation between duty holders.
5. The principal contractor must ensure a work health and safety management plan is prepared for the tunnelling work before tunnelling work starts. The client should include this requirement in contract documents.
6. The designer must give the results of calculations, analysis, testing and examinations necessary to ensure the design is without risks to health and safety to: the person conducting a business or undertaking commissioning the design, and any person who is provided with design information.
7. The assumed geotechnical conditions used in the design should also be provided to the principal contractor by the designer to allow these to be monitored and compared with the actual conditions experienced during the tunnelling work.

Development in tunnel design-

Tunnel design is based on less reliable assumptions than other designs. To minimise the associated risks, so far as is reasonably practicable, the following tasks should be carried out:

1. **Reviewing existing geological information** and conduct a workplace investigation to determine whether existing information is accurate and sufficient.
2. **Consulting with national bodies** about environmental and geological conditions, mineral workings, and planning and transport issues.
3. **Reviewing specifications** of the geological conditions assumed in the design.

4. **Implement an inspection plan** to compare the actual geological conditions as the excavation progresses with the assumed conditions.

4.2.2-WORKPLACE INVESTIGATION

Safe tunnel design and construction depends on pre-construction investigation of the ground conditions, the workplace and proper interpretation of this information. Designers should be:

- ✓ provided with available and relevant information
- ✓ told of gaps in the information for planning and construction
- ✓ involved in collecting data during workplace investigations, and
- ✓ included in on-site investigations.

The workplace investigation should be carried out by suitably qualified and experienced people competent in conducting investigations of similar ground conditions. The workplace investigation may include:

- climatic and prevailing weather conditions
- local topography - location, condition and influence of existing structures, services and old workings
- geophysical conditions - drilling boreholes or examining existing borehole results, laboratory assessment of soil and rock properties, rock cutting, dust production and blasting trials, and
- Hydrology - ground water conditions including location, volume and possible changes due to tunnelling and other activities. The workplace investigation will provide information to assist the geotechnical risk assessment of ground and other conditions. The assessment should consider:
- rock mass geology
- planes of weakness
- mechanical properties of rock including the influence of planes on the rock mass
- in-situ rock stress field magnitude and orientation
- induced rock stress field due to excavation
- potential rock failure mechanisms
- blast damage effects to the rock mass if blasting is being considered
- likely scale and nature of the ground behaviour e.g. movement
- possible effects on other work places or installations
- groundwater presence and quantity

Possible contaminated environments including groundwater, hazardous gases like methane, liquids like industrial waste and solids like naturally occurring or dumped asbestos, and previous relevant experience and historical data for the area.

4.2.3-DETERMINING THE EXCAVATION METHOD

The workplace investigation including geotechnical investigations, risk assessments, the tunnel design, entry limitations and other local factors should be used to establish the most suitable excavation methods.

To determine the most suitable excavation methods the following should be considered:

- excavation site risks during past excavations under similar conditions water table levels and possibility of flooding from surface run-off, tidal water, rivers, dams, reservoirs, lakes or swamps ,leaking storm water drains, water mains or flooded communications conduits intersection of old flooded workings or an underground water-bearing structure.

- whether there are other excavations like shafts, tunnels or trenches nearby other hazards, either natural or man-made e.g. heavy loadings above or adjacent to the tunnel like roadways, railway lines or buildings rivers or planned or existing spoil stockpiles chemical contamination from past dumping, leaking tanks, pipes or natural deposits the presence of methane or other hazardous or flammable gases and vapours where vegetation has decayed in the soil or hydrocarbon contamination from historical fuel leaks exist dynamic loads or ground vibration near an excavation from road or rail traffic excavation plant explosives dust production and dust control measures, and airborne contaminants

4.2.4-GROUND SUPPORT DESIGN

- Most tunnels and open excavations need some form of temporary and permanent ground support that should be specified in the tunnel design. Removing material causes unbalanced soil or rock stresses that reduce the capacity of the tunnel to support itself. Varying geological conditions mean control measures that have worked previously may not be satisfactory under these changed conditions. The person conducting a business or undertaking should carry out a detailed analysis of existing geophysical conditions and the design requirements to identify the most suitable temporary ground support that may be installed without requiring workers to work under unsupported ground.
- When designing ground support systems you should consider structural design and soil and rock mechanics. Ground support designed for the unique circumstances of the tunnel is essential to control the risk of a collapse or tunnel ground support failure. Design specifications for engineering control measures like shoring support structures should be prepared by a competent person in accordance with relevant legislative requirements, Australian Standards and codes of practice.

4.2.5 VENTILATION SYSTEM DESIGN

The ventilation system should be designed to provide ventilation throughout the tunnel during construction, use and maintenance. This includes providing extra localised extraction ventilation for dust, heat or fumes during excavation, post-blasting, operating large plant or other activities like maintenance. The design should include being able to install ventilation equipment or ducting during excavation to maintain air supply to the working face.

4.2.6 DETAILS TO BE INCLUDED IN THE TUNNEL DESIGN

Information from the workplace investigation and the likely excavation methods to be used should be considered in preparing the tunnel design.

The design should detail the:

- excavation methods and ground conditions
- tunnel dimensions and allowable excavation tolerances
- limitations for installing ground support during excavation e.g. maximum and minimum distances from the tunnel face
- temporary ground supports during construction
- ventilation systems

- final ground support and lining requirements for each location within the tunnel, and
- Other requirements for the finished tunnel.

If a different excavation method is chosen or the assumed ground conditions change, the design should be reviewed before starting to excavate.

4.3 REVIEWING THE TUNNEL DESIGN BEFORE CONSTRUCTION

The person conducting the business or undertaking who commissioned the design and the principal contractor should review the design for construction and tell the designer where amendments are needed or if in their opinion the tunnel cannot be constructed safely. The designer will then make amendments or modifications to the design before construction starts. This review should consider a range of tunnelling work issues including the:

- excavation method
- extra excavation for temporary entry
- ventilation systems
- construction phase electrical systems
- materials handling systems including spoil removal
- Loadings from roof mounted spoil conveyors and ventilation systems, and places of safety including refuge chambers..

Inspection planning

- Tunnelling work should be inspected regularly to ensure the tunnel and supporting systems remain stable, intact and work can be carried out safely.
- The inspection should compare the actual conditions with those assumed in the original or amended designs, excavation method or safety management plan and the adequacy of control measures.
- Inspection plans should be developed collaboratively with the person conducting the business or undertaking and the principal contractor.
- The inspection plans should include a section for the principal contractor to confirm support elements have been installed in accordance with the design specifications and the corresponding construction sequences.

observations and recommendations in Inspection plan activities-

Activities for inclusion in inspection plan	Extra considerations for open excavations
• -mapping and visually assessing actual ground conditions and excavated shape as exposed by the tunnel excavation • monitoring ground support performance including: possible support failures. • Evidence of excessive load . • anchoring or pulling out tests on rock bolt type supports . • falling or fretting ground monitoring	• excavated and other material being placed within the zone of influence of the excavation plant operating within the zone of influence of excavations causing weight and vibration influences surface soil falling into the excavation . • water seeping into excavations from side walls or base changes to soil and weather conditions • surface water or run-off entering the

time-based deterioration, like spalling or slaking from weathering through temperature and humidity changes or exposure to air . • monitoring water entry quantity, quality and location measuring closure or subsidence of roof or walls by installing extensometers or by regular survey and testing core rocks • measuring in-situ ground stresses o reviewing results of the most recent monitoring of tunnel atmosphere	excavations or accumulating on the surface near the excavation subsidence along side the excavations .

4.4 -LOCATING AND COMMUNICATING WITH WORKERS-

It is important for people working above and below underground to be in contact with each other. People above ground should know where underground workers are in case an incident occurs.

COMMUNICATION SYSTEMS

A communication system should allow a person using it to efficiently and effectively	The communication system should be used to link:	When selecting the communication system consider the:
• distribute information and instructions • control operations like lifting, transporting people, materials and plant • monitor plant and systems like ventilation and help co-ordinate maintenance • Manage an emergency including contacting emergency services.	• remote or isolated workers • major workplaces • tunnel portal and faces • top and bottom of shafts • restricted spaces, like smoke ducts and conduit passages • site offices • Safety critical locations like first aid and emergency control rooms.	• size and length of the tunnel • number of people in the tunnel • system of tunnelling work used • potential hazards including the speed of operations

A system of signalling by bells or coloured lights can be suitable for routine communications, like controlling train movements or requesting lining segments or other materials be sent forward. Details about audible or visual signal code used, call signs and channel allocations and how to use them should be explained to and practised by everyone affected by the tunnelling work. For shafts this applies to the doggers, winch and hoist drivers and those working in or about the shaft itself. The communication system should be able to operate independently of the tunnel power supply through an uninterruptible power supply, known as a UPS. It should be installed so if one unit fails or a collapse occurs it will not interrupt the other units in the system. Communication cables and wiring, especially those used to transmit warnings in an emergency, should be protected from fire, water and mechanical shock.

Working shafts should have a standby means of communication which can be operated from throughout the shaft. There should be an effective warning system capable of being activated quickly in an emergency to alert people underground to evacuate the tunnel. Emergency warning systems should be tested using emergency evacuation drills.

4.5 -Emergency planning-

WHAT TO INCLUDE IN AN EMERGENCY PLAN

An emergency plan must provide for:

- emergency procedures including an effective response to an emergency
- evacuation procedures
- notifying emergency service organisations at the earliest opportunity
- medical treatment and help
- effective communication between the person authorised by the person conducting the
- business or undertaking to co-ordinate the emergency response and people at the workplace
- testing emergency procedures including the frequency of testing, and
- information, training and instruction to relevant workers about implementing the emergency procedures.

All types of emergency and rescue scenarios should be considered when developing emergency procedures. Information from a risk assessment will help in this task and will depend on control measures implemented. Table 3 sets out some questions to consider when establishing emergency procedures.

Developing emergency procedures-

Considerations	questions
Coverage plans	How will the safety of people at the workplace including visitors or people who need help to evacuate in an emergency, be considered in the plan?
emergencies	• What emergencies could happen with the

	tunnelling work? How will you respond to emergencies like collapse, fire, flood or failure of ventilation systems?. • What control measures can be implemented to reduce the severity of the emergency, like self-closing bulkheads to eliminate or minimise, so far as is reasonably practicable, the risk of water inrush? • What equipment will be needed to deal with emergencies, like: • spill kits • fire extinguishers • early warning systems like fixed gas monitors or smoke detectors • automatic response systems like sprinklers. • Should there be specific procedures included in the plan for critical functions, like a power shut-off? •
evacuations	• What triggers for an evacuation, like a confirmed or suspected underground fire, should be considered in the plan? • How will the controlled evacuation of people from the workplace be handled? Are there planned regular evacuation drills at least every 6 months or as soon as practicable after the plan is changed?
Workplace location	• Is the tunnelling work carried out in a remote or isolated place? How accessible is it in an emergency and how far away is it from medical facilities? • Can a person be rescued immediately without relying on emergency services? • Are there areas where special emergency provisions like emergency rescue cages and the means to extract people from difficult locations like the base of a shaft needed? • Have safe places and assembly points been identified?
Roles and responsibilities	• Who should be allocated roles and responsibilities in an emergency e.g. area

	wardens? • Who has the relevant skills for specific actions in an emergency?
Training	• Who requires regular and on-going training? When should this be provided? Does the training include an understanding of the emergency plan and actions to be taken in an emergency, escape options and emergency equipment? • How will workers who enter the tunnel be trained in entrapped procedures, like remaining calm, alert and making conservative decisions?
communication	• How can workers doing tunnelling work communicate in an emergency will clear lines of communication between the person authorised to co-ordinate the emergency response and people at the workplace be maintained will alarms be activated. • who will notify people at the workplace? • Is there a system in place to identify who is underground, like tag boards or electronic tagging? • Have you clearly displayed the workplace site plan showing where fire protection equipment is stored, the location of emergency exits assembly points and emergency phone numbers?
Rescue equipment	• Has rescue equipment been selected based on the nature of the work and the control measures used? Can it carry out the planned emergency procedures? • Is rescue equipment kept close to the work area so it can be used quickly?

4.5- Common hazards and risks associated with tunnelling work-

Common tunneling work hazards, risks observed and control measures-

Hazards or risks	Control measures
• Confined spaces with build-up of gas and fumes	• planning and implementing tasks in accordance with Code of Practice: *Confined spaces* and AS 2865-2009:

	Confined Spaces • Using suitable ventilation and dust extraction systems monitoring atmospheric conditions. • developing rescue procedures including use of self-rescuers • having training and certification for work in confined spaces • using personal protective equipment (PPE)
• High water and mud inflow	• grouting old drill holes • pre-grouting before excavation starts • injecting grouting ahead of the face • probing, drilling and draining • dewatering and pumping from surface bores • using other forms of ground treatment e.g. freezing • installing sump and drainage systems • setting limits on maximum height of water and mud flow during work e.g. less than boot height
• Gas inrush	• • increasing face ventilation and extraction • probing drill hazard areas through check valves • monitoring for gas • installing automatic plant cut-off and flame-proofing plant in possible flammable atmospheres • restricting smoking to designated areas
• • Heat stress	• • reducing use of high heat output plant • increasing ventilation o Providing air conditioned offices and meal rooms o cool water o using cool suits o heat acclimatisation strategies o scheduling frequent rests
• • Noise	• • insulating plant • using hearing protection • silencing engines to achieve a noise level not exceeding LAeq 85 dbA at a distance of 1 metre

• Dust, hazardous chemicals	•
	• increasing face extraction ventilation
	• using water sprays on cutting equipment or over muck heaps and spoil conveyors
	  ○ providing: information like safety data (SDS) sheets
	  ○ spill kits
	  ○ using PPE

• • Fire or explosion, flammable gases and vapours	• • eliminating ignition sources underground where practicable • isolating fuel sources from remaining ignition sources • removing potential fuel sources from the work area • monitoring atmospheric conditions • storing only necessary fuel underground • implementing fire fighting training and procedures • ensuring availability of fire fighting resources • restricting smoking to designated areas • using a hot work permit system

- **Tunnel boring machines**

Commons hazards risks observed and their control measures related to TBM

• Hazards and risk	• Control measures
• Chemical exposure	• limiting underground chemical storage • providing training and information, like SDS • using PPE
• Crush areas, around grippers, walking feet or shields	○ using: visual lock out devices ○ cameras and alarms to increase the visual field ○ ensuring operators can clearly see when grippers and pads are deployed and if there are obstructions
• Cutter head transport and	○ using: an isolation process for cutter head access

access including heat exposure	○ rear loading cutters and protecting cutter rings ○ restricting other maintenance when work on the cutter head or cutter head entry is in progress ○ ensuring ventilation for the task ○ instigating safe manual handling procedures
• dust	• isolating dust generating processes • using: dust suppression, air filtration and scrubbers units • water sprays and dust suppression on conveyor belts
• Fire	• providing fire suppression • having individual electrical cabinet fire detection and suppression systems • installing aqueous film forming foam systems at locations where grease, oil and fuel lines and tanks are present • designing tunnel lining for fire durability • substituting equipment to reduce diesel and oils • having detailed safe work method statements (SWMS) for hot works, like oxy cutting and welding ○ using: fire resistant hydraulic fluid and fire resistant power cables for high voltage supply ○ fire retardant tail shield grease
• Heat exposure	○ supplying: ventilation ○ supplying chilled drinking water ○ managing fatigue
• TBM operation	• isolating TBM access during maintenance ○ ..using: l lock out systems to prevent accidental starting ○ auto cut-offs for TBM roll and friction pads on grippers ○ ○ ..deeming TBM operators competent by an

	independent party or the TBM supplier o ..developing and practising contingency plans
• Tunnel collapse including ground and rock fall near shields and fingers; lining failure leading to potential ground and rock falls and degradation of excavated ground through drying, flaking and support failure	• using geotechnical assessment during TBM design • on-going assessment of ground conditions and ground support with geologists and designers during excavation • using finger shields including hoods • mapping ground conditions immediately behind shields • designing tunnel lining using geotechnical data and assessment including faults (shearing) and seismic activity including liquefaction • having quality assurance programs for lining and annulus void filling

4.6 Mechanical ventilation

Mechanical ventilation is one way to:

- ensure oxygen is available for respiration from fresh air
- dilute and transport harmful atmospheric contaminants away from work areas
- have enough air flow to eliminate or minimise contaminants, so far as is reasonably practicable, and
- Provide cooling for people working in warm and humid environments.

The ventilation design should check there is:

- no dead spots
- no low air speed areas
- no flow reversals
- no areas of dust concentration
- no recirculation, and
- Inspection points are fitted where blockages are likely to occur.

When a mechanical ventilation system is used to eliminate or minimise, so far as is reasonably practicable, the risk of exposure to a contaminated atmosphere the system should be:

- located as close as possible to the source of the contaminant to minimise the risk of inhalation by a person at work
- used for as long as the contaminant is present

- kept free from accumulation of dust, fibre and other waste materials and maintained regularly, and designed and constructed to prevent the occurrence of fire or explosion if the system is provided to eliminate or minimise, so far as is reasonably practicable, contaminants arising from flammable or combustible substances

Ventilation equipments

TYPES

Types of ventilation systems include:

- forced supply
- extraction
- alternating or a combination of extraction and forced supply
- overlap systems

FANS

Fans are used to force or extract air in the methods above. Fans may be:

- single, double or multiple stage
- contra-rotating or non contra-rotating normally in matched pairs
- direct driven with the motor within the fan casing or driven with motor outside the fan casing, and
- flameproof type suitable for use in hazardous atmospheres or non-flameproof type.

Fans are generally designated to be:

primary fans located either on the surface or underground but providing the main ventilation airflow or basic ventilation capacity to the tunnelling work may be centrifugal or axial are electrically powered, sometimes adjustable and often monitored, and are often remain installed in a fixed position during the works. auxiliary fans located underground in the proximity of the tunnel face providing the required flows at the active areas particularly in blind or dead-end headings used for regulating the airflows about the tunnelling work may be installed in-line as booster fans to increase the whole airflow in that line are often moved forward as work progresses or ventilation needs alter, and are generally axial flow and electric but may be compressed air powered for small short-term airflow applications.

Recommendations- should be with a shroud with a screen to prevent people or materials coming in contact with the blades available for special circumstances, like potentially flammable or explosive atmospheres, with very specific safety features, motor types and requirements

MONITORING THE VENTILATION SYSTEM

Ventilation systems are monitored by measuring a number of atmospheric conditions. This can be done by using instruments including:

- a mercury or aneroid barometer to determine air pressure differences at different points in the system
- wet and dry thermometers to determine the temperature and humidity in the tunnel
- a sling psychrometer to more accurately determine the relative humidity in the tunnel
- a Kata thermometer to determine the cooling effect of air

- a water gauge for measuring air pressure differences e.g. across a fan and normally used with a pitot tube
- an anemometer (usually mounted on a stick) to measure the air velocity in the tunnel
- continuous dust and gas monitoring equipment, and
- hand held electronic gas monitors or gas test tubes to determine the concentration of contaminants or other gases in the air.

Some more Hazards and conclusions related to tunnel and its construction-

s.no	Source of hazard	hazard	solution	recommendations
1	trenching	Trench collapses cause dozens of fatalities and hundreds of injuries each year	• Never enter an unprotected trench. • Always use a protective system for trenches 5 feet deep or greater. • Employ a registered professional engineer to design a protective system for trenches 20 feet deep or greater. • Protective Systems: _ Sloping to protect workers by cutting back the trench wall at an angle inclined away from the excavation not steeper than a height/depth ratio of 1 :1, according to the sloping requirements for the type of soil.	• Shoring to protect workers by installing supports to prevent soil movement for trenches that do not exceed 20 feet in depth. • Shielding to protect workers by using trench boxes or other types of supports to prevent soil cave ins. • Always provide a way to exit a trench—such as a ladder, stairway or ramp--no more than 25 feet of lateral travel for employees in the trench. • Keep spoils at least two feet back from the edge of a trench. • Make sure that trenches are inspected by a competent person prior to entry and after any hazard-increasing event such as a rainstorm,vibrations or excessive surcharge loads.
2	cranes	Significant and serious injuries may occur if cranes are not inspected before use and if they are not	Check all crane controls to insure proper operation before use. • Inspect wire rope, chains and hook for any damage.	• Barricade accessible areas within the crane's swing radius. • Watch for overhead electrical distribution and transmission lines and maintain a safe working

		used properly. Often these injuries occur when a worker is struck by an overhead load or caught within the crane's swing radius. Many crane fatalities occur when the boom of a crane or its load line contact an overhead power line.	• Know the weight of the load that the crane is to lift. • Ensure that the load does not exceed the crane's rated capacity. • Raise the load a few inches to verify balance and the effectiveness of the brake system. • Check all rigging prior to use; do not wrap hoist ropes or chains around the load.	clearance of at least 10 feet from energized electrical lines.
3	Hazard communication	**:** Failure to recognize the hazards associated with chemicals can cause chemical burns, respiratory problems, fires and explosions.	• Maintain a Material Safety Data Sheet (MSDS) for each chemical in the facility. • Make this information accessible to employees at all times in a language or formats that are clearly understood by all affected personnel. • Train employees on how to read and use the MSDS. • Follow manufacturer's MSDS instructions for handling hazardous chemicals. • Train employees about the risks of each hazardous chemical being used. • Provide spill clean-up kits in areas where chemicals are stored.	• Train employees to clean up spills, protect themselves and properly dispose of used materials. • Provide proper personal protective equipment and enforce its use. • Store chemicals safely and securely.
	forklift	proximately 100 employees are fatally injured and approximately 95,000 employees are injured	• Train and certify all operators to ensure that they operate forklifts safely. • Do not allow any	• Drive safely--never exceed 5 mph and slow down in congested or slippery surface areas. • Prohibit stunt driving and horseplay.

		every year while operating powered industrial trucks. Forklift turnover accounts for a significant number of these fatalities	employee under 18 years old to operate a forklift. • Properly maintain haulage equipment, including tires. • Do not modify or make attachments that affect the capacity and safe operation of the forklift without written approval from the forklift's manufacturer. • Examine forklift truck for defects before using. • Follow safe operating procedures for picking up, moving, putting down and stacking loads.	• Do not handle loads that are heavier than the capacity of the industrial truck. • Remove unsafe or defective forklift trucks from service. • Operators shall always wear seatbelts. • Avoid traveling with elevated loads. • Assure that rollover protective structure is in place. • Make certain that the reverse signal alarm is operational and audible above the surrounding noise **level.**

4.7- Atmospheric contamination in tunnelling work

Atmospheric contamination in tunnelling work can occur because: excavations can be a receptacle for gases and fumes heavier than air gases and fumes like methane, sulphur dioxide, carbon monoxide and carbon dioxide leak from gas bottles, fuel tanks, sewers, drains, gas pipes and LPG tanks into the tunnel particularly when other work is taking place nearby oxygen in a non-ventilated area can be depleted due to internal combustion plants, oxidation or other natural processes, and through blasting activities. The ventilation requirements should be determined through a risk assessment. Due to the nature of tunnelling work, contaminants generated in one area of the tunnel will move readily to other areas. Protection against airborne hazards should be provided to workers. Control measures should be implemented to eliminate or minimise, so far as is reasonably practicable, the risks associated with atmospheric contaminants

observed risks of atmospheric contaminants and control measures-

Hazards and risk	Control measures	recommendations
silica dust, refractory ceramic or other mineral fibres and diesel particulate material ,toxic gases, fumes and vapours explosive and asphyxiant gases	storing materials on the surface in places away from where ventilation fresh air intakes could be compromised through a surface fire or chemical spill using a ventilation system which is: monitored and upgraded to ensure air flows are always provided to the workplace	The tunnel should be monitored throughout the work period in accordance with a suitable procedure.

4.8- Monitoring air quality

WHEN MUST AIR MONITORING BE DONE?

Air monitoring must be carried out to determine the airborne concentration of a substance or mixture at the workplace to which an exposure standard applies if: it is not certain on reasonable grounds whether or not the airborne concentration of the substance or mixture at the workplace exceeds the relevant exposure standard, or monitoring is necessary to determine whether there is a risk to health and safety.

HOW DO YOU DETERMINE IF AN ATMOSPHERE IS HAZARDOUS?

Risks to health and safety associated with a hazardous atmosphere at the workplace must be managed. An atmosphere is a hazardous atmosphere if: the atmosphere does not have a minimum oxygen content in air of 19.5 percent by volume under normal atmospheric pressure and a maximum oxygen content of air of 23.5 percent by volume under normal atmospheric pressure the concentration of oxygen in the atmosphere increases the fire risk the concentration of flammable gas, vapour, mist, or fumes exceeds 5 percent of the lower explosive limit for the gas, vapour, mist or fumes, or a hazardous chemical in the form of a combustible dust is present in a quantity and form that would result in a hazardous area. .

WHAT AIR MONITORING SHOULD BE DONE?

After blasting, tests should be carried out before people are allowed to re-enter the tunnel. The tunnel should be monitored throughout the work period in accordance with a suitable procedure. The workplace should be examined by suitably qualified people using detection and measuring equipment.

The monitoring should include air testing for:

- flammable fumes or gases
- oxygen deficiency and the presence of asphyxiant gases
- unsuitable temperature and humidity, and
- airborne contaminants like toxic gases, fumes or respirable dusts.

4.9- Visibility and lighting

Table 7-hazards and risks observed due to poor visibility and control measures

Hazards and risk	Control measures
• collisions • people being struck or run over by plant • inability to assess ground and plant conditions and other potential hazards • slips, trips and falls and fatigue	• providing hard-wired lighting at: transformer installations ,workshops or service bays ,fuelling points, pump stations or sumps ,stores areas and meal rooms ,loading and unloading points ,shaft and tunnel intersections ,plant rooms ,the transition zone some

	distance into the tunnel. • Providing extra lighting at the face area including lighting on the platform of mobile plant lighting for detailed work, hazardous processes and where plant is being operated • emergency exit lighting

4.10-Vibration

Some types of plant when used in tunnelling can expose people to vibration. Control measures should be implemented to eliminate or minimise, so far as is reasonably practicable, the risks associated with that exposure

HAND AND FULL BODY VIBRATION-

Controls –

Hand arm vibration	Full body vibration

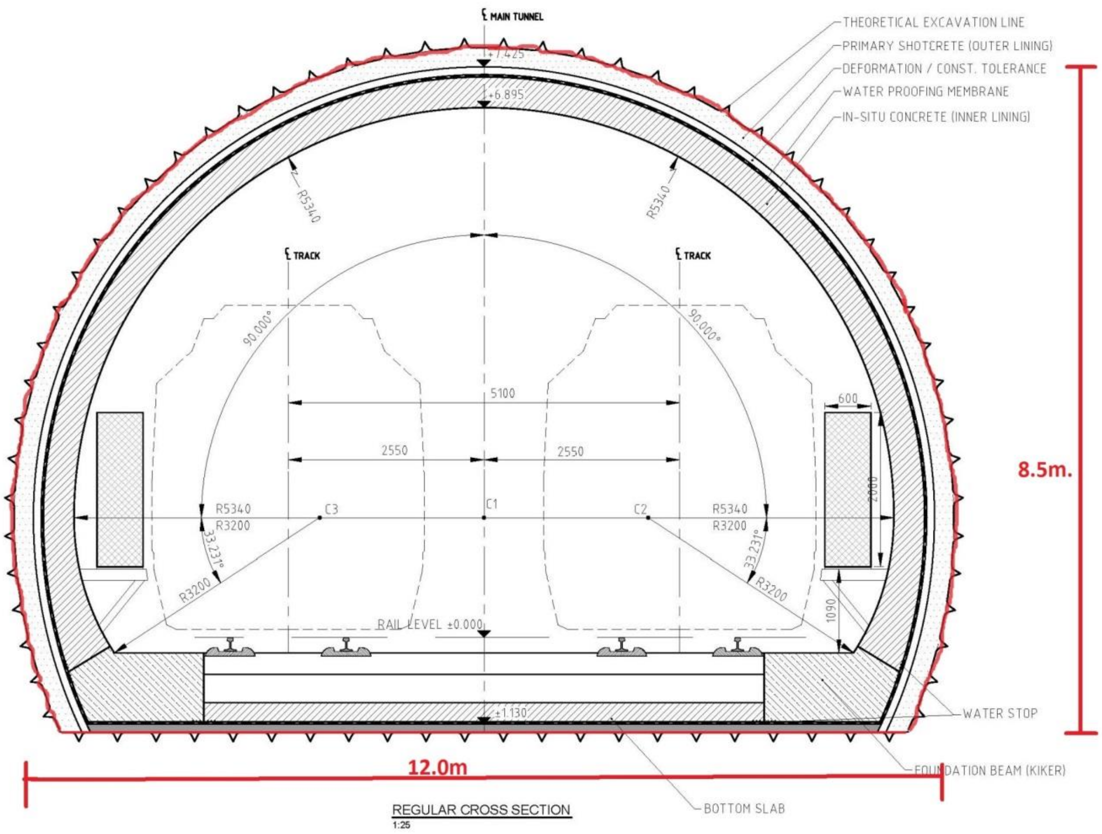
• regularly servicing plant to the manufacturers' specifications to reduce vibration
• using vibration-absorbing handles or rubber-type vibration insulating devices between the tool and the hands
• issuing suitable clothing and gloves to assist blood circulation by keeping the worker's hands warm
    o providing workers with training and instruction before work starts about keeping vibration exposure down to avoid hand-arm vibration syndrome
    o keeping tools sharp through a tool maintenance regime
    o handling tools
    o job sharing
    o keeping hands warm and dry
the increased risks of vibration health effects caused by smoking.
 	
Recommendation-
Hand-arm vibration exposure should be managed, controlled and maintained below 2.5 m per s2 over the
	• using foot-pusher plates for sinking drills
	• using suspended or vibration-absorbing seating in plant
	• using suspension dampened and padded seating in personnel-riding vehicles
	• travelling at reduced speed when travelling over uneven surfaces.
	
	Recommendations-
	
	Whole-body vibration exposure should be managed, controlled and maintained below 0.5 m/s2 over an entire 8 hour shift so far as is reasonably practicable. If vibration exposure exceeds this limit the exposed worker should have regular health monitoring as determined by a medical practitioner. Whole-body vibration exposures should never exceed 1.15 m/s2 over an 8 hour shift.
	Plant operators who are pregnant or have recently given birth should not be exposed to work involving: whole-body vibration, particularly at low frequencies, micro traumas and shaking that exceed an 8 hour daily exposure of 0.5 m/s2, and shocks, jolts or blows

entire 8 hour shift, so far as is reasonably practicable. If vibration exposure exceeds this limit workers should have regular health monitoring as determined by a medical practitioner. Hand-arm vibration exposures should never exceed 5.0 m per s2 over an 8 hour shift.	delivered to the lower body

Chapter-5

-RISK MITIGATION STRATEGIES FOR TUNNEL

Tunnel layout



STRUCTURE TYPE SELECTION

During preliminary design, construction techniques and associated structure type alternatives that used either a “bottom-up” or “top-down” construction method were considered for cut and cover tunnel construction. The “bottom-up” alternative consisted of excavating a trench section and building a conventional cast-in-place (CIP) CIP concrete box structure within the trench prior to backfilling of the trench. For this alternative the sides of the excavation would require temporary excavation support. Three temporary excavation bracing methods were evaluated structure type for this construction type: soil nail walls, sheet pile walls and a soldier pile and lagging walls. Soil nail excavation bracing was eliminated due to risks associated with groundwater and saturated sand and gravel seams that would be encountered. Sheet pile walls were eliminated due to risks associated with anticipated installation difficulties of driving sheet piles in the presence of boulders, cobbles and hard glacial tills. Thus, the “bottom-up” construction alternative was evaluated assuming solider pile and timber lagging for the required temporary excavation support. The primary advantage of the bottom up construction alternative is that it would be possible to apply waterproofing and groundwater collection drains around the outer perimeter of the CIP tunnel structure, making it relatively easy to avoid ground water from seeping into the tunnel interior. The disadvantages of this alternative technique were long construction duration and high initial construction costs. The most significant disadvantage, this alternative required dewatering, which was considered very challenging if not infeasible based on results from the pump test program. Top-down construction methods consisted of installing either a reinforced concrete slurry wall, secant pile wall, or tangent pile wall that would function as both the excavation bracing and be used for the permanent structural side walls of the tunnels. The tangent pile wall option was the only “topdown” wall option considered that was not a water-cutoff type wall. Initial construction cost for the tangent pile wall option was slightly less than the secant pile option. However, the risks of potential problems from groundwater seepage entering the excavation during the construction phase and concerns over the long term durability of the completed structure outweighed the modest initial cost savings. Thus, the tangent pile wall option was eliminated from further consideration. An advantage of the slurry trench wall is that it was comprised of larger wall segments which would have less construction joints compared to the secant pile wall option and therefore was likely to be more watertight compared to a secant pile wall. The disadvantages was that construction duration was longer for the reinforced concrete slurry wall and a higher construction

Underdrain System Required: An underdrain system was recommended and detailed to be installed under the invert slabs. With an installed underdrain system under the invert slab and the small volume of seepage anticipated, it was not necessary to design the invert slab to resist hydrostatic uplift pressure. The tip elevation of secant pile walls in the tunnels could generally be terminated at depth of approximately 45 feet to provide adequate ground water cut-off to minimize ground water seepage under the invert slabs.

Geotechnical Analysis

A complete geotechnical analysis was utilized to simulate the different construction phases along with the final condition of the tunnel prior to completion of the structural design as differences in performance were possible between the short term and final conditions. An undrained analysis is used to analyze each construction stage due to the shorter term durations between each stage. Adrained analysis is also performed for a few select cases in order to evaluate the performance of the excavation support system under the long term and worst case condition. For the final loading condition, a drained analysis is performed using drained soil strength parameters. Consolidation analysis is performed to simulate long-term consolidation allowing complete dissipation of excess pore pressures prior to changing the soil shear strength during the analysis, from undrained to drained parameters. Elastic material properties were used to model the walls and slabs with beam elements that have both axial and bending stiffness. Analysis of the secant pile walls and CIP top slab included non-linear behavior due to stiffness reduction from concrete cracking. The use of elastic material properties, which may be stiffer than the actual condition, could result in higher forces in the structural members. However, this would result in a relatively conservative structural design.

RISK MITIGATION

Several mitigation strategies were employed and incorporated into the construction contract to address these risks:

Subsurface Conditions' Risk: To mitigate this risk the comprehensive subsurface exploration program described above was conducted conducted. The cost of these investigations were approximately 1.5% of the estimated construction cost of the three cut and cover tunnel structures. The subsurface information obtained was incorporated into the construction contract documents in the form of a geotechnical baseline report that defined an equal baseline subsurface condition for all bidders, mitigating risk for claims associated with differing site conditions.

Risk of water bearing sand and gravel: Due to the presence of water bearing sand and gravel bearing layers that can be encountered at the bottom of the shafts, it was required to keep a positive head of water inside the casing in order to mitigate this risk.

Unqualified Contractor's Risk: To mitigate the potential risk of having inexperienced contractors attempt installation of the secant piles, a prequalification process for contractors or subcontractors who intended to perform the installation of drilled secant shafts for the cut and cover sidewalls was required.

Prequalification was based on recent applicable experience on similar projects and having an adequate inventory of the specialized drilling equipment that could be committed to the project. Contractors seeking prequalification had to demonstrate relevant experience on similar projects along with the listing of qualified personnel available and committed for this project. Four prequalified drilling subcontractors were identified in the contract bid documents and the contract required that only the listed prequalified subcontractors could perform the secant pile work.

Inspection Risk: Training on the installation of drilled shafts, was conducted for all on-site inspection staff.

CONSTRUCTION

The overall risk mitigation strategy was passed from design to construction. The specified construction methods, along with extensive materials information provided in the project documents allowed the contractor to maintain a project schedule despite encountering challenging conditions which were both anticipated and unanticipated.

Installation Overview

The installations of secant piles were performed in accordance with the prequalification requirements and bid documents. Large top drive drill rigs (Figure 3) with the ability to deliver high torque and crowd were able to install segmental temporary casing in advance of the excavation over the entire drilled shaft length. The lead casings were outfitted with carbide tipped drill teeth allowing the tip of the casing to act like a core barrel. The sectional casing was able advance through obstructions and concrete from previously installed adjacent drilled shafts when installing Sequence Two drilled shafts.

Top Drive Drill

Placement of concrete was accomplished by the tremie concrete placement method. Both the tremie pipe and temporary casing remained embedded into the concrete throughout concrete placement.

Installation Sequence

In order to prevent disturbance of recently installed drilled shafts a minimum center to center spacing of 3.5 times the shaft diameter (D) was maintained. This spacing was increase periodically as dictated by localized subsurface. A sample sequence is shown in Figure 4 where the numbers represent which day a particular shaft was installed.

Inspection Risk: Training on the installation of drilled shafts, was conducted for all on-site inspection staff.

CHAPTER-6

Recommendations by osha

Introduction

The construction of underground tunnels, shafts, chambers, and passageways are essential yet dangerous activities. Working under reduced light conditions, difficult or limited access and egress, with the potential for exposure to air contaminants and the hazards of fire and explosion, underground construction workers face many dangers. To help employers protect the safety and health of underground construction workers, the Occupational Safety and Health Administration (OSHA) has prepared a number of guidance documents, including the underground construction regulations, found in Part 1926, section 800 of Title 29 of the Code of Federal Regulations (29 CFR 1926.800).

OSHA regulations relating to underground construction were originally adopted in 1971 and revised over the years to add new protective measures and enhance worker safety. This publication summarizes OSHA's regulations related to underground construction. As such, it should be used as a guide but not as a substitute for the complete text of 29 CFR 1926.800.

Construction operations covered by the OSHA standard

The OSHA underground construction regulation (29 CFR 1926.800) applies to the construction of underground tunnels, shafts, chambers, and passageways. It also applies to cut-and cover excavations connected to ongoing underground construction as well as those that create conditions characteristic of underground construction. These hazards include reduced natural ventilation and light, difficult and limited access and egress, exposure to air contaminants, fire, flooding, and explosion. The regulation does not apply to excavation and trenching operations for above ground structures that are not physically connected to an underground construction operation or to underground electrical transmission and distribution lines.

OSHA has developed the following definitions for construction activities that fall within the underground construction field:

A tunnel is "an excavation beneath the surface of the ground, the longer axis of which makes an angle not greater than 20 degrees to the horizontal."

A shaft is "(1) a passage made from the surface of the ground to a point underground, the longer axis of which makes an angle greater than 20 degrees to the horizontal; or (2) a pit in which there are employees, and it is foreseeable that they may enter (or do enter) the horizontal excavation; or (3) a pit that has typical underground construction hazards and is connected to a horizontal excavation."

Requirements of the OSHA standard

The underground construction standard covers many topics of concern to those who work in the challenging environment of underground construction. A sampling of items covered by the standard includes requirements for safe access and egress routes, employee training in hazard recognition, a "check-in/check-out" procedure, and emergency procedures. This booklet summarizes all requirements of the standard.

The standard provides some flexibility in methods to control workplace hazards in underground construction as long as appropriate precautions are taken to protect workers in a variety of situations. OSHA requires that a "competent person" be responsible for carrying out several requirements of the underground construction regulations. Situations that require intervention by a "competent person" are identified in the following sections.

The need for a "competent person"

The definition of a "competent person" in 29 CFR 1926.32 (f) is as follows: One who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Under Subpart S, Underground Construction, caissons, cofferdams, and compressed air, a competent person is responsible for inspecting and evaluating workplace conditions, including air monitoring and the presence of air contaminants, ground stability, and the drilling, hauling and hoisting of equipment, to identify and correct any deficiencies

Training requirements

All employees involved in underground construction must be trained to recognize and respond to hazards associated with this type of work. Training should be tailored to the specific requirements of the jobsite and include any unique issues or requirements.

The following topics should be part of an underground construction employee training program:

- Air monitoring and ventilation
- Illumination
- Communications
- Flood control
- Personal protective equipment
- Emergency procedures, including evacuation plans
- Check-in/check-out procedures
- Explosives
- Fire prevention and protection
- Mechanical equipment

Notification and communication requirements

Any time an employer receives a notification of a hazardous condition, all oncoming shifts must be notified of occurrences or conditions that either have affected or might affect their safety. Examples of this type of situation include equipment failures, earth or rockslides, cave-ins, flooding, fires, explosions, or release of gas.

The employer must also maintain open lines of communication with other employers at the worksite to ensure a rapid and complete exchange of information concerning events or situations that may impact worker safety. Employers must maintain lines of communication with employees during underground construction activities. To ensure effective communications are always available, communication systems must be tested upon initial entry of each shift to the underground and as often as necessary at a later time to ensure they are in working order. Powered communication systems must operate on an independent power supply and be installed so that the use of or disruption of any single communication device or signal location will not disrupt the operation of the system in any other location. If natural unassisted voice communication is ineffective at any time, a power-assisted means must be used to ensure communication between the work face, the bottom of the shaft, and the surface. In the case of an individual employee working alone underground in a hazardous location who is out of range of natural unassisted voice communication and not able to be observed by other employees, the employer must provide an effective means of obtaining assistance in the event of an emergency.All shafts being developed or used for personnel access or hoisting require two effective means of communication. In addition, hoist operators must have a closed-circuit voice communication system connected to each landing station, with speaker microphones located so that the operator can communicate with individual stations while the hoist is in use. (See the section on cranes and hoists later in this booklet for more specific information.)

Site control procedures

Check-in/check-out procedures

The employer must maintain a check-in/check-out procedure to ensure that above ground personnel maintain an accurate accounting of the number of persons underground and to prevent unauthorized persons from gaining access to the site. This is especially important in the event of an emergency but is a common sense requirement at all times. The only time this procedure is not required is when an underground construction project designed for human occupancy is completed to the point that permanent environmental controls are effective and any remaining construction activity does not have the potential to create an environmental hazard or structural failure in the construction area .Any time an employee is working underground, at least one designated person must be on duty above ground. This person is responsible for calling for immediate assistance and keeping an accurate count of employees who remain underground in the event of an emergency.

Control of access and egress

In addition to establishing a check-in/check-out procedure, the employer must ensure safe access to and egress from all workstations at the construction site to protect employees from potential hazards, such as being struck by excavators, haulage machines, or other moving equipment .To help control access, all unused openings, including chutes and man ways, must be tightly covered, bulk headed, barricaded, or fenced off, and posted with warning signs that read, "Keep Out" or similar language.

Ground support of portal and subsidence areas

Portal openings and access areas must be guarded by shoring, fencing, head walls, shot creting or equivalent protection to ensure that employees and equipment have a safe means to access these areas. Subsidence areas must be similarly guarded by shoring, filling in, or placing barricades and warning signs to prevent entry. Adjacent areas must be scaled or secured to prevent loose soil, rock, or fractured materials from endangering portal, subsidence, and access areas.

Ground support of underground areas

A competent person must inspect the roof, face, and walls of the work areas at the beginning of each shift and as often as necessary to ensure ground stability. The competent person tasked with such inspection responsibilities must be protected from loose ground by location, ground support, or equivalent means. The ground conditions along all haulage ways and travel ways must also be inspected as frequently as necessary to ensure safe passage and loose ground considered to be hazardous to employees must be scaled, supported, or taken down. A competent person must determine how often rock bolts need to be tested to ensure that they meet the necessary torque, taking into consideration ground conditions, distance from vibration sources, and the specific bolt system in use. Only torque wrenches should be used when torsion-dependent bolts are used for ground support.Employees involved in installing ground support systems must be adequately protected from the hazards of loose ground. The bottoms of any support sets installed must have sufficient anchorage to prevent ground pressures from dislodging the support base. Lateral bracing (including collar bracing, tie rods, or spreaders) must be provided between immediately adjacent sets to increase stability.Any dislodged or damaged ground supports that create a hazardous condition must be promptly repaired or replaced. The new supports must be installed before removing the damaged supports. Some type of support, such as a shield, must be used to maintain a safe travel way for employees working in dead-end areas ahead of any support replacement operations.

Ground support of shafts

Shafts and wells more than 5 feet in depth (1.53 m) entered by employees must be supported by steel casing, concrete pipe, timber, solid rock, or other suitable material. The full depth of the shaft must be supported except where it penetrates into solid rock that will not change as a result of exposure. Where the potential for shear exists, where the shaft passes through earth into solid rock in either direction, or where the shaft ends in solid rock, the casing or bracing must extend at least 5 feet (1.53 m) into the solid rock.The casing or bracing must also extend 42 (± 3) inches above ground level unless a standard railing is installed, the adjacent ground slopes away from the shaft collar, and barriers exist to prevent mobile equipment operating near the shaft from jumping over the bracing. If these conditions are met, the casing or bracing may be reduced to 12 inches above ground.

Fire prevention and control

In addition to the basic fire prevention and control guidance set forth in 29 CFR 1926 Subpart F, underground construction operations are subject to several specific requirements.Open flames and fires are prohibited in underground construction areas except as permitted for welding, cutting, or other hot work operations. Smoking is prohibited unless an area is free of fire and explosion hazards. Signage prohibiting smoking and open flames should be placed throughout work areas. Fire extinguishers of at least 4A:40B:C rating or equivalent extinguishing means must be available at the head and tail pulleys of underground belt conveyers. All underground structures and those within 100 feet (30.48 m) of an opening to the underground must be constructed of materials with a fire resistance rating of at least one hour. Also, no flammable or combustible material may be stored above ground within 100 feet (30.48 m) of any access point to an underground operation. If space limitations make this unfeasible, the material must be positioned as far as possible from the entrance with a fire resistant barrier that has at least a one-hour rating between the material and the opening.

Alternative precautionary measures may be adopted from industry practices used under similar working conditions or measures recommended under industry consensus standards. A site hazard analysis may be helpful to determine the effectiveness of precautionary measures. Any spill of flammable or combustible material must be cleaned up immediately.

Gasoline may not be underground at any time for any purpose due to its volatile qualities. Internal combustion engines (except diesel-powered engines on mobile equipment) are prohibited underground. Acetylene, liquefied petroleum gas, and methyl acetylene propadiene stabilized gas may be used underground for welding, cutting, and other hot work if all requirements of OSHA regulations pertaining to such activities are met. (See 29 CFR 1926 Subpart J and 29 CFR 1926.800(j)(k)(m)(n) for a complete explanation of these requirements.) Only enough fuel gas and oxygen cylinders for welding, cutting, or hot work during a 24-hour period are allowed underground. Noncombustible barriers must be installed below such activities if they are performed in or over a shaft or rise.Oil, grease, and diesel fuel stored underground must be kept in tightly sealed containers in fire-resistant areas at least 300 feet (91.44 m) from underground explosive magazines, and at least 100 feet (30.48 m) from shaft stations and steeply inclined passageways. Storage areas must be positioned or diked to ensure that if a container breaks open, any fluids will not flow out of the storage area. Any hydraulically-actuated underground machinery must use fire-resistant hydraulic fluids unless it is protected by a fire suppression system or multi-purpose fire extinguisher rated at least 4A:40B:C and of sufficient capacity for the type and size of equipment involved.

Several specific requirements apply to the use of diesel fuel in underground construction operations, as follows:

- A surface level tank holding diesel fuel to be pumped to an underground storage site must have a maximum capacity no greater than the amount of fuel required to supply underground equipment for 24 hours.
- A surface level tank must be connected to the underground fueling station by an acceptable pipe or hose system controlled at the surface by a valve and at the bottom by a hose nozzle.
- The transfer pipe must remain empty at all times except when transferring diesel fuel.
- All hoisting operations in the shaft must be suspended during refueling operations if the supply piping in the shaft is not protected from potential damage.

Ventilation requirements

Fresh air must be supplied to all underground work areas in sufficient amounts to prevent any dangerous or harmful accumulation of dusts, fumes, mists, vapors, or gases. If natural ventilation does not provide the necessary air quality through sufficient air volume and air flow, the employer must provide mechanical ventilation to ensure that each employee working underground has at least 200 cubic feet (5.7m3) of fresh air per minute.When performing work that is likely to produce dust, fumes, mists, vapors, or gases (such as blasting or rock drilling), the linear velocity of air flow in the tunnel bore, shafts, and all other underground work areas must be at least 30 feet (9.15 m) per minute. When such operations are complete, the ventilation systems must exhaust smoke and fumes to the outside atmosphere before resuming work in all affected areas. When drilling rock or concrete, dust control measures such as wet drilling, vacuum collectors, and water mix spray systems must be used to maintain dust levels within limits set in 29 CFR 1926.55, which includes gases, vapors, fumes, dusts, and mists.The direction of mechanical airflow must be reversible but ventilation doors must be designed and installed to remain closed when in use, regardless of the direction of the airflow. If the ventilation system has been shut down and all employees are removed from the underground area, only competent persons authorized to test for air contaminants may be allowed underground until the ventilation system has been restored and all affected areas have tested at acceptable limits for air contaminants.

Illumination requirements

As in all construction operations, OSHA requires that proper illumination be provided during tunneling operations (see 29 CFR 1926.56 for details). When explosives are handled, only acceptable portable lighting equipment may be used within 50 feet of any underground heading. For general tunneling operations, a minimum illumination intensity of 5 foot-candles must be maintained, although 10 foot candles must be provided for shaft heading during drilling, mucking, and scaling.

Special air monitoring requirements

The employer must assign a "competent person" to perform air monitoring. If this individual determines that air contaminants may present a danger to life at any time, the employer must immediately take all necessary precautions and post a notice at all entrances to the underground site about the hazardous condition. In performing air monitoring duties, the competent person must take into consideration the location of the jobsite (its proximity to fuel tanks, sewers, gas lines, etc.); the geology of the site, including soil type and permeability; the history of the site and the construction operation (changes in levels of substances monitored over time); and work practices at the jobsite (use of diesel engines, explosives, and fuel gas; hot work, welding, and cutting; and the physical reactions of employees to working underground.

Test for oxygen first

The competent person charged with air monitoring must test for oxygen content before testing for air contaminants. All underground work areas must be tested as often as necessary to verify that the atmosphere at normal atmospheric pressure remains within the acceptable parameters of 19.5 and 22 percent oxygen. After verifying oxygen levels, the competent person must test all underground work areas for carbon monoxide, nitrogen dioxide, hydrogen sulfide, and other toxic gases, dusts, vapors, mists, and fumes as often as necessary to ensure that levels remain within permissible exposure limits (see 29 CFR 1926.55 for detailed information on these limits).

Testing for methane and other flammable gases

The competent person must also test all underground work areas for methane and other flammable gases to determine whether the operation must be classified as potentially gassy or gassy. If the atmosphere meets the criteria for these designations, the precautions listed in the section discussing gassy or potentially gassy operations later in this booklet must be followed. Other precautions to take when testing for methane or other flammable gases include:

- If 20 percent or more of the lower explosive limit for methane or other flammable gases is detected in any underground work area or in the air return, all employees must be evacuated to a safe location above ground (except those employees required to eliminate the hazard). Electrical power (except for acceptable pumping and ventilation equipment) must be cut off to the area until concentrations reach less than 20 percent of the lower explosive limit.

- If 10 percent or more of the lower explosive limit for methane gas or other flammable gases is detected near any welding, cutting, or other hot work, the work must be suspended until the concentration is reduced to below 10 percent of the lower explosive limit.
- When 5 percent or more of the lower explosive limit for methane or other flammable gases is detected in an underground work area or in the air return, steps should be taken to increase ventilation air volume or otherwise control the gas concentration (unless all requirements of operating under potentially gassy or gassy operations are met).

Hydrogen sulfide levels

When air monitoring reveals the presence of 5 ppm or more of hydrogen sulfide, the affected underground areas must be tested at the beginning and midpoint of each shift until the concentration is measured at less than 5 ppm for three consecutive days. Employees must be notified if hydrogen sulfide is detected in amounts exceeding 10 ppm and a continuous sampling and indicating monitor must be used to keep track of levels. If the concentration of hydrogen sulfide reaches 20 ppm, the monitor must be designed to provide both visual and audible alarms to warn that additional measures (respirator use, increased ventilation, evacuation) may be appropriate.

Special conditions for drilling and blasting underground

Before initiating any drilling operation underground, a "competent person" must inspect all drilling and associated equipment as well as the drilling area and correct any hazards. Employees are not allowed on a drill mast when a drill bit is in operation or a drill machine is being moved. Also, when moving a drill machine, all associated equipment and tools must be secured and the mast placed in a safe position.

Working on or around jumbo decks involves special safety precautions, including the following:

- Locate all receptacles or racks to store drill steel on jumbos.
- Warn employees working below jumbo decks when drilling is about to begin.
- The top deck of a jumbo must have a mechanical way to lift unwieldy or heavy items.
- Only employees assisting the operator may ride on the jumbo unless it is equipped with seating for each passenger and protection from crushing or catching hazards.
- Jumbo decks more than 10 feet high must be equipped with guardrails on all open sides unless an adjacent surface provides fall protection. Jumbo decks and stair treads must be slip resistant, secured, and maintained to prevent slip, trip, and fall hazards.
- Jumbos must be chocked so they will not move when employees are working on them.

Whenever an underground blasting operation in a shaft is complete, a "competent person" must check the air quality and make sure that no walls, ladders, timbers, blocking, and wedges have been loosened as a result of the activity. If repairs are required, only employees involved in repair activity may be in or below affected areas until repairs are complete. All blasting wires must be kept clear of electrical lines, pipes, rails and other conductive material (except earth), to prevent explosions or exposure of employees to electric current.

Special requirements for using cranes and hoists underground

The OSHA standard has provisions for the use of cranes or hoists that are unique to underground construction. In addition to provisions that apply to all construction activities using cranes or hoists (29 CFR 1926.550 and 29 CFR 1926.552), cranes used in underground construction must be equipped with a limit switch to prevent over travel at the top and bottom of the hoist way. The limit switch should only be used when operational controls malfunction. Hoist controls must be arranged so the operator can reach all controls and the emergency power cutoff without reaching beyond his/her normal operating position.

Underground hoists must be designed to allow powering of the hoist drum in both directions and so that brakes are automatically applied upon power release or failure. The hoist operator must have a closed-circuit voice communication system with speaker microphones to communicate with individual landing stations. Also, hoists must be equipped with landing level indicators (marking the hoist rope is not adequate) and fire extinguishers (rated at least 2A:10B:C) in each hoist house.

Before using a hoist that has been out of operation for a complete shift or after repair or service, the operator must test run the equipment and correct any unsafe conditions before use. Inspections and load testing to 100 percent of capacity must be performed at least annually and after any repairs or alterations affecting the structural integrity of the hoist.

For material hoists, wire rope used in load lines must support at least five times the maximum intended load or the factor recommended by the rope manufacturer, whichever is greater. Personnel hoists must have at least two means to stop the load, each able to stop and hold 150 percent of the hoists' rated line pull. For personnel hoisting, a broken-rope safety, safety catch, or arrestment device are not adequate means of stopping.

Other aspects of hoist safety that apply to underground construction include:

- Employees may not ride on top of any cage, skip, or bucket unless inspecting or maintaining the system and wearing a safety belt or harness.
- Personnel and materials must be hoisted separately (except small tools and supplies secured in a nonhazardous manner).
- When sinking shafts 75 feet (22.86 m) or less, cages, skips, and buckets that may swing, bump, or snag against shaft sides must be guided by fenders, rails, ropes, or a combination. If the shaft is more than 75 feet, hoisted objects must be rope- or rail guided for the full length of travel.

Additional safety requirements for personnel hoists in underground operations include:

- The operator must be able to see and hear signals at the operator's station.
- All cages must be equipped with a steel-plate protective canopy that slopes to the outside and can be pushed up for emergency egress and have a locking door that opens only inward.
- The sides of personnel cages must be enclosed by 1/2 inch wire mesh to a height of at least 6 feet (1.83 m). If the cage is being used as a work platform and is not in motion, the sides may be reduced to 42 inches (1.07 m).

During sinking operations in shafts where guides and safeties are not used, the personnel platform may not exceed 200 feet (60.96 m) per minute and governors must be used during personnel hoisting. The speed may increase to 600 feet (182.88 m) per minute when guides and safeties are us **Potential hazards that require special precautions**

Emergency procedures

Whenever an employee is working underground at least one designated person must be on duty above ground, responsible for maintaining an accurate count of the number of employees underground and summoning emergency aid if needed. Every employee working underground must have a portable hand lamp or cap lamp for emergency use unless natural light or an emergency lighting system provides adequate illumination for escape. Employers must provide self-rescuers approved by the National Institute for Occupational Safety and Health (NIOSH) in all underground work areas where employees might be trapped by smoke or gas. (See CFR 1926.103 for more information.)

If 25 or more employees work underground at one time, the employer must provide at least two 5-person rescue teams, one at the jobsite or within 30 minutes travel time from the entry point to the site and the other team within two hours travel time. If less than 25 employees work underground, the employer must have one 5-person rescue team at the jobsite or within 30 minutes travel time. In both situations, advance arrangements can be made for local rescue services to meet this requirement. Rescue team members must be trained in rescue procedures, the use and limitations of breathing apparatus, and the use of firefighting equipment with qualifications reviewed annually. When flammable or noxious gases are anticipated at a jobsite, rescue teams must practice using self-contained breathing apparatus once a month. The rescue teams must be available through the duration of a construction project.

If a shaft is used as the means of egress, the employer must arrange for a readily available power-assisted hoisting capability in case of emergency, unless the regular hoisting means will function in the event of a power failure.

Recordkeeping requirements

Records of all air quality tests must be maintained above ground at the worksite and be available on request to the Secretary of Labor or his or her representative. The record must include the location, date, time, substance and amount monitored. Records of exposures to toxic substances must be kept for 30 years. (See 29 CFR 1910.1020 for more detailed information on access to employee exposure and medical records.) All other air quality test records must be retained until the project is complete. Inspection certification records for all hoist equipment indicating the date of the most recent inspection and load-test, the signature of the person performing the inspection and test, and a serial number or other identifier for the hoist must be maintained on file until the project is complete.

OSHA assistance

OSHA can provide extensive help through a variety of programs, including technical assistance about effective safety and health programs, state plans, workplace consultations, voluntary protection programs, strategic partnerships, and training and education, and more. An overall commitment to workplace safety and health can add value to your business, to your workplace, and to your life.

Safety and health management system guidelines

Effective management of worker safety and health protection is a decisive factor in reducing the extent and severity of work-related injuries and illnesses and their related costs. To assist employers and employees in developing effective safety and health programs, OSHA published recommended Safety and Health Program Management Guidelines (Federal Register 54 (16): 3904-3916, January 26, 1989). These voluntary guidelines can be applied to all places of employment covered by OSHA.

The guidelines identify four general elements critical to the development of a successful safety and health management system:

- Management leadership and employee involvement.
- Worksite analysis.
- Hazard prevention and control.
- Safety and health training.

CHAPTER-7

CONCLUSION-.

This plan provides core guidance on actions necessary for all emergency situations with could cause hazard to life or property from accidental causes.The major emergency is defined as one which may affect one or several areas of the site and may cause serious injuries, loss of containment or environmental impacts and may require the help of outside resources in addition to our own to handle it effective. This thesis contains the observations and recommendations according to the existing emergency management plan of the company i.e SHE PLAN 22.12.07 C1 in such a manner so as to take immediate action by various groups to meet and control the critical situation within shortest period with minimum loss of Material, Machine and Property & also to minimize the loss of personnel injuries. The report started by walk through survey and site inspection followed by reviewing the emergency management according to the SHE PLAN of the company. Observations of hazards are recorded and control measures and recommendations are given.

KEY POINTS OF REPORT-

- Consideration of rock mechanics
- Careful excavation
- Maintenance of rock strength, avoidance of loosening and over-breaks
- Continuous control by geo-mechanical instrumentation and monitoring systems
- Installation of support system without delay in the correct sequence
- Usage of proper PPEs

References

[1] Hughes, W. Roles in construction projects: Analysis & Terminology, A Research Report undertaken for the Joint ContractsTribunalLimited,JCT,2000.

[2] Smith, N. J. Managing Risk in Construction Project, BlackwellScience,Oxford,1999.

[3] Wu, S.; Fleming, A.; Aouad, G. and Cooper, R.G. The Development of the Process Protocol Mapping Methodology and Tool, International Postgraduate Research in the Built and HumanEnvironment,2001.

[4] Kolltveit, B. J.; Grønhaug, K. The Importance of the Early Phase: The Case of Construction and Building Projects // International JournalofProjectManagement,Vol.22, 2004 pp.545-551.

[5] Godfrey,P.S.;Sir Halcrow,W;Partners Ltd Control Of Risk- A Guide to the Systematic Management of Risk from Construction,CIRIA,1996.

[6] RAMP Risk Analysis and Managements for Projects, 2nd ed. Thomas Telford ooks,2005.

[7] Ceri ,A.A Framework for Process-Driven Risk Management in Construction Projects, PhD Thesis, Research Institute for the Built& Human Environment, School of Construction and PropertyManagement,UniversityofSalford,Salford,2003.

[8] Hendrickson, C.; Au, T. Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects and Builders. Upper Saddle River, New Jersey: PrenticeHall,1989.

[9] Evans, J. R.; Olson, D. L. Introduction to simulation and risk analysis,PrenticeHall,1998.

[10 Vose, D. Risk Analysis :A Quantitative Guide, John Wiley & Sons Ltd ,2000.

ANNEXURE-

10 - Confined Spaces					
No.	Item Addressed	Compliant			Comments
		Y	N	N/A	
1	Is a confined space entry permit in place, displayed, valid with method statement and risk assessment in place?	yes			
2	Is the appointed person in charge/entry supervisor in place and located at the work location and hold a good understanding of the permit requirements?	yes			
3	Is the confined space adequately barricaded and signed to warn of the hazards? i.e. "DANGER - No entry to unauthorised personnel"	yes			
4	Has a system been introduced to control access/egress within the confined space and an attendant in place to supervise this process?	yes			
5	Is suitable access installed, where practical, to and from the confined space?	yes			
6	Where applicable, has lock-out/tag-out been performed to isolate energised sources within the confined space?	yes			
7	Where identified on the permit, has gas detection been utilised within the confined space both prior to entry and during the work?	yes			
8	Have all employees been trained and briefed each day on the confined space hazards and risks by a competent person?	yes			
9	Is all equipment (i.e. PPE, hand tools etc.) used to perform the work in the confined space in good condition?	yes			
10	Have adequate emergency provisions been installed to rescue personnel within the confined space?	yes			

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23 - Excavations					
No.	Item Addressed	Compliant			Comments
		Y	N	N/A	
1	Is an excavation permit displayed/available at the work location and is it valid and in date?	yes			
2	Has the excavation been inspected by a competent person that day and is that inspection recorded formally and displayed at the work site?	yes			
3	Has the excavation been clearly signed to warn those working around the area? i.e. "Warning - Deep Excavation"	yes			
4	Have suitable barricades been installed around the excavation? i.e. physical barrier for vehicles; soft barrier for pedestrians;	yes			
5	Are all barricades kept at least 1.8m from the edge of the excavation?	yes			
6	Is soil removed from the excavation kept at a suitable distance away from the edge of the excavation? i.e. at least same width away as depth of excavation	yes			
7	Is the excavation in general good condition with no evidence of cracks/minor collapse of material?	yes			
8	Have excavations deeper than 1.2m been designed to prevent collapse? i.e. use of sloping/benching/stepping	yes			
9	If adequate sloping/benching/stepping is not possible, have the use of trench boxes been used to protect workers from collapse?	yes			
10	Has sufficient access been provided to/from the excavation? i.e. access through barricades; access points every 25ft within excavation	yes			