WorkCover
NEW SOUTH WALES

TUNNELS
UNDER CONSTRUCTION

CODE OF PRACTICE 2006

WorkCover. **Watching out for you.**

New South Wales Government

CONTENTS

WHAT IS AN INDUSTRY CODE OF PRACTICE?

An approved industry code of practice is a practical guide to employers and others who have duties under the *Occupational Health and Safety Act 2000* (the OHS Act) and the *Occupational Health and Safety Regulation 2001* (the OHS Regulation) for achieving the standard of safety required by the OHS Act and OHS Regulation for a particular area of work.

An approved industry code of practice should be followed unless there is an alternative course of action that achieves the same or better standard of health and safety in the workplace.

An industry code of practice is approved by the Minister for Commerce. It takes effect on the day specified in the code or, if no day is specified, on the day it is published in the *NSW Government Gazette*.

An approved industry code of practice may be amended from time to time (or it may be revoked) by publication in the gazette.

An approved industry code of practice is designed to be used in conjunction with the OHS Act and the OHS Regulation but does not have the same legal force. An approved industry code of practice is advisory rather than mandatory. However, in legal proceedings under the OHS Act or the OHS Regulation, failure to observe a relevant approved industry code of practice can be used as evidence that a person or company has contravened or failed to comply with the provisions of the OHS Act or OHS Regulation.

A WorkCover NSW inspector can cite an approved industry code of practice in a direction, or in an improvement or prohibition notice, indicating the measures that should be taken to remedy an alleged contravention or non-compliance with the OHS Act or the OHS Regulation. Failure to comply with a requirement in an improvement or prohibition notice is an offence.

In summary, an approved industry code of practice:

- gives practical guidance on how the required standard of health, safety and welfare can be achieved in an area of work
- should be followed, unless there is an alternative course of action that achieves the same or better standard of health and safety in the workplace
- can be used in support of the preventive enforcement provisions of the OHS Act or OHS Regulation
- can be used to support prosecutions for failing to comply with or contravening the OHS Act or OHS Regulation.

FOREWORD

This code of practice replaces the *1990 Code of practice for tunnels under construction*, which commenced on 7 June 1991.

WHAT IS THE AIM OF THIS CODE OF PRACTICE?

The code gives practical advice on how to decide on appropriate measures to eliminate or control the OHS risks that may arise in the course of tunnel construction. In doing this it provides guidance to employers in the industry on implementing the requirements of the OHS Act and the OHS Regulation, which should be read in conjunction with this code of practice.

WHAT IS THIS CODE OF PRACTICE ABOUT?

The code explains the processes involved in the systematic management of OHS risks and outlines how to apply a risk management approach to the hazards commonly encountered in tunnel construction in NSW. It is intended to help in identifying the hazards, determining how serious the risks from those hazards are and implementing the most effective means of eliminating or controlling those risks.

WHO IS THIS CODE OF PRACTICE FOR?

The code is principally aimed at employers, employees, self-employed persons, principal contractors and subcontractors, but is also intended to assist others involved in the process such as clients and tunnel designers. The code is not intended to be applied in the construction of mines.

WHEN TO USE THIS INFORMATION

The provisions of this code should be considered during the tendering phase, as well as the planning and preparation stages for carrying out the work. The code outlines regulatory requirements (under the OHS Act and OHS Regulation), as well as safety recommendations that may need to be factored into these processes. To effectively implement the code, employers need to be aware of these requirements and have procedures in place to apply them.

WHAT DO THE SYMBOLS IN THE CODE OF PRACTICE MEAN?

The following symbols are used in the text to highlight things you need to take into account and to help you work out what to do and the tools you require to do the job.

Assess the risks in your workplace

Consult and communicate with employees

Tools that can help you work out your plan

Legal obligations that must be followed

The process of finding things that cause harm, working out how big a problem they are, and then fixing them

CHAPTER 1 – ESTABLISHMENT

1.1 Title

This is the *Code of practice for tunnels under construction.*

1.2 Purpose

The purpose of this code of practice is to provide practical guidance on the prevention of illness and injury to persons engaged in, and affected by, construction of tunnels and associated construction works in NSW.

This code provides practical guidance on implementing the requirements of the OHS Act and the OHS Regulation and promotes consultation and cooperation between employers, employees, principal contractors and subcontractors and/or their representatives.

In terms of the relationship and relevance of the WorkCover 'Excavation code' to tunnelling work, it is noted that, although involving some initial excavation work, tunnelling work is almost entirely underground work and is not the primary focus of the excavation code. Accordingly, for those involved in tunnel works the WorkCover *Code of practice: Tunnels under construction* is intended to be the primary guidance document.

1.3 Scope

This code of practice applies to employers, employees, self-employed persons, principal contractors, subcontractors and visitors to workplaces across NSW, whose work involves, includes or is in connection with the construction of tunnels (including mined cut and cover excavations and associated construction works).

This code does not apply to mines within the meaning of the *Coal Mines Regulation Act 1982* and the *Mines Inspection Act 1901*.

1.4 Commencement

This code of practice will take effect on and from 17 November 2006.

1.5 Authority

This is an industry code of practice approved by the Minister for Commerce under section 43 of the Act on the recommendation of the WorkCover Authority of New South Wales (WorkCover NSW).

1.6 Repeal of 1990 code of practice

This code of practice replaces the *1990 Code of Practice: Tunnels under construction*, which commenced on 7 June 1991. The 1990 code is revoked under section 45 of the OHS Act and is replaced by this code.

1.7 Interpretation

Recommended practices

Words such as 'should' indicate recommended courses of action. 'Consider' indicates a possible course of action that the code is suggesting the duty holder consider. However, you may choose an alternative and equally effective or better method of achieving safe workplaces.

1.8 Legal requirements

Words such as 'must', 'requires' or 'mandatory' indicates that legal requirements exist that must be complied with.

1.9 Definitions

The following terms are used in this code of practice with these meanings:

client means any person who commissions design work for a tunnel construction.

Note: the client and owner of the place of work for the purposes of clause 210 of the OHS Regulation (re the appointment of the principal contractor) are often one and the same entity.

competent person for any task means a person who has acquired through training, qualification or experience, or a combination of these, the knowledge and skills to carry out that task.

contractor means a principal contractor or subcontractor.

controller of premises means a person who has control of premises used by people as a place of work, including:

- a person who has only limited control of the premises
- a person who has, under any contract or lease, an obligation to maintain or repair the premises (in which case any duty imposed on a controller under the OHS Act or OHS Regulation applies only to the matters over which the person has control).

designer includes designers of buildings, structures (including tunnels), whether permanent or temporary, or plant whether intended for use by themselves or others.

employee means an individual who works under a contract of employment or apprenticeship.

employer means a person who employs persons under contracts of employment or apprenticeship.

Note: Unless the context implies otherwise, employer also includes self-employed persons.

high risk construction work means all categories of work listed in clause 209 of the OHS Regulation and includes construction work in tunnels.

incident means any incident prescribed in clauses 341 and 344 of the OHS Regulation.

noise	includes sound and vibration.
OHS management plan	means a site specific plan that includes: • a statement listing names, positions and responsibilities of all persons who will have specific responsibilities on the site for occupational health and safety (OHS) • the arrangements for ensuring OHS induction training • the arrangements for managing OHS and safety incidents • site safety rules and the manner of communication of the rules to all persons at the site • safe work method statements for relevant work activities.
owner	means a person who is the owner of a place of work who is required by clause 210 of the OHS Regulation to appoint a principal contractor. For the purposes of clause 210 of the OHS Regulation, owner has the same meaning as in the *Local Government Act 1993* (see below for definition of owner in the *Local Government Act 1993*).
owner (definition of owner in the *Local Government Act 1993*)	(a) in relation to Crown land, means the Crown and includes: (i) a lessee of land from the Crown, and (ii) a person to whom the Crown has lawfully contracted to sell the land but in respect of which the purchase price or other consideration for the sale has not been received by the Crown, and (b) in relation to land other than Crown land, includes: (i) every person who jointly or severally, whether at law or in equity, is entitled to the land for any estate of freehold in possession, and (ii) every such person who is entitled to receive, or is in receipt of, or if the land were let to a tenant would be entitled to receive, the rents and profits of the land, whether as beneficial owner, trustee, mortgagee in possession, or otherwise, and (iii) in the case of land that is the subject of a strata scheme under the *Strata Schemes (Freehold Development) Act 1973* or the *Strata Schemes (Leasehold Development) Act 1986*, the owners corporation for that scheme constituted under the *Strata Schemes Management Act 1996*, and (iv) in the case of land that is a community, precinct or neighbourhood parcel within the meaning of the *Community Land Development Act 1989*, the association for the parcel, and (v) every person who by this Act is taken to be the owner, and (c) in relation to land subject to a mining lease under the *Mining Act 1992*, includes the holder of the lease, and (d) in Part 2 of Chapter 7, in relation to a building, means the owner of the building or the owner of the land on which the building is erected.

personal protective equipment (PPE)	means any equipment or substance (such as sun protection cream) used to protect health and safety.
principal contractor	in relation to construction work (or a construction project involving construction work) means a person who is, under clause 210 of the OHS Regulation, for the time being appointed or taken to be the principal contractor for the construction work. Where construction work is being undertaken and the owner has not appointed a principal contractor, the owner is taken to be the principal contractor for the construction work. Principal contractors have special duties under the OHS Regulation. The principal contractor is usually the main contractor/contractor undertaking the construction works.
safe work method statement (SWMS)	means a statement that: • describes how work is to be carried out • identifies the work activities assessed as having safety risks • identifies the safety risks • describes the control measures that will be applied to the work activities and includes a description of the equipment used in the work, the standards or codes to be complied with, the qualifications of the personnel doing the work and the training required to do the work.
subcontractor	means a person who has a sub-contract with the principal contractor to carry out work in accordance with a subcontract.
self-employed person	means a person who works for gain or reward otherwise than under a contract of employment or apprenticeship, whether or not employing others.
WorkCover NSW	means the WorkCover Authority of New South Wales established by section 14 of the *Workplace Injury Management and Workers Compensation Act 1998*.

CHAPTER 2 – A SYSTEMATIC APPROACH TO MANAGING RISKS IN UNDERGROUND CONSTRUCTION

2.1 Overview

The OHS Act and the OHS Regulation place responsibilities on a number of parties in relation to ensuring workplace health and safety.

The following is an overview of the responsibilities of particular individuals or corporations involved in construction work, the application of risk management principles and requirements for consultation and coordination.

The way to systematically plan and manage health and safety in the workplace is to build risk management and consultation into all those activities that may have OHS implications. This will include activities such as purchasing, work methods or procedures, using contractors, reporting OHS problems, investigating incidents and planning emergency procedures.

The provisions of this code should be considered during the tendering phase as well as the planning and preparation stages for carrying out the work. The code outlines regulatory requirements (under the OHS Act and Regulation) as well as safety recommendations that may need to be factored into these processes. To effectively implement this code, employers need to be aware of these requirements and have procedures in place to apply them.

For full details of legal obligations, the OHS Act and the OHS Regulation need to be consulted.

2.2 Understanding responsibilities

2.2.1 Clients

The client's responsibilities under the OHS Act and OHS Regulation will depend on their role in the tunnel design and construction. Clients are in a key position to influence the safe construction of the project. This is because they usually develop the concept design for the tunnel and engage the contractor (the contractor is usually also appointed as the principal contractor under the OHS Regulation) to undertake the construction of the tunnel.

Many aspects of the tunnel that influence the safe construction of a tunnel, such as the need to tunnel in soft ground, are set in place in the concept design. Accordingly, the client should consider these issues at the concept-design stage. The client is also in the best position to influence others to ensure that issues relating to safe construction and maintenance are considered at the design stage and therefore to reduce construction and ongoing operation and maintenance risks. Setting realistic timeframes for tendering, planning and project execution can also assist planning and execution of construction work.

However, the client is not always aware of all the complexities, such as the range of construction techniques, ground conditions and their effect on safety. It is therefore often appropriate for communication to occur between the client and other parties at an early stage to ensure coordination so as to take advantage of the opportunity to identify the best concept design in terms of OHS outcomes. It also allows for a better understanding of the extent of geotechnical investigation required, estimate of likely time needed to prepare a tender offer, construction time and areas of potential delay.

Whilst written for building construction, the WorkCover NSW publication *Construction Hazard Assessment Implication Review (CHAIR)* provides useful guidance.

Through the contract documents, the client is able to require that occupational health and safety plans are implemented during construction to ensure that safe working practices are employed. It would be appropriate for clients to include such a requirement and specifically reference this code of practice in contract documents.

The client, depending on the contractual arrangements, can improve the information flow between the various contractors, especially in relation to the health and safety aspects of the design, and require that relevant records developed during the course of design and construction are made available to the persons responsible for the ongoing operation and maintenance of the tunnel.

2.2.2 Controllers of work premises, plant or substances

Controllers of work premises, plant or substances have health and safety legal responsibilities under the OHS Act and OHS Regulation. They must make sure that the premises used as a place of work as well as the plant and substances used in the work process are safe and without risks to health when properly used. For persons who have only limited control of the premises, plant or substances, their responsibilities apply only to the matters over which they have control.

2.2.3 Designers

Designers should ensure that:

(a) to the extent that they have control over a particular section of design work, the structure (or plant) can be safely erected, used, repaired, cleaned, maintained, demolished or abandoned, such that the health and safety of any person is not put at risk by the design,

(b) information is provided to the client about the health and safety aspects of the design,

(c) the tunnel design includes a conceptual construction method statement and risk assessment.

Designers should also ensure that, as far as practicable, hazards associated with the following are identified before commencement of the construction work (Refer to Section 2.3):

(i) the design of the structure (whether permanent or temporary)

(ii) systems of work required to construct, repair and maintain the structure

(iii) the intended use of the structure

(iv) materials required to be used in the construction of the structure, or

(v) the demolition or abandonment of the structure.

Note: In relation to the design of plant, the OHS Regulation contains detailed risk control measures applicable to designers, manufacturers and suppliers of plant.

Where there is more than one designer, critical aspects of the project should be documented and liaison carried out between the client, principal contractor and the relevant designers so that the work can be coordinated to ensure the safe interaction of the different design aspects.

When risks remain in the design work, information should be included with the design to alert others to the risks.

The designer should document the assumed geotechnical conditions used in their design to enable exposed conditions to be compared against the design assumptions as the tunnelling progresses. This allows for monitoring of the conditions and a reassessment of the design where the geotechnical conditions are found to differ from those assumed in the design. This applies to plant likely to be affected by such a change, as well as the tunnel and associated ground support systems.

2.2.4 Principal contractors

The principal contractor, whether an employer or the person in control of the workplace, must provide and maintain, in relation to those matters over which they have control, a workplace that is safe and without risks to health for its employees and other persons present at the workplace or affected by the work. To fulfil these obligations the principal contractor must plan for the work to be done safely.

The principal contractor must ensure that a site-specific OHS management plan is prepared and documented for each place of work where construction work is to be carried out, before the work commences (see Section 3.8.1). This plan must be developed in consultation with the subcontractor(s) and their employees or representatives. The plan must include safe work method statements, provided by the subcontractors where they are used, for all work activities assessed as having risks. It must also include the following details:

- arrangements for OHS induction training
- arrangements for managing OHS incidents, including response persons
- site-safety rules and arrangements for informing persons affected
- details where persons have specific site OHS responsibilities.

The site-specific OHS management plan must be monitored to ensure that work is carried out safely according to that plan, and that the plan is effective. The plan must be maintained and kept up to date during the course of the construction work, and must be made available for inspection to any person working at the site and to any person about to commence work at the site, employee members of the OHS committee and OHS representatives. The principal contractor must stop work immediately, or as soon as it is safe to do so, where there is a risk to the health or safety of a person.

2.2.5 Subcontractors

The subcontractor(s) doing the work must provide and maintain a workplace that is safe and without risks to health for their employees in relation to those matters over which they have control.

In addition to coordination with the principal contractor in the overall job planning, each subcontractor must develop written safe work method statements, including an assessment of the risks and the controls used to carry out the work safely. Safe work method statements must be provided to the Principal Contractor (Clause 229(2)). A subcontractor must not allow an employee to carry out construction work unless the employee has completed the required induction training.

2.2.6 Employers

Under the OHS Act and the OHS Regulation, employers have an obligation to ensure the health, safety and welfare of employees at work and that other people at the workplace are not exposed to risks to their health and safety. When contracting out work, employers must ensure that contractors are planning and carrying out work in a safe manner and according to the requirements of the OHS Act and OHS Regulation, and this code of practice.

Employers must ensure that any employee employed to carry out construction work has been provided with the required OHS induction training.

The provisions of this code should also be considered during the tendering phase, as well as the planning and preparation stages for carrying out the work. This code outlines regulatory requirements (under the OHS Act and OHS Regulation), as well as safety recommendations that may need to be factored into these processes. To effectively implement this code, employers need to be aware of these requirements and have procedures in place to apply them.

Employers are advised to consult the OHS Act and the OHS Regulation, as well as the following WorkCover NSW publications, for details of their obligations and how they can be met:

- *Code of practice for OHS consultation*
- *Code of practice for risk assessment*
- *Guide: Risk Management at Work.*

2.2.7 Employees

Employees must take reasonable care of the health and safety of themselves and others. Employees must cooperate with employers in their efforts to comply with occupational health and safety requirements. This means that employees must notify their employer of safety and security hazards, risks and incidents, in line with the requirements of the OHS Act. These requirements should be outlined by the employer's OHS policy, procedures and safety-related instructions.

Employees must not be required to pay for anything done or provided to meet specific requirements made under the OHS Act or OHS Regulation.

2.2.8 Self-employed persons

Self-employed persons must ensure that their undertakings do not expose others to health or safety risks.

2.2.9 Coordination of responsibilities

There may be a number of parties involved in a tunnelling project, such as the following:

- the client
- the principal contractor
- controllers of premises, plant or substances
- designers
- employers (principal contractor or subcontractors) who employ persons at the site, including labour hire agencies providing persons to the site
- self-employed persons
- suppliers of plant, materials or prefabricated components
- manufacturers of plant.

Where more than one party has responsibilities at a specific workplace, each party retains their legal responsibilities and must discharge their responsibilities in a coordinated manner.

2.3 Consultation and risk management

The OHS Act and the OHS Regulation require employers to address workplace health and safety through a process of consultation and risk management.

The way to systematically plan and manage health and safety in the workplace is to build risk management and consultation into all those activities that may have OHS implications. This will include activities such as purchasing, work methods or procedures, using contractors, reporting OHS problems, investigating incidents and planning emergency procedures.

2.3.1 Consultation arrangements

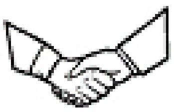
In order to consult with employees, employers are required to set up consultation arrangements and develop and implement consultation procedures.

The OHS Act provides three methods of consultation, which can be used in combination:

- OHS committee
- OHS representatives
- other agreed arrangements.

When the consultation arrangements have been decided, employers are required to record them and advise all existing and new employees of the arrangements.

2.3.2 When should consultation be undertaken?



After setting up the consultation arrangements, employers need to consider when and how these consultation arrangements need to be applied.

Employers are required to consult their employees when decisions are being considered that may affect the employees' health, safety or welfare. These include:

- assessing, reviewing and monitoring risks to health and safety
- eliminating or controlling risks to health and safety
- planning for new premises or modifying existing premises
- purchasing new plant, equipment or substances
- planning, designing or changing work tasks or jobs
- determining or reviewing workplace amenities
- determining or reviewing consultation arrangements.

Other decisions which could also affect health and safety include the following:

- coordination and communication with subcontractors in the workplace
- investigating incidents or accidents
- developing emergency procedures.

Note: Any procedures that are developed to encompass these activities should incorporate consultation. It may not be practical or reasonable to involve the OHS committee or the OHS representative in every purchase decision or task change, however the OHS committee or OHS representative must be consulted on what process is used to ensure that affected employees are consulted.

2.3.3 How should consultation be undertaken?

When engaged in consultation, Section 14 of the OHS Act requires employers to:

- share all relevant information with employees eg if an employer is going to change a work task, employees need to be told of any risk to health and safety that may arise and what will be done to eliminate or control these risks
- give employees reasonable time to express their views – employees need adequate time to assess the information given to them, obtain relevant safety information and consult with fellow employees to enable them to form their views
- value the views of employees and take them into account when the decision is made to resolve the matter – in many cases, agreement will be reached on how the safety issues are to be addressed. When agreement cannot be reached, the employer should explain how the employees' concerns have been addressed.

2.3.4 Managing risks in the workplace

Employers and self-employed persons must identify any foreseeable hazards, assess their risks and take action to eliminate or control them.

A hazard identification and risk assessment process must be carried out at the planning and preparation stage by the person doing the work to determine what risks may arise when the work is being carried out. Safe systems of work must then be put in place to eliminate or control these risks. For tunnel construction work, the safe system of work must also be documented by each subcontractor in safe work method statements.

2.3.5 Hierarchy of control measures

For each risk identified, control measures must be considered in the following order, starting with (a) first. Each risk identified must be minimised to the lowest level reasonably practicable:

(a) The first obligation is to eliminate risk eg choose a different construction method.
Elimination gives the best level of safety and must be adopted unless it is not reasonably practicable. Where elimination is not reasonably practicable, risk must be minimised to the lowest level reasonably practicable by applying controls in the order (b) to (e).

(b) Substitute the hazard giving rise to the risk with a hazard that gives rise to a lesser risk.
For example, redesign the work process so that less hazardous equipment, materials or substances are used; use less toxic chemicals or less flammable substances; have products packaged in smaller quantities if lifting them poses risks.

(c) Isolate the hazard from the person put at risk.
For example, set up a restricted work area; reduce emissions and noise from machinery through venting and containment or isolation barriers.

(d) Minimise the risk by engineering means.
For example, ensure that exposed moving parts on equipment are adequately guarded and lockout devices are fitted; reduce noise levels from machinery by installing dampening methods like mufflers; look for better safety design features on equipment.

(e) Minimise the risk by administrative means.
For example, organising the way tasks are done can sometimes reduce exposure to risks; job rotation and task variety can reduce the risks associated with repetitive manual handling tasks; provide appropriate safety training, instruction or information; use written safe work procedures; develop preventative maintenance schedules to identify and fix faulty machinery, use hazard warning signs.

(f) Use personal protective equipment (PPE).
For example, use safety eyewear and footwear, hearing protective earplugs or muffs, safety helmets, respirators. PPE is the least preferred solution to OHS problems because it does not really address the hazard but merely provides a shield to protect the worker. However, in some cases, it may be the only practicable means.

This hierarchy provides a basis for determining the most appropriate control measures when discussing and developing your safety plans. There may be cases where no single control measure is sufficient and a combination of control measures will be required. Those at a higher level have greater ability to reduce risk and greater reliability. Administrative control measures require regular monitoring to ensure they are used. Training of workers about each control measure is needed so that workers know how to implement them.

The control measures recommended by a subcontractor should be considered by the principal contractor as part of the OHS management plan. Any new control measures should be evaluated to ensure that they are effective and safe and that new hazards created (directly or indirectly) by them are also controlled.

2.3.6 Monitor and review risk assessments and control measures

Clause 12 of the OHS Regulation states that employers must review a risk assessment and any measures adopted to control a risk, whenever:

(a) there is evidence that the risk assessment is no longer valid

(b) an injury or illness results from exposure to a hazard to which the risk assessment relates, or

(c) a significant change is planned to the place of work, work practices or work procedures to which the risk assessment relates.

CHAPTER 3 – DESIGN FOR SAFE TUNNEL CONSTRUCTION

3.1 Overview

The design of tunnels differs significantly from the design of plant and other structures due to the difficulty of ascertaining accurate geological properties and the potential variability of these properties along the tunnel. Thus, the design is based on less reliable material property assumptions than most other designs.

To reduce the risk resulting from this material property uncertainty and variability:

- existing geological information should be reviewed and a site investigation undertaken to confirm the existing information and obtain more specific local geological information as per Section 3.2
- the design should specify the geological conditions assumed in the design, including the relevant issues listed in Section 3.2
- an inspection plan should be developed in order to compare the actual geological conditions as the excavation progresses with the assumed conditions as per Section 3.6
- procedures should be implemented to assess the implications of any such differences and to reassess the adequacy of the design of the tunnel and ground support before the differences constitute a risk to health and safety – this may include ceasing relevant work while the reassessment is being conducted. See section 3.7.

3.2 Site investigation

The safety of tunnelling works depends on adequate investigation of the ground and site before construction commences, and proper interpretation of the information obtained. Designers should be provided with all available relevant information and should be involved in the data acquisition for the site investigation program. This may include on-site involvement during the site investigation.

The nature, scope and extent of site investigations should be based on the nature, scope and extent of the project, its location, environments and the proposed tunnel design. It should be planned to provide sufficient information on site conditions, ground and groundwater conditions, previous history and constraints, and to enable realistic assessments of different tunnelling methodologies and designs.

The site investigation should be carried out by suitably qualified and experienced personnel, competent in conducting investigations of similar ground conditions for the range of methodologies being considered.

The following types of study may need to be included in the site investigation:

- topography, geology and hydrology
- location, condition and influence of existing structures, services and old workings and planned future works in the area
- climate and prevailing weather conditions, including seasonal variations
- drilling of boreholes or examining existing borehole results
- assessment of properties of soils and rock, including collection of samples and laboratory testing
- geophysical investigation
- underground survey
- structural survey
- groundwater tests – location, volume and effects on, or resulting from, tunnelling
- blasting trials.

The site investigation will provide information that can assist in the geotechnical risk assessment of ground and other conditions. This should take into consideration at least the following:

- rock mass geology
- planes of weakness
- mechanical properties of soil and rock, planes and 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 response (movement)
- possible effects on other working places or installations
- groundwater presence and quantity
- possible contaminated environments – whether by gases, liquids or solids, including contamination of the groundwater, eg chemical plumes
- previous relevant experience and historical data for the area.

3.3 Tunnel design

The design stage offers the opportunity for hazards to be eliminated or, where this is not reasonably practicable, be minimised to the lowest level reasonably practicable in design. See 2.3.5. The concept design, the information obtained from the site investigation and the anticipated excavation methods should be considered in preparing a design for the tunnel.

The design should include details on the tunnel dimensions and allowable excavation tolerances, the design support and lining requirements for each location within the tunnel and any other requirements for the finished tunnel. The design should also include details for the temporary support, if designed at this stage, or at least the support methods assumed in the design. It should also include information on the excavation methods and ground conditions, including anticipated tunnel deformations, considered in the design. This will allow the design to be reviewed should another excavation or support method be chosen or the actual ground conditions change as the excavation proceeds. See section 3.7.

3.4 Design review for construction

This initial tunnel design, referred to in Section 3.3 above, should be reviewed for construction, usually by or in consultation with the tunnelling principal contractor, to take into account any construction needs.

The tunnel design, assumed construction needs, or both may need to be amended to produce a buildable design. This review should consider a range of construction issues, such as the excavation and support installation methods, additional excavation for temporary access, ventilation, spoil removal, refuges, rail sidings, and loadings from roof mounted spoil conveyors and ventilation systems.

As well as amending the tunnel design itself, the design review should produce at least concept designs for ground support systems and construction systems such as ventilation, electrical, water, compressed air, access and materials handling. These systems should be fully designed before excavation commences.

The interdependence of the tunnel design, the chosen construction methods and the ground and environmental conditions are critical and need to be constantly monitored (or addressed). Consequently, continuity in engineering practices at the stages of planning, investigation, design and construction are desirable. This is more effectively achieved by the involvement of a single organisation throughout. If, however, there is a change in the engineering direction of the works, a way should be devised to ensure that the essential continuity is maintained and that the total planning, design and construction process is not fragmented.

3.5 Ground support design

Most tunnels and open excavations require some form of permanent ground support, which should be specified in the tunnel design referred to in Section 3.3 above.

Excavation of material causes changes in stress in the surrounding soil or rock that may reduce the capacity of the soil and rock to support itself. Varying geological conditions mean that control measures that have worked previously may not be satisfactory for a current situation.

A risk assessment should be undertaken into the construction phase, as temporary ground support may be needed in addition to, or in advance of, the proposed permanent ground support. Where persons are required to work under unsupported ground, eg for the manual installation of the support, they should be protected by an adequate overhead protection structure.

Ground support systems include engineering issues that involve both structural design and soil/rock mechanics. The use of ground support that is designed for the unique circumstances of the current situation is essential to control the risk of a collapse or tunnel support failure. Consequently, a variety of support systems may need to be developed in advance to cater for the expected range of conditions to be encountered.

Design specifications for engineering controls, such as shoring support structures, should be prepared by a competent person in accordance with relevant Australian Standards, codes and legislative requirements.

3.6 Ventilation system design

The ventilation system must be designed to provide adequate levels of ventilation (refer to Section 5.3 and Appendix 5) throughout the tunnel during construction. The ventilation should include the provision for additional localised ventilation to deal with ground gases, production of dust, heat or fumes from the excavation process, operation of large plant or other activities such as maintenance.

The design should allow for the need to install ventilation as the tunnelling progresses to maintain ventilation to the face.

3.7 Inspection plans, assessment and reporting procedures

Excavation work, whether a tunnel or an open excavation, must be inspected at regular intervals to ensure that the excavation and its supporting systems are stable and intact to ensure the safety of work proceeding.

The risk assessment must be used to determine an inspection plan, including the frequency, scope of the inspections, and appropriate competencies of the person(s) undertaking the inspections. The inspection frequency, whether based on time or face advance, should take into account the delay due to the assessment and reporting procedures established, so that any identified issues are dealt with before presenting a risk to safety.

Assessment and reporting procedures should be developed in conjunction with the inspection plan, prior to the commencement of excavation on the relevant section of the project.

These procedures should include the competencies for the person(s) conducting the assessment and reporting paths for routine reporting and urgent reporting where the inspection information is assessed as requiring modification to the ground support requirements or otherwise reveals an apparent risk to safety. The procedures should also include reporting procedures for the excavation crew to report urgent matters they identify during excavation.

Where the assessment is to be conducted by the same person(s) undertaking the inspections, the urgent reporting procedures should include provision of advice directly to the person in control of the excavation work.

The assessment and reporting procedures may include the use of hold points and 'approval(s) to excavate', but should not prevent the installation of additional support should the excavation crew determine it is needed.

The procedure should include a formal process for approval of any assessment recommendation to reduce the support from that currently in use. This should apply even at locations where the design specifications include a change to reduced support.

The inspection plan and assessment and reporting procedures should be reviewed based on the results of the inspections and assessments, or after collapses or falls of materials, support failure or adverse weather conditions.

The following activities should be considered for inclusion in the inspection plan:

- mapping and visual assessment of the actual ground conditions and excavated shape as exposed by the tunnel excavation
- monitoring support performance, including:
    - support failures, if any, including during installation
    - evidence of excessive load on supports
    - falls or fretting of ground
- monitoring of time based deterioration such as spalling or slaking eg weathering from temperature changes, humidity changes or exposure to air
- monitoring ground water inflows
- tunnel deformations eg by installing extensometers or by regular survey
- anchor or pull out tests on supports
- core tests of rock
- measuring in-situ ground stresses.

Additional considerations for open excavations include:

- excavated and other material being placed within the zone of influence of the excavation
- machinery operating within the zone of influence of excavations causing weight and vibration influences
- surface soil falling into the excavation
- water seeping into excavations from its side walls or base
- changes to soil and/or weather conditions
- surface water or run-off entering the excavations or accumulating on surface near the excavation
- subsidence alongside the excavations.

Further guidance concerning excavation work on construction sites may be obtained by referring to the WorkCover NSW *Code of practice: excavation*. The trench or excavation may be a confined space and if so the requirements of the OHS Regulation must be observed (Clauses 66-78). Guidance can be found in *AS 2865 – Safe working in a confined space.*

3.8 Site-specific planning and preparation

3.8.1 OHS management plan

The principal contractor must ensure that a site-specific occupational health and safety management plan is prepared for each place of work at which the construction work is to be carried out before the work commences, and that the plan is maintained and kept up to date during the course of the work.

The principal contractor must provide sub-contactors with a copy of the relevant parts of the plan and should also ensure that sub-contractors are briefed as to the contents of the plan and understand the risks they may be exposed to.

The plan must include the following:

- the OHS responsibilities of specified people or positions
- the arrangements for ensuring OHS induction training
- the arrangements for managing OHS and safety incidents
- site safety rules and the manner of communication of rules to all persons at the site
- safe work method statements for relevant work activities.

The effective communication of this information is critical at the worksite. Valuable information should be exchanged between outgoing shifts and incoming shifts about the status of the work being performed, the state of the workplace, any changes to work methods required, any relevant safety information or other issues that exist at the workplace.

All workplaces should be thoroughly inspected by the incoming shift to ensure that the place is safe for work to commence.

The OHS Act places an obligation on employers and self-employed persons to provide all necessary supervision to ensure safety. This will mean that those persons with OHS responsibilities outlined in the OHS plan should have the necessary authority to perform and implement their supervisory obligations.

3.8.2 Safe work method statements

Clause 227 of the OHS Regulation requires safe work method statements (SWMSs) where the cost of the work undertaken exceeds $250,000, or for high-risk construction work where the cost does not exceed $250,000. Construction work in tunnels is one category of high-risk construction work, so tunnelling work requires SWMSs for all work activities assessed as having safety risks.

The SWMS:

- describes how the work is to be carried out
- identifies the work activities assessed as having safety risks
- identifies the safety risks
- describes the control measures that will be applied to the work activities, and
- includes a description of the equipment used in the work, the standards or codes to be complied with, the qualifications of the personnel doing the work and the training required to do the work.

A SWMS should show the work method in a logical sequence. The hazards associated with each process should be identified, and the measures for controlling these hazards specified.

Break down each job into a series of basic job steps to identify the hazards and potential accidents in each part of the job. The description of the process should not be so broad that it leaves out activities with the potential to cause accidents and prevents proper identification of the hazards.

The SWMS could also be used to nominate the competencies, and the number of employees and items of plant required to safely perform the task(s), together with any permits and licences required under the OHS Regulation. Where this is the case, it may be useful to provide copies of such documents and training records with the SWMS.

Employees should be involved and consulted during the development and implementation of any SWMS. All persons involved in carrying out the work should understand the SWMS before commencing the work.

3.8.3 Communication systems

Good communication throughout the construction site is fundamental to the safety and efficiency of all aspects of a tunnel project, in particular to the passing of information and instructions, the monitoring of systems and the control of operations such as lifting; transporting persons, materials and plant; coordinating maintenance and managing emergencies.

The communication system should link major workplaces, tunnel portal and face(s), or shaft top and bottom, site offices and safety critical locations on site (eg first aid room or emergency control room or dedicated mobile phone or two-way radio that is permanently attended whilst persons are underground). Means of contacting the emergency services from the site should be available and operational at all times.

A risk assessment should determine whether communication with all mobile vehicles, including personnel transporters, is required. Where electronic communication (non voice) methods are being relied upon, the point of communication reception (eg control room) should be monitored at all times by personnel who have received training in the implementation of the emergency action plan.

For a small and simple job employing few people, unaided voice communication may be adequate. However, consider the need for electronic signalling systems, such as telephones, radios and CCTV for effective safety communication. The communications system may need to accommodate the communication of information on a variety of safety-related items, such as machine-condition monitoring, instrumentation monitoring, atmospheric monitoring and fire alarms.

Means should be available whereby the person in charge of a workplace can communicate requirements for materials and equipment, and raise the alarm and receive instructions in the event of an emergency. The system adopted should depend on the size and length of the tunnel, the number of persons in the tunnel, the system of tunnelling employed and its potential hazards, including the speed of operations.

A system of signalling by bells or by coloured lights can be appropriate for routine communications, such as controlling train movements or requesting that lining segments or other materials be sent forward. Details of any signal code adopted, whether audible or visual, should be communicated effectively to all affected by the operations under way – eg at the top and bottom of each shaft or incline, and in clear view of the plant operator.

The communication system should be independent of the tunnel power supply and installed so that destruction of one unit or the occurrence of a collapse will not interrupt the use of the other units in the system. All wiring, especially that used to transmit warnings in an emergency, should be protected. All communication cables needed to transmit warnings in an emergency should have increased integrity under emergency conditions, such as fire, water or mechanical shock, and a back up communication system should be considered for critical locations.

At all working shafts, a standby means of communication should be available. This should be able to be operated from any position throughout the depth of the shaft.

The codes for both audible and visual signals, as well as call signs and channel allocation should be displayed at strategic locations for all operators. In the case of shafts, this applies to the banksmen, winch and hoist drivers, and all those working in or about the shaft itself.

3.8.4 Amenities

Clause 18 of the OHS Regulation requires that employers ensure that appropriate amenities are available for all of the employer's employees while they are at work. To determine the appropriateness of amenities, employers must take into account matters such as the nature of the work undertaken, the size and location of the place of work, and the number of persons at the place of work.

Employers must also ensure that any amenities provided for workers are maintained in a safe and healthy condition.

The WorkCover NSW *Code of practice: Amenities for construction work* provides details of amenities requirements.

3.8.5 Personal protective equipment (PPE)

The use of PPE to control risks is lowest on the hierarchy of control measures listed earlier (see Section 2.3.5). The measures at the lower levels are less effective and they require more frequent reviews of the hazards and systems of work. They should only be used when other control measures are impracticable or when a residual risk remains after implementing other controls.

PPE selection and suitability

Where PPE is to be used, it should be appropriate for the risk and conform with the relevant Australian Standard. Employees should be competent in the proper selection, use and maintenance of the PPE. There should be sufficient supervision and monitoring conducted to ensure PPE is used and employees are competent in its use. PPE should be regularly inspected, maintained and replaced as necessary.

Clothing for protection

Where there is a risk that workers may be exposed to chemicals or contaminated environments, they should wear clothing for protection against chemicals that conform to the relevant Australian Standards.

Eye protection

Dust, flying objects and sunlight are the most common sources of eye damage in excavation work.

Where persons are carrying out cutting, grinding or chipping of concrete or metal, or welding they should be provided with eye protection that conforms to *AS/NZS 1337: Eye Protectors for Industrial Applications.* Eye protection that conforms to AS/NZS 1337 should also be provided where persons carry out other work, such as carpentry or handling of chemicals, where there is a risk of eye injury. Selection, use and management systems should conform to *AS/NZS 1336: Recommended Practices for Occupational Eye Protection.*

For tunnelling activities, such as rock drilling, rock cutting, concreting, service installing, steelwork and plant maintenance, the risk assessment would reasonably be expected to identify a heightened risk of eye injury, and thus require eye protection to be used at all times.

Some above ground works will require eye protection for the above reasons and/or as protection from sunlight UV radiation.

Fall-arrest equipment

Harnesses and other fall arrest equipment should be provided where persons are exposed to the risk of a fall when working at height. Such equipment should be selected, used and maintained in accordance with *AS/NZS 1891.4: Industrial Fall-arrest Systems and Devices – Part 4: Selection Use and Maintenance.*

Hearing protection

Where personal hearing protection is provided it should conform with *AS 1270: Acoustics – Hearing Protectors.* Control measures including training should conform to *AS/NZS 1269.3: Occupational Noise Management – Hearing Protector Program.*

High visibility garments/safety reflective vests

Persons working underground or near traffic, mobile plant or equipment under operator control, should be provided with and use high visibility garments. Such garments should be selected, used and maintained in accordance with *AS/NZS 4602: High Visibility Safety Garments.* Other clothing not covered by the high visibility garment should be light coloured and all garments should be selected for best contrast with the surrounding background.

Respiratory protective equipment

Where persons could be exposed to harmful atmospheric contaminants, such as silica dust or welding fumes, respiratory protective equipment that conforms to *AS/NZS 1716: Respiratory Protective Devices* must be used (providing it is within the performance capability of the PPE). Such equipment should be selected and utilised in accordance with *AS/NZS 1715: Selection, use and maintenance of Respiratory Protective Devices.*

Note: These standards do not apply to environments where there is an oxygen deficiency due to the presence of asphyxiant gases.

Footwear

Persons working on tunnel construction should wear safety footwear that conforms to *AS 2210: Occupational Protective Footwear.* Staff working on broken ground should wear footwear that gives ankle support and metatarsal (arch) protection.

Safety helmets

The use of safety helmets may prevent or lessen a head injury from falling objects or a person hitting their head against something. Where there is a likelihood of persons being injured by falling objects, and overhead protection is not provided, persons must be provided with, and must use, an appropriate safety helmet. Appropriate safety helmets should also be provided and used where a person may strike their head against a fixed or protruding object, or where there is a risk of accidental head contact with electrical hazards.

All persons on excavation sites should wear head protection that conforms to *AS/NZS 1801: Occupational Protective Helmets* and be used in accordance with *AS/NZS 1800: Occupational Protective Helmets – Selection, care and use.*

Safety gloves

Where there is a risk of hand injury, such as exposure to a harmful substance, excessive heat or cold, or to a mechanical device, hand protection appropriate to the risk and that conforms to *AS/NZS 2161: Occupational Protective Gloves* should be provided and used.

Self rescuers

Self rescuers provide the user sufficient oxygen to walk to the surface, the next cache of self rescuers or designated sealable oxygen equipped refuge. They are used in emergencies, such as fire, when the tunnel atmosphere is depleted of oxygen or has levels of contamination beyond the capacity of the respiratory protective equipment provided.

Waterproof clothing

Waterproof clothing provided as a system of work relating to weather or site conditions should be effective and suitable for the task. Waterproof clothing should also incorporate light reflective features in accordance with the requirements of the section above.

3.8.6 Hazard and incident reporting

A system to report health and safety hazards and incidents should be established. Hazards and OHS problems should be reported as soon as they are noticed so that the risks can be assessed and addressed as quickly as possible. Records of reported hazards should be kept and should include details of the action taken to remove the hazard or control the risk arising from the hazard.

The OHS Act and OHS Regulation also prescribe a number of requirements concerning incident and injury reporting. Refer to the WorkCover NSW website for further details.

3.8.7 First aid

Clause 20 of the OHS Regulation requires employers and self-employed persons to provide first aid facilities that are adequate for the immediate treatment of injuries and illnesses that may arise at the place of work and, if more than 25 people are employed, trained first aid personnel.

To ensure adequate first aid provisions, employers and self-employed persons must identify their potential problems, assess their requirements and consult with employees in the process.

When determining the nature, number and location of first aid facilities, and the number of trained first aid personnel, employers must take into account the location and type of work being undertaken. The type of work performed will influence the hazards and the possible harmful consequences for employees. For example, office workers will have different first aid requirements from construction workers. Workplaces using hazardous substances may require specialised first aid facilities, such as eyewash stations and emergency showers. The risk assessment process will assist in identifying the particular needs of the workplace.

Where a first aid room is required, it must only contain equipment or articles, and must only be used, for first aid or occupational health and safety purposes.

For further information regarding matters such as contents of first aid kits, who qualifies as 'trained first aid personnel', and other requirements relating to first aid rooms, consult the OHS Regulation or WorkCover NSW's *First Aid in the Workplace Guide 2001.*

3.8.8 Emergency response

Clause 17 of the OHS Regulation specifies that an employer and self-employed person must ensure that, in the event of an emergency at the workplace, arrangements have been made for:

(a) the shutting down and evacuation of persons from the place of work, and

(b) emergency communications, and

(c) appropriate medical treatment of injured persons.

Employers and self-employed persons must also ensure that details of the arrangements for any such evacuation are to be kept on display in an appropriate location(s) at the place of work and that one or more persons are appointed and trained to oversee any such evacuation and, if appropriate, in the use of onsite fire fighting equipment.

Types of emergencies considered should include the following:

- treatment and evacuation of a seriously injured person
- fire underground eg a tunnel-boring machine (TBM)
- sudden flooding eg inrush from above or from an underground water feature
- underground explosion eg ignition of methane inrush
- tunnel collapse, resulting in persons being trapped
- power failure
- above ground emergency that compromises tunnel safety eg fire or chemical spill.

Controls that employers should consider in relation to emergency response include:

- providing a system to identify who is underground, such as a tag board
- developing site emergency procedures, appropriate for the level of risk, including establishing an emergency assembly area and a plan for contacting, and subsequently interacting with, emergency services
- provision of emergency response equipment and training in its use
- provision of control measures to reduce the severity of the emergency eg self-closing bulkheads to control water inrush
- providing self rescuers, breathing apparatus and sealable, self contained atmosphere refuges as well as instruction in their use.

3.8.9 Fire and explosion

Clause 62 of the OHS Regulation states that employers must control risks associated with fire and explosion.

Fire in the underground workplace is of particular concern, as the rapid production of noxious fumes and gases makes the severity of this risk extreme.

Controls that employers should consider when implementing fire prevention procedures include the following:

- eliminating activities that could generate flammable or explosive atmospheres, or control such generation by providing adequate ventilation. This could include gas monitoring when excavating in strata suspected of containing ground gas.
- eliminating potential ignition sources, such as naked flames, hot work (eg welding, cutting and grinding), electrical equipment and sources of static electricity, near flammable substances, dusts or waste materials.

  Note: battery recharging stations are potential sources of both flammable gas and ignition. When tunnelling in known gas strata this may include the use of intrinsically safe electrical equipment.
- removing unnecessary flammable substances, dusts or waste regularly.

- providing an appropriate number and type of fire extinguishers strategically located around the site (including flammable goods storage areas)
- instructing persons working underground in the correct usage of fire extinguishers and fire control underground
- highlight fire extinguishers, fire hoses, fire blankets and hydrants so that they are easily identifiable, and give clear access
- providing flammable goods storage areas, identified with appropriate warning signs
- managing hot work close to dry vegetation by the removal, covering or regular wetting of the vegetation.

3.8.10 Record keeping

The OHS Regulation requires records to be kept for induction training, hazardous substances, safe work method statements, confined spaces, plant, electricity, asbestos, atmospheric monitoring and notification of injuries. Refer to the relevant chapters of the OHS Regulation for further information.

Keeping other relevant health and safety records assists in effective risk management. These could include the following:

- subcontractor monthly reports
- risk assessments
- geotechnical reports
- inspection reports
- health and safety workplace inspection reports
- minutes of safety meetings/site meetings
- incident/accident investigation reports
- hazard reports
- non-conformance reports
- site instructions and diary notes.

3.8.11 Existing services

Before starting the work, the location of any underground services (eg gas, water, sewer, electricity, telecommunication cables, etc) should be identified and marked. Wherever service plans are available they should be obtained by the principal contractor and provided to the subcontractor and operator carrying out the excavation work. Contact the online service plan request provider at **www.dialbeforeyoudig.com.au** or by phone on 1100.

The subcontractor carrying out the work should allow for inaccuracies and the possibility of other unknown or hidden services. This may be assisted by:

- contacting organisations that can assist in locating underground services
- using remote location devices
- using gas detectors

- being alert for signs of disturbed ground eg change in material (sand in clay), warning tape or pavers during excavation.

Persons whose work may be affected by an underground service should be advised of the location of the underground services. Appropriate control measures should be implemented after consultation with relevant service providers. These measures may include the protection, support, disconnection or removal of services to ensure safety of workers.

For underground electrical services that have not been removed or de-energised, hand excavation in the vicinity should only be undertaken after consultation with the service owner and determination of appropriate controls, considering the voltage, level of insulation provided and local conditions. Controls may include using tools with non-conductive handles, wearing rubber boots and wearing insulating gloves that conform to *AS2225 – Insulating gloves for electrical purposes.*

Gas lines that have been disconnected should be 'blown down' to remove residual gas prior to commencing work.

3.8.12 Access

When conducting a risk assessment in connection with safe access and egress to, from and within the work place, the following should be included:

- the layout and condition of the premises (including the presence of any confined spaces)
- the physical working environment, including the potential for people slipping, tripping or falling, and objects or structures falling on people
- controlling the risks to visitors eg contractors, drivers and other people coming into the work site. Also see Site Security, section 3.8.13
- controlling access in areas with moving plant
- emergency access requirements – see section 3.8.8.

An assessment of access requirements should also take into account the number of persons using particular access points, and any tools and equipment that may be required to be carried to or from the work site. Ensuring safe access includes considering a number of other factors, such as lighting, ramps, walkways, stairways, scaffolding and ladders.

Access hazards include wet or oily floors or surfaces, untidy work areas, cluttered passageways, steep or slippery steps and stairs, exposure to plant and poorly-lit work areas.

Control measures that might be introduced include the following:

- installing overhead and fall protection
- storing materials and plant
- keeping work areas and passageways clear and free of obstructions
- removing rubbish, including construction waste and excavated material
- providing handrails
- introducing traffic and plant controls
- erecting safety fences and warning signs.

3.8.13 Site security

Clause 235 of the Regulation states that the site is to be secured by perimeter fencing, unless a risk assessment identifies that isolation of hazards at the site can be achieved by other means and such means are provided. The Regulation (Clause 174ZT) also states that access to any dangerous goods and any unauthorised activities on site must be prevented.

Signs are to be erected around the site, clearly visible from outside the site, showing the name and contact telephone number (including after-hours emergency number) of the principal contractor or subcontractor.

Additional consideration should be given to securing hazards at the site from access by authorised visitors eg delivery drivers or persons attending meetings. The following control measures should be considered:

- locating offices, parking and delivery areas away from hazardous areas
- isolating the hazardous area, such as fall zones, sediment ponds and electrical apparatus, with perimeter fencing, barricades, screens, barriers, handrails and/or covers, to prevent unauthorised access
- visitor tags, tag in and out or logged security card access for specific areas
- removing or lowering ladders when not in use
- immobilising plant to prevent unauthorised use
- installing hazard warning lights, signs, markers or flags
- using security guards
- installing night lighting
- locking fuel dispensers.

CHAPTER 4 – TRAINING, INSTRUCTION, INFORMATION AND SUPERVISION

The OHS Act requires employers and self-employed workers to provide such information, instruction, training and supervision as may be necessary to ensure the health, safety and welfare of their employees while at work.

In addition, some activities are restricted to persons holding the relevant certificate of competency – eg erecting scaffolds and operating cranes and some load-shifting equipment. See the OHS Regulation or the WorkCover NSW publication *Industrial Certification Manual* for a full list of such activities.

4.1 Induction training

The OHS Regulation (Clause 213) requires that employees employed to carry out construction work receive OHS induction training, including general health and safety induction training, work activity based induction training and site specific induction training, and that the training cover the topics set out in the WorkCover NSW *Code of practice: Occupational health and safety induction training for construction work 1998.*

Clause 13 of the OHS Regulation requires that each new employee receives induction training that covers:

(a) arrangements at the place of work for the management of occupational health and safety, including arrangements for reporting hazards to management

(b) health and safety procedures at the place of work relevant to the employee, including the use and maintenance of risk control measures

(c) how employees can access any health and safety information that the employer is required to make available to employees

(d) any other matter that the Regulation specifies should be the subject of induction training. The induction training shall be relevant to the place of work concerned, having regard to the competence, experience and age of the new employee.

Also see provisions contained in section 4.4.

4.2 Training topics

Training should draw on a knowledge of the known hazards and risks in your operations, including matters described in this code of practice. The source of risks should be pointed out and the adverse outcomes that have been experienced by others should be used to stress the importance of safety.

The content of health and safety training should be tailored to suit the particular work activities and conditions of the workplace and should be based on the risk assessments being carried out.

The training provided and the instruction given should at least include the following:

- all safe work methods to be used on the job, including matters described in this code of practice – ie all hazards, risks and control measures for control of underground hazards, including gases, atmospheric contaminants and ventilation, ground support and tunnel plant

- all information and procedures relevant to controlling risks (this may include regular updated geotechnical risks and controls)
- dust, gas and fire risks that may be present and the controls adopted, including procedures to follow if equipment, such as dust extraction, fails
- the correct use, care and storage in accordance with the manufacturer's recommendations or Australian standards (where appropriate) of plant and associated equipment, personal protective equipment and tools
- how to observe any administrative controls, such as restrictions on entry and warning signs
- emergency and evacuation procedures, including recognising the fire alarm, fire fighting measures, the location of fire fighting equipment and other emergency equipment, the use of fall arrest equipment, confined spaces entry procedures, and the rescue of entrapped persons.

4.3 Who should receive training?

The target groups for training at a workplace include the following:

- managers and supervisors of employees and/or other persons undertaking the tunnelling work who are considered at risk of injury and/or have responsibility for implementing safe operating procedures
- members of OHS committees and OHS representative(s)
- staff responsible for the purchasing and maintenance of plant, PPE and for designing, scheduling and organising work activities
- persons undertaking risk assessments or preparing SWMSs
- employees and subcontractors undertaking the tunnelling work, including employees of labour hire organisations.

The needs of each target group are different and the content and methods of presenting training material should be tailored to meet the specific needs of each group.

4.4 Provision of information and instruction

Information may include the following (refer to OHS Regulation Clause 13):

- the results of any applicable risk assessment
- safe work method statements
- a review of risk assessments and/or safe work method statements or operating procedures
- use and maintenance instructions for plant and PPE
- any other relevant OHS information.

Employers should brief each employee as to the contents of risk assessments and safe work method statements when each employee and/or other person first begins to perform tunnelling work, at regular intervals thereafter, and whenever there are changes to risk assessments or new information about health and safety risks becomes available.

Employees and other workers should have, on request, ready access to risk assessments and safe work method statements.

4.5 Supervision

Employers must ensure that employees are provided with such supervision as may be necessary to ensure the health and safety of the employees and any other persons at the employer's workplace. Supervision must be undertaken by a competent person and should take into account the competence, experience and age of each employee.

Supervision is essential to ensure that control measures are applied and safe work method statements are followed.

CHAPTER 5 – MANAGING RISKS DURING TUNNELLING

The principal contractor and subcontractors have an obligation under the OHS Act to provide and maintain a workplace that is safe and without risks to health for their employees and others in relation to those matters over which they have control.

Control measures to prevent persons being injured during all stages of the tunnel construction and fit out must be provided and maintained as part of a safe system of work.

5.1 Risk controls in common tunnelling methods and activities

The common hazards and areas of potential risk in most, if not all, tunnels under construction are closely related to, or exacerbated by, the confines of the underground workplace. They include the following:

- tunnel stability – rock or earth falls and rock bursts
- changing conditions – strata and stress field fluctuations
- limited space and access
- level of expertise – even long-term tunnellers may lack experience in certain specialised aspects or methods
- air contamination or oxygen depletion
- fire or explosion
- the use and maintenance of fixed and mobile plant
- close proximity to electrical supplies and circuits
- use of compressed air and high pressure hydraulics
- projected particles from rock breaking, drilling or cutting
- manual handling
- large scale materials handling, spoil out, and materials and equipment
- uneven surfaces
- wet or other slippery surfaces
- heights
- falling objects
- overhead seepage, ground and process water
- ground gas or water inrush
- contaminated groundwater
- reduced visibility
- loss of power, including lighting and ventilation
- noise levels
- vibration
- hazardous substances and dangerous goods.

For further information on some of these common hazards see section 5.5.

The systems of work and control measures selected are generally determined by individual job factors identified in the consultation and risk assessment process.

The following table outlines common hazards, risks and control measures. This may be used to identify some of the common workplace hazards.

Common tunnelling and excavation activities	
Examples of specific hazards or risks	**Example risk control measures**
Rock falls	• More frequent inspection and scaling • Mechanical scaling and bolting • Mark out bolting pattern by laser survey • Timely installation of ground support • Change ground support methods/density • Overhead protection whilst installing ground support manually
Failure of floor or roadway	• Concrete the floor/roadway
High water inflow	• Grout old drill holes • Injection grouting ahead of the face • Probe drill and drain • Pumping from surface bores
Scaling	• Mechanical equipment • Work from elevating work platform basket • Overhead protection
Gas inrush	• Probe drill hazard areas through check valves • Wet drilling and gas monitoring • Increased face extraction ventilation
Falls from height	• Maintenance platforms with guardrails • Fall arrest • PPE
Moving plant	• Planned vehicle movement procedures • Isolate moving plant from pedestrians • Operator to ensure clear path before moving • Stop plant, pedestrians to walk past • Restrict access • Provide lighting
Loss of lighting	• Emergency lighting and cap lamps

Common tunnelling and excavation activities	
Examples of specific hazards or risks	**Example risk control measures**
Manual handling, eg handling air tools, drill rods, supports, cutters, grout.	• Engineering assessment of tasks • Use mechanical equipment with automatic feed • Use lifting aids • Team lifting • Select light weight rock drills, smaller bags • Use vibration insulation on handles
Heat stress	• Increase ventilation • More frequent rests and cool water • Cool suits • Reduce use of high heat output equipment
Noise	• Insulation of plant • Hearing protection
Dust	• Increase face extraction ventilation • Water sprays on cutting equipment or over muck heaps and spoil conveyors

5.1.1 Excavation methods

The site investigation, including geotechnical investigations and risk assessment, the tunnel design, access limitations and other local factors should be used to establish the appropriate excavation methods. It is usual for a number of different excavation methods to be used on a single project.

The tunnel design will usually assume particular excavation and support methods, but other methods may be used provided they are confirmed as not compromising the safety of the tunnel.

The methods of excavation should permit the designed ground support to be installed as planned, and allow for the installation of additional ground support should ground conditions be found to be worse than considered in the design.

Factors to include in determining appropriate excavation methods would include the following:

- the tunnel design, including the dimensions, shape, excavation tolerance of the excavation, and the tunnel support and lining design
- the expertise of the contractors
- available access
- the nature of the ground eg reclaimed ground
- the water table level
- historical excavation experience in the area under similar conditions

- the 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, such as a fault, cast or perched water table
- the proximity of existing underground services, such as water mains, sewer, drainage, electricity, gas and telephone
- soil nails, rock anchors, basement underpinning, or other pre-existing ground support
- adjacent excavations eg shafts, tunnels or trenches
- other hazards, either natural or man-made, such as:
  - heavy loadings, above or adjacent to the tunnel eg roadways, railway lines, buildings, rivers or planned or existing spoil stockpiles
  - chemical contamination eg from past dumping or natural deposits
  - the presence of methane, or other hazardous gases eg where coal seams are present or vegetation has decayed in the soil
- dynamic loads or ground vibration near an excavation, including:
  - traffic (highway or rail)
  - excavation equipment
  - explosives.

5.1.1.1 Hand excavation

The use of hand methods of excavation is generally limited to small sections of work within larger projects eg a small shaft, sump or drive-in area with limited access and limited possibility for mechanisation.

Many of the common underground construction hazards described in section 5.1 of this code of practice will apply.

Hazard areas that should be considered in greater detail include the following:

- manual handling eg additional physical lifting and activity
- falls from heights eg non mechanised access
- falling objects eg proximity to the worked face
- vibration effects on the body-use of hand tools eg rock drills or jackpicks
- impact eg air leg kick out or broken steels
- noise eg proximity to air tools and drills
- dust eg closer proximity to the face
- heat stress eg due to physical exertion.

Note: Hand excavation might be required in a confined space and these risks are covered in Section 5.5.7.

5.1.1.2 Machine excavation

Most tunnelling excavation is mechanised to a considerable extent, therefore, the implications of plant use are very significant in risk management, as detailed in Section 5.4. Plant use in itself presents significant hazards and risks that must be identified and controlled

The hazard areas that should be considered in addition to, or in greater detail to, those common hazards covered in 5.1 include the following:

- moving plant and moving components on plant eg crush, nip or shear
- height eg elevated areas of plant including service access points
- restricted operator visibility and communication eg controls including audible warning sounds, hazard lights, operating lights
- ergonomics – visibility, seat belts, hand rails, seating, controls, stairs, manual handling
- locking and security mechanisms, including power isolation
- fire eg flammable liquids and materials
- high-pressure liquids or gases
- heat eg burns from localised heat sources or heat exhaustion for general heat
- air contamination eg from excavation dust or exhaust emissions
- radiation from lasers.

5.1.1.3 Drill and blast methods

Drill and blast methods for tunnel construction are less widely used with the continued evolution of continuous excavation methods and the environmental impact constraints inherent in many tunnel locations.

For shorter tunnels, or where ground conditions are very hard, drill and blast is often the only alternative. The drill and blast method has particular hazards that require a number of controls for the associated risks.

The hazard areas to be considered in the assessment and control of risks include the following:

- storage, transport and use of explosives
- ground support requirements
- the effect on surrounding strata and existing ground support
- drilling of faces
- firing times and prevention of access to firing areas
- clearance of blasting fumes and dust (refer to section 5.3).
- dealing with misfires.

Explosives are controlled in NSW under the *Explosives Act 2003* and the *Explosives Regulation 2005*, together with any requirements and conditions published by WorkCover NSW. If explosives are to be stored and used at a tunnel construction site, the employer is responsible for the control and safe storage and use of those explosives.

The explosives legislation in NSW requires that anyone who handles explosives must be licensed to do so. To obtain a licence to store explosives, a person or company must apply to WorkCover NSW. The licence to store must be accompanied by a security plan. Guidance material for the compilation of the security plan and other requirements, such as the need for an unsupervised handling licence, is available from WorkCover NSW or by visiting **www.workcover.nsw.gov.au**.

The explosives legislation also requires that explosives are handled safely and requires compliance with *AS 2187: Explosives – storage, transport and use, Parts 1 and 2*. This standard provides details on methods of safe storage and safe use. Site procedures and work methods for controlling the handling of explosives must conform to these standards eg when storing explosives, detonators must never be stored in the same magazine as other explosives.

5.1.2 Portal protection

Portal entries, if below the ground surface and not constructed with the final concrete or other permanent structure at the commencement of tunnelling to provide protection, will require other support and protection.

This support will vary but should, at a minimum, include the following:

- ground support of the highwall, if any, above the portal entrance
- support of the portal brow or lip
- protection at the portal, protruding sufficiently out from the tunnel to protect persons entering or leaving the tunnel from material that might be dislodged off the highwall above the portal entrance.

A fence or other barricade should be provided above the portal to retain people and objects if there is access or work being carried out above the portal.

Drainage should be provided to prevent heavy run off entering the tunnel.

5.1.3 Scaling and inspections

Inspection of the roof and walls, and scaling of loose rock, should be conducted immediately after excavation. As the effects of time can cause deterioration to rock surfaces, periodic follow-up inspection and scaling should be conducted on unlined areas. A risk assessment, with ongoing revision based on the inspection results, should be used to determine an appropriate period for initial and regular inspection and scaling.

At shift changes, there should be a handover discussion to pass on information on the status of inspection and scaling, including the areas not yet inspected and the location of any identified drummy ground still in need of supporting.

Scaling should take place:

- for drill and blast excavation – after every blast when the face area and spoil heap have been washed down
- for other excavation methods – at intervals as determined by the risk assessment above
- during the support cycle if more loose rock is revealed and as the support installation moves forward from supported ground
- whenever inspection reveals the possibility of loose rock on any wall or roof.

The excavation should be thoroughly washed down prior to the initial inspection. Regular inspections should continue in the unlined tunnel areas, to a schedule determined by the above risk assessment.

Inspections and scaling should be conducted from supported and scaled areas. Where practical, machine scaling is preferred to hand scaling. Where hand scaling is used it should be from an elevated platform (basket).

Drummy ground that can not be scaled down should have additional support installed.

Particular attention should be taken at breakthroughs, as the previous excavation and associated stress changes may have weakened the ground.

5.1.4 Ground-support controls

Most tunnels require some form of permanent ground support. The permanent lining can be installed directly as the excavation progresses, or temporary support installed initially, followed by a permanent lining. This may be followed by the installation of a non-structural secondary lining.

It is a legal requirement that an adequate system of safety, involving shoring, earth retention equipment or other appropriate measures, is in place to control risks to health and safety arising from one or more of the following:

(a) the fall or dislodgment of earth and rock

(b) the instability of the excavation or any adjoining structure

(c) the inrush of water

(d) the placement of excavated material

(e) instability due to persons or plant working adjacent to the excavation.

If a system of shoring is used, the employer must ensure that an adequate supply of shoring equipment and material is provided and used to prevent a fall or dislodgment of earth, rock or other material that forms the side of or is adjacent to the excavation work.

It is also a legal requirement that an employer must ensure that adequate measures are taken in the immediate vicinity of excavation work so as to prevent the collapse of the work. In particular, an employer must ensure that no materials are placed, stacked or moved near the edge of excavation work so as to cause the collapse of the work.

Because unsupported ground is often a high risk of falling materials, all tunnels should have some form of ground support or overhead protection during the construction phase.

It is usual for the planned ground support to vary throughout the project as the tunnel dimensions or ground conditions vary, and the locations of changes should be included in the design documentation.

The support actually installed as a tunnel progresses will often alter with exposure and assessment of the actual ground conditions and experience gained from the monitoring of the performance of the supports.

Unless robotically installed, ground support should be installed from supported areas or using plant which provides overhead protection for the installers. The design advance and ground support system may result in the area between the last support and the face as being considered as supported. If so, this should be specified in the design.

The ground conditions should be inspected as the excavation progresses, in accordance with the inspection plan as outlined in Section 3.7.

The results from the inspections should be assessed and the ground support system reassessed, and changed if necessary, when ground conditions deteriorate from that allowed for in the design or the ground support system is not performing as designed. Similarly, changes could be made if the ground conditions are better than allowed for in the design.

Inspection and assessment of the performance of the support system and, if appropriate, changes to the specification, should be carried out by competent persons. Each ground support method or type, despite being a control for the hazards of ground conditions, has its own hazards and risks attached to the process of installation, which need to be controlled.

5.2 Risk controls in specialist construction methods and activities

The system of work and the control measures selected should be determined by considering individual job factors identified in the consultation and risk assessment process.

Designers and constructors with extensive and relevant experience in the selected specialist methods should be used during this process. The following sections describe some of the specialist construction methods and activities. They provide examples of relevant specific hazards, risks and control measures that should be considered in addition to, or in greater detail than, the common examples given earlier.

5.2.1 Shaft sinking

Shafts vary greatly in construction technique depending on conditions and their purpose, and may be vertical or inclined, lined or unlined, of various shapes, and excavated using various techniques.

Shaft sinking involves excavating a shaft from the top, with access and spoil removal from the top.

Specific hazards and risks may be identified in the following areas:

- shaft dimensions limit clearance
- falls from heights
- falling objects, including fine material and water from shaft wall
- hoisting and winching personnel, materials, spoil, and plant
- working platforms or material kibbles hang up
- communications
- dewatering
- ventilation
- emergency egress.

Examples of control measures include:

- guidance of working platforms and kibbles
- early lining of the shaft
- avoiding the overfilling of kibbles
- cleaning underside of kibbles before lifting
- closing shaft doors before tipping
- cleaning spillage off doors, stage and any steelwork.

5.2.2 Raise boring

Raise boring is a method of constructing a shaft (or raise) where underground access has already been established. Raise bored shafts can be from the surface or from one horizon (level) to another underground. The method is remote and does not require personnel to enter the shaft.

The method involves:

- installing a raise borer rig at the top of the planned raise, above the existing tunnel (or other underground excavation)
- drilling a pilot hole down into the tunnel
- attaching a reaming head and back reaming to the rig to create the raise
- supporting the completed hole if it is required – eg by lining or installing ground support.

Specific hazards and risks may be identified in the following areas:

- poor surface materials for set-up
- breakthrough causes unexpected rock fall
- rock fall as breakthrough area not secured prior to bit removal
- manual handling problems with bit removal and reamer head attachment
- spoil 'mud rush' after a hang up
- flooding from surface or ground water sources
- fall into shaft when removing reamer head or rig
- working platforms or material kibbles hang up
- communications
- dewatering
- ventilation
- dust
- emergency egress.

Control measures include:

- barricading breakthrough area to prevent access well before breakthrough
- coordinating spoil clearance to reduce likelihood of hang ups or falling material entering the tunnel
- monitoring spoil flow – stop reaming if hang up occurs to reduce potential mud rush.

5.2.3 Raised shafts and excavations

From underground access, a raise or a vertical or sub-vertical excavation may be required to the surface or to another horizon. Certain methods are available, including:

- blind methods where no top access is available, such as:
  - conventional or ladder raise, now largely obsolete for vertical raises, may have application for some inclined excavations
  - Alimak or raise climber working off rail segments
  - shrink method for short excavations working off broken spoil.
- other methods where top access is available, such as:
  - cage or gig rise using a moving cage/platform hoisted through a rope in a pilot hole
  - long-hole rise (using drill and blast)
  - underhand benching or rise stripping.

Specific hazards and risks include the following:

- working and accessing from below the excavated face, which may not have been inspected and scaled
- working upwards, material enters the eyes
- falling objects, and fine material and water from the shaft wall
- communications
- ventilation is more difficult
- isolation, emergency, access and egress issues.

Control measures include the following:

- providing access using a two-level cage, with the top level providing overhead protection when not at the face
- drilling large diameter pilot hole for cage rope and establishing ventilation up the hole
- barricading the bottom area and limiting access to the authorised persons
- barricading and restricting access to the breakthrough area well before breakthrough.

5.2.4 Pipe jacking

This method is mostly used in soft tunnelling conditions. The tunnel is lined with a pipe that is installed in sections, pushed or jacked into the increasing tunnel length from the portal. It consists of a typical sequence where:

- a jacking pit is excavated, supported and reinforced to resist the jacking forces
- excavation of a small section of tunnel takes place ahead of a leading pipe
- the continuous line of pipe sections is manually or automatically jacked into position, pushing the leading pipe up to the face

- the face is excavated and the pipe pushed further, adding sections at the rear as space permits.

The support and lining is provided by the pipe. Face support may be required depending on the conditions.

Specific hazards and risks include the following:

- restricted access and dimensions, including the pipe-positioning area
- jack operation and jacking forces
- soft material, which leads to face failure
- water or liquefied soil or mud inflow
- pipe binds, leaving face and excavated section exposed for longer than planned.
- visibility.

Control measures include the following:

- using mechanical rather than manual lifting where possible
- locating jack power pack away from work area in the pit
- supporting the face during jacking
- dewatering or grouting to reduce water inflow
- lubricating pipes or installing intermediate jacking stations in longer tunnels.
- lighting.

5.2.5 Caissons

This method is used to sink shafts in very soft or wet ground conditions. The method is suitable for shafts generally larger than bored shafts. The caisson method involves:

- concrete (or steel) sections stacked upon each other at the surface, the lower or leading section having a cutting edge
- excavation of the shaft bottom undercuts the edge of the leading caisson and the sections move downward together under their own weight, or they are driven down.

The shaft remains fully supported and lined for its entire length.

Caissons may be pressurised in certain circumstances with compressed air to provide temporary ground support and reduce water ingress at the shaft bottom. For controls applicable to working in a pressurised atmosphere with this method refer to *AS 4774.1: Work in compressed air and hyperbaric facilities – Part 1: Work in tunnels, shafts and caissons.*

5.2.6 Ground freezing

Ground freezing is used to sink shafts in very soft and wet ground conditions and where there are free running saturated sands. It is rarely used in Australia but, due to different ground conditions, is more common in Europe.

The wet ground where the shaft is to be sunk is artificially frozen, excavated as though it were solid rock, then lined and sealed before being allowed to thaw. The process can also be applied to horizontal development.

The additional hazards stem from the reduced temperature and include the effect of cold on personnel and equipment, spoil removal (it may melt or resolidify depending on the ambient temperature), and the risk of collapse from localised or general thawing.

Control measures include the following:

- warm clothing and footwear, job rotation, rest periods
- heated operators' cabins, rest areas
- temperature and refrigeration plant monitoring
- excavation and spoil-removal equipment adapted for cold operation.

5.2.7 Compressed-air tunnelling

The use of a compressed-air atmosphere is not commonly used in Australia. For the additional requirements and controls applicable to working in a pressurised atmosphere, refer to *AS 4774.1: Work in compressed air and hyperbaric facilities – Part 1: Work in tunnels, shafts and caissons.*

This method is used to provide additional temporary ground support in very soft and extremely wet ground conditions, and where other means of preventing excessive ingress of water or the collapse of ground into the tunnel are not practical.

The pneumatic support process involves providing a bulkhead, with air locks for access into the tunnel, and pressurising the tunnel with compressed air to hold back the water and weak strata.

5.2.8 Pressure grouting

Pressure grouting involves pumping a grout (eg cement slurry or chemical grout) under pressure into a void or permeable ground. Pressure grouting:

- fills voids behind a tunnel or shaft lining to increase the integrity and strength of the lining or to reduce water inflow
- stops or reduces direct water inflows into the excavation
- improves ground conditions by cementing unstable areas.

Prior to implementing a pressure grouting program, employers should review the relevant risk assessments and measures adopted to control risks.

Specific hazards and risks include the following:

- cement or chemical grout dust
- eye or skin contact with grout, which causes chemical burns, poisoning and other toxic effects
- high-pressure hoses and connections.
- fracturing of the ground
- damage to nearby services, buildings or structures.

Control measures include the following:

- easy to read pressure gauge assists in reducing risk of exceeding specified grout pressure
- presetting the specified grout pressure
- washing and eye-wash facilities at grout site
- PPE, such as gloves and full-face eye shields.

5.3 Air quality and ventilation systems

Clause 51 of the OHS Regulation requires employers to ensure that no person is exposed to an airborne concentration of an atmospheric contaminant above the relevant exposure standard (refer to Section 5.3.2).

Employers are also required to ensure that:

(a) mechanical ventilation appropriate for the work being carried out is used to control atmospheric contaminants and that the ventilation is maintained regularly, and

(b) if a mechanical ventilation system is used to control exposure to a contaminant, the system:

  (i) is located as close as is practicable to the source of the contaminant to minimise the risk of inhalation by a person at work

  (ii) is used for as long as the contaminant is present

  (iii) is kept free from accumulations of dust, fibre and other waste materials and is maintained regularly

  (iv) is designed and constructed so as to prevent the occurrence of fire or explosion if the system is provided to control contaminants arising from flammable or combustible substances

(c) if a ducted ventilation system is used, an inspection point is fitted at any place where blockages in the ventilation system are likely to occur.

Tunnels are usually at risk of having atmospheric contamination and require mechanical ventilation, unless connections to the surface or other ventilated areas provide measured airflows that are adequate to control the atmospheric contamination. Sources of contamination, or other atmospheric risks, that ventilation may control, include:

- gases and fumes seeping or flowing into the tunnel eg ground gases such as methane, carbon dioxide and sulphur dioxide, engine fumes such as carbon monoxide and carbon dioxide, and leakage from nearby gas bottles or tanks, fuel tanks, sewers, drains or gas pipes. (See table in section 5.3.2)
- dust, gases and fumes created by the activities in the tunnel eg silica dust, flammable dusts such as coal and sulphide and the gases and fumes above
- excess heat and humidity created by the activities in the tunnel
- oxygen depletion due to internal combustion engines, oxidation or other natural processes.

As well as tunnel excavations, these hazards can be encountered in excavations for foundations, bored and drilled pier holes, shafts, drives, pits and trenches. The detrimental effects of inadequate ventilation can be short term, or accumulative and long term.

Tunnel ventilation is usually achieved through a mechanical ventilation system. It ensures that sufficient oxygen is available for respiration (from fresh air), and dilutes and transports harmful atmospheric contaminants away from work areas.

Air flow velocities can be very low in large tunnels, therefore current industry practice in most tunnels is to maintain a minimum 0.5 m/sec velocity to provide sufficient air velocity to clear contaminants. This will provide a clean and safe atmospheric work environment and provide cooling for persons working in warm and humid environments.

The arduous and changing nature of tunnelling means there should be:

- an adequately designed ventilation system that is capable of supplying all the necessary ventilation quantity requirements by supplying sufficient air flow to all those underground areas at all times when persons are present throughout the construction
- regular monitoring of air flows and atmosphere
- ongoing and effective maintenance on the ventilation system including prompt repair of all leaks and maintenance of rigid and flexible ducts, barricades and fans
- a regularly advanced and upgraded ventilation system in accordance with the results of the monitoring program results, so that sufficient air flows are always maintained
- appropriately sign posted unauthorised entry for areas without adequate ventilation
- self contained breathing apparatus (or self rescuer) supplied to any person working in an area that is at risk of not maintaining a safe atmosphere
- specific controls and monitoring of explosive gases
- continued monitoring and control of the sources of contaminants eg reduce diesel emissions, block boreholes, store materials on surface
- personal or machine mounted continuous monitoring devices that sound an alarm when dangerous gas levels, or oxygen depletion, are detected.

5.3.1 Monitoring air quality

Clause 52 of the OHS Regulation requires appropriate risk control measures to be put in place when atmosphere in a place of work contain an unsafe oxygen level.

A safe level is defined as not less than 19.5 per cent or more than 23.5 per cent by volume under normal atmospheric pressure. A safe oxygen level does not, however, mean that there are no toxic or flammable gases present.

The risk assessment process should be used to:

- determine the engineering controls, work practices and onsite atmospheric or biological monitoring required
- determine the monitoring program for airborne contaminants such as dust and fumes, including taking air samples and ensuring compliance with NOHSC standards.

The monitoring program should include testing before work recommences after a break where ventilation has not been maintained. The work areas should be examined by competent persons using appropriate detecting and measuring equipment.

It should include air testing for the following:

- flammable fumes or gases
- oxygen deficiency (presence of asphyxiant gases)
- airborne contaminants (toxic gases, fumes or respirable dusts).

When PPE is provided, employers should ensure any respirators supplied are capable of preventing persons inhaling hazardous dust or other airborne contaminants at the concentration and duration of the exposure. Refer to *AS/NZS 1715: Selection, use and maintenance of respiratory protective devices.*

If a risk assessment indicates that monitoring of atmospheric contaminants should be undertaken, clause 55 of the OHS Regulation requires employers to ensure that:

(a) appropriate monitoring is undertaken in accordance with a suitable procedure, and

(b) the results of the monitoring are recorded, and

(c) any employee or other person working at the employer's place of work who may be or may have been exposed to an atmospheric contaminant that has been monitored is provided with the results of the monitoring, and

(d) the monitoring records are readily accessible to any such employee or person.

Employers must ensure that exposure to an airborne concentration of a contaminant classified as a hazardous substance is not at a level greater than that established by the adopted national *Exposure standards for atmospheric contaminants in the occupational environment.*

5.3.2 Hazardous contaminants

Personnel may be exposed to contaminants by inhaling, swallowing, or absorbing by contact with skin or eyes. Hazardous materials can present a physical, chemical and/or biological risk to human health.

Hazardous materials include the following:

- silica dust and synthetic mineral fibres
- toxic gases, fumes, vapours and other toxic chemicals
- explosive and asphyxiant gases
- biologically active substances, microorganisms
- hazardous wastes.

These contaminants can:

- arise from the mechanical process of tunnelling eg drilling or cutting or be uncovered excavation eg silica dust
- be produced in-situ (eg exhaust gases from internal combustion engines) or from blasting activity (eg carbon monoxide)
- be introduced into the tunnel from the external environment eg liquid fuels or chemicals.

Common source activities for harmful airborne contaminants are contained in the table below.

Activity	**Contaminant**	**Harmful components**
Hot work	Welding/cutting fumes	Metal oxides, oxides of nitrogen, ozone, fluorides
Operation of internal combustion engines	Exhaust fumes	Carbon monoxide, carbon dioxide, particulates, oxides of nitrogen, fuel vapours, aldehydes and hydrogen sulphide. Oxygen depletion can occur.
Tunnelling	Rock dust	Silica and other mineral dusts including coal dust
Shotcreting, concreting, grouting	Cement dust/ accelerator	Cement dust, ammonia and chemical accelerating compounds
Shot firing	Blasting fumes	Silica dust, ammonia, oxides of nitrogen, carbon monoxide, sulphur dioxide, hydrogen sulphide, carbon dioxide
Battery charging	Vapours	Flammable gas, acid fumes

Clause 51 of the OHS Regulation requires employers to ensure that no person is exposed to an airborne concentration of atmospheric contaminants (other than synthetic mineral fibre dust) as determined in accordance with the documents entitled:

- *Guidance Note on the Interpretation of Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC: 3008)*
- *Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC: 1003)*

as amended from time to time by amendments published in the *Chemical Gazette of the Commonwealth of Australia.*

An approximate guide to the effects and consequences of some common air contaminants (and oxygen depletion) at concentrations beyond acceptable national exposure standards is provided in the following table. For the applicable exposure standards, refer to the 'Hazardous Substances Information System (HSIS)' located on the Australian Safety and Compensation Council website (**www.ascc.gov.au**).

Common contaminants	**Range of typical effects at increasing levels of exposure above acceptable limits**
Carbon dioxide	• Increased depth of breathing within 15 mins of exposure • Feeling of inability to breathe, headache, dizziness, sweating, and disorientation • Nausea, strangling sensation, stupor and loss of consciousness within 15 minutes. Many deaths reported from exposure above 20 per cent.
Carbon monoxide	• Headache within a few mins. Possibility of collapse in half hour, coma in 1 hour and possible death in 1.5 hours.

Common contaminants	Range of typical effects at increasing levels of exposure above acceptable limits
Hydrogen sulphide	• Initial eye irritation, then loss of sense of smell • Rapid breathing, respiratory arrest, collapse, and then death.
Nitrogen dioxide	• Considered dangerous for short-term exposure. Moderately irritating to eyes and nose • Fatal within 30 minutes. Death is due to fluid build up in lungs (pulmonary edema) leading to asphyxia.
Sulphur dioxide	• Irritation of the eyes, nose, and throat, choking, and coughing within minutes • Immediately dangerous • A 10 minute exposure has been fatal at high concentration.
Silica dust	• Cumulative exposure leads to lung damage/disease (silicosis) • Can occur after 15 to 20 years of moderate to low exposure, or after a few months of very high exposure • Death can occur.
Non contaminants	
Oxygen depletion	• Rate of respiration increased • Fatigue on exertion, disturbed respiration • Nausea, inability to move freely, collapse • Respiration stops, heart stops within a few mins.

5.3.2.1 Dusts and silica

When airborne dust particles are less than 5μm in size, they are too fine to be filtered by the nasal cavity and can be inhaled, or respired, deep into the lungs. Long term exposure to respirable dusts can lead to diseases ranging from bronchitis to various cancers. Even if the dust is not at harmful levels or sizes, it can increase the risk of physical injury or harm because of the reduced visibility and irritation to eyes and throat.

Non-hazardous nuisance dust can be generated about the site or underground by dry roadways, bare soil or rock, vegetation removal, traffic, wind and the like.

There are several dusts of particular concern, including the following:

- silica (classified as a carcinogen and particularly applicable to tunnelling)
- asbestos (see Section 5.3.2.3)
- coal, lead or anything containing radioactive elements (not generally encountered in tunnelling).

The risk assessment of the tunnel should consider the presence of silica and the likely generation of dust containing silica. Crystalline silica is a common mineral present in sandstone, quartz and many other rocks. Respirable particles of silica can be produced in tunnelling operations. Exposure to respirable silica is known to cause silicosis, a respiratory lung disease that can be fatal. Further information on silica dust is contained in the WorkCover NSW publication *How to Prevent Silicosis.*

Note: The national exposure standard for respirable quartz (silica) is 0.1 mg/m^3.

During the tunnelling operation, mineral dust can be generated and released into the atmosphere when:

- rock or concrete is broken, drilled, cut or blasted, or wherever ground is disturbed
- rock-cutting with road headers or tunnel-boring machines (TBMs)
- loading broken rock at face
- transporting spoil on conveyor belts
- working at spoil transfer points
- installing or removing ventilation ducts
- concreting and shotcreting, spraying and handling bagged ingredients
- moving traffic
- muck piles dry out.

Controls for harmful airborne substances include:

- designing, using and maintaining an exhaust ventilation system
- maintaining extraction at, or close to, the point of generation – such as the face and spoil conveyor transfer points
- using extractors or dust collecting devices inline, near the face
- provision of procedures and equipment for the cleaning of scrubbers and changing of air filters used with atmospheres containing silica dust
- increasing the extraction rate (ventilation capacity) when and where required
- isolation of the dust producing area eg by the provision of bulkheads, mist curtains or 'butchers doors'
- wet spraying, to suppress dust at the point of generation
- adding surfactant (detergent) to dust suppression water
- using other substances for dust suppression eg salting roads
- using tools fitted with dust extraction or water attachments
- wet drilling
- installing water applicators onto the machinery, rather than using hand held applicators
- wetting muck piles, spoil conveyors, roadways
- spraying water over spoil heaps after blasting and while loading
- limiting exposure times to dust
- providing PPE eg respirators rated for concentration and duration of exposure
- fitting air-filtering systems to the air-conditioning units of excavators and other machinery
- keeping man-vehicles dust sealed
- assessing and controlling the risk of cross contamination between worksites, work processes or workers' clothing.

Information on dust diseases and workers compensation can be obtained from the Workers Compensation and Dust Diseases Board of NSW.

5.3.2.2 Diesel emissions – scrubbers and catalytic converters

Internal combustion engines other than diesel should not be used underground, and only low sulphur diesel fuel should be used (see 5.4.4). The exhaust emissions from diesel engines can constitute a major source of contamination and oxygen depletion to a tunnel atmosphere. This should be considered in the plant selection and in the design, operation and monitoring of the ventilation system.

Where diesel engines are used, the tunnel ventilation should be monitored by testing the tunnel air for the products and effects of diesel engines, such as:

- oxygen deficiency (and the presence of asphyxiant gases)
- airborne contaminants such as toxic gases and fumes.

Similarly, the performance of the engines should be tested at the exhaust prior to being certified for underground use, then at three-monthly intervals after being put into service, to determine that the emissions of carbon monoxide, carbon dioxide and nitrogen oxides are below the appropriate limits.

In addition to the dilution and extraction provided by the ventilation system, exhaust conditioners such as water baths or catalytic converters should be installed and maintained on diesel engines that are used underground.

Generally, catalytic converters are most suited to large engines used for heavy workload conditions, such as materials handling. Catalytic converters need cleaning, or replacing, at intervals as recommended by manufacturers.

Smaller engines, and those subject to intermittent running, such as service vehicles, are more suited to water-bath type exhaust conditioners. Remember, the water baths require regular, often daily, filling-up to remain operational. Low level shut down devices may be installed to stop operation before the conditioner becomes ineffective.

Emission levels should be monitored through full-load exhaust-gas testing on the plant, and by testing the diluted tunnel atmosphere. The contaminants should be monitored and controlled to meet the exposure standards set out in Section 4.3.1.

5.3.2.3 Asbestos

Asbestos is a hazardous mineral made up of tiny fibres. When disturbed, it forms a dust. The fibres can be inhaled into the lungs and remain for decades. Carcinogen and exposure to airborne asbestos fibres can cause mesothelioma, asbestosis, pleural plaque and lung cancer.

There are different types of asbestos eg *chrysotile* (white asbestos), *amosite* (brown asbestos) and *crocidolite* (blue asbestos) and all are prohibited carcinogenic substances.

In the past, asbestos was widely used in building, plumbing and industrial applications because of its inert and insulating properties. To identify asbestos, a risk assessment should be conducted on building sheet materials, electrical panels and boards, lagging and pipe insulation, gaskets, brake pads and insulation wool, rope and blankets, and buried fill.

Asbestos can also occur as a natural deposit in the rock strata.

Clause 43 of the OHS Regulation requires controllers to ensure that risk assessment and control measures for asbestos work are carried out in accordance with the *Guide to the Control of Asbestos Hazards in Buildings and Structures* (NOHSC: 3002 (1988)) and the *Code of Practice for the Safe Removal of Asbestos* (NOHSC: 2002 (1988)).

If a risk assessment indicates the need for atmospheric monitoring of a workplace in which asbestos or asbestos containing material is located, the employer must ensure that the monitoring is carried out by a competent person in accordance with the document entitled *Guidance note on the membrane filter method for estimating airborne asbestos dust* ((NOHSC: 3003 (1988)).

5.3.3 Heat stress management

Clause 47 of the OHS Regulation requires employers to ensure that:

(a) adequate ventilation and air movement is provided in indoor environments that may become hot, and

(b) appropriate work and rest regimes relative to the physical fitness, general health, medication taken and body weight of each employee exposed to heat are implemented.

To determine the level of heat-related risks for a worker, the following factors interact with each other:

- environmental conditions eg air temperature, radiant heat, humidity, air flow
- physical work eg strenuous or light
- work organisation eg its duration, exposure to heat, time of day
- clothing eg heavy protective clothing.

A combination of these conditions can cause heat stress or heat stroke and the effects can range from simple discomfort to life threatening illnesses.

Heat stress reduces work capacity and efficiency. Signs of heat stress include tiredness, irritability, clammy skin, confusion, light-headedness, inattention and muscular cramps.

Signs of heat stroke include high body temperature, no sweating, hot and dry skin, confusion and, if life-threatening, loss of consciousness.

Conditions of high, wet bulb temperatures and low air velocities give little cooling effect. The current industry practice has found it is necessary to maintain a **minimum** of 0.5 m/s velocity in the tunnel and other headings because the air cooling power or cooling effect on the clothed body is a function of air velocity. See Appendix 5.

Current industry practice suggests that personnel be moved away from the area when the air-cooling power is less than 140 W/m^2 (being the metabolic heat production rate for medium work) ie air velocity of 0.5 m/s, and a wet bulb temperature of 30°C.

For more detailed guidance on managing and measuring hot work hazards, refer to the WorkCover NSW *Code of practice for work in hot and cold environments.*

Controls for preventing heat stress include the following:

- providing adequate ventilation
- undertaking a risk assessment and determining monitoring regime
- reducing items of heat-producing equipment in tunnel
- monitoring air velocity and wet-bulb temperature regularly, determining cooling effect, assessing and recording results
- regulating air flow, or modifying ventilation, to ensure adequate cooling
- refrigerating the air supply in extreme conditions
- providing additional ventilation fans to create air flows in low-flow areas
- rotating personnel in hot areas
- providing rest breaks in cool environments
- providing cool vests
- educating personnel to recognise symptoms of heat stress
- providing cool drinking water – current industry practice suggests workers drink half a litre of water each hour when hot environments cause excessive sweating
- providing PPE for surface heat exposure eg shade, hats.

5.4 Plant-related risks

Tunnelling operations invariably involve a variety of plant – plant that may be hand held, fixed, rubber tyred, tracked or rail mounted, and powered electrically, by diesel engine or compressed air. Internal combustion engines other than diesel should not be used underground.

Because of the confines of underground work and other factors, including visibility, noise, congestion, roadway conditions and pedestrian traffic, there are many and varied risks to be assessed and controlled in relation to plant design, selection, use and maintenance.

5.4.1 General

Chapter 5 of the OHS Regulation sets out the requirements for managing the risks arising from operating plant. Plant is the term used for all machinery, tools, appliances and equipment. These requirements also include a registration system for certain plant designs and certain items of plant.

Control measures to prevent persons being injured during the use and maintenance of plant must be provided and maintained as part of a safe system of work. The WorkCover NSW *Guide for Plant 2001* and the *Code of practice for moving plant on construction sites* provide information to assist in controlling workplace risks arising from the use of plant and moving plant respectively, and should be read in conjunction with this code.

The OHS Regulation also requires that powered mobile plant be designed to include devices that protect the operator against rollover, falling objects or ejection, and warning devices for those at risk from moving plant. Earthmoving machinery designed to have a mass of 700–100,000 kg must include a protective structure conforming *to AS2294: Earth-moving machinery – protective structures.*

For certain plant eg some mobile cranes, forklifts, elevating work platforms, excavators and loaders, and certain activities eg scaffolding, rigging and dogging, the OHS Regulation requires the operator to hold an appropriate certificate of competency.

Controls applicable to most plant include the following:

- guarding to prevent contact with moving or hot parts, eg nip, shear and pinch points, rotating shafts and exhaust systems
- barricading or fencing to prevent access to hazardous areas or as fall protection
- installing roll over protection (ROPS) and falling object protection (FOPS)
- using eye protection
- installing reversing beepers, flashing hazard lights
- installing reversing cameras, or reversing sensors on mobile plant with restricted rear visibility
- providing adequate lighting
- installing fire safety equipment
- providing ongoing maintenance, including underground servicing complexities.

5.4.2 Plant and vehicle movement procedures

Plant movement may be hazardous. The risk is commonly a crush injury and can arise from activities such as:

- transporting and installing fixed equipment eg transformers
- moving self-relocatable plant eg road-header, TBM, drill rig, rock bolter
- other moving vehicles in the tunnel eg haul trucks, left-hand drives, service vehicles, personnel carriers, locomotives, rail cars, loaders, delivery vehicles.

Vehicle movement procedures should be developed on the basis of a risk assessment, and should be updated as the conditions on the site change.

The WorkCover NSW *Code of practice for moving plant on construction sites* provides general guidance in relation to the issues involving moving plant but, due to the confined environment and restricted lighting and noise, the tunnelling environment places additional constraints on the available controls.

Control measures include the following:

- reducing vehicle movements by using conveyors to remove spoil, and coordinating deliveries to and from the working areas to reduce empty or near-empty journeys eg by backloading
- scheduling activities to reduce periods of traffic congestion
- using a block system eg traffic lights
- providing vehicle passing bays
- lining the tunnel floor, or maintaining it regularly
- having vehicle operators remain in the cabin during loading/unloading, provided there is no risk from remaining in the cabin and they are not required to assist with the loading/unloading activities
- using vehicles designed to keep the occupants appropriately contained/restrained
- providing pedestrian shelters
- cleaning windows and lights
- providing high visibility, reflective clothing and cap lamps.

5.4.3 Machine suitability and assessment

Manufacturers of plant and equipment design it for specific applications and should provide instruction manuals or other information that will assist in determining its suitability for the intended application and appropriate control measures when used as designed.

Plant selected for a tunnelling project should be chosen for its performance and suitability against a number of criteria, including the following:

- duty requirements eg whether designed for use underground or in need of modification
- compliance with regulations and relevant standards eg electrical standards
- physical dimensions and requirements eg clearance available, ventilation, power and water
- appropriate levels of emissions eg exhaust, noise, vibration and heat
- suspension eg vehicle or suspension seating to suit the surface conditions
- safety and ease of operation
- ease of maintenance
- skills and training required to operate and maintain.

Clause 105 of the OHS Regulation requires that a manufacturer of plant provide other persons who have responsibilities under the OHS Regulation with all available information about the plant that is necessary to enable the other persons to fulfil their responsibilities.

Such information includes the following:

(i) the purpose for which the plant was designed

(ii) testing or inspections to be carried out on the plant

(iii) installation, commissioning, operation, maintenance, cleaning, transport, storage and, if the plant is capable of being dismantled, dismantling of the plant

(iv) systems of work needed for the safe use of the plant

(v) knowledge, training or skill necessary for persons undertaking testing and inspection of the plant

(vi) emergency procedures.

Note: Equipment specifically designed for a project, including one-off items constructed by the tunnel builder, also require a risk assessment and provision of the above information.

Where plant is used for purposes for which it was not designed eg due to the fitting of an attachment, direct modification or a change in the manner of use, a competent person should conduct an assessment as to whether the change presents an increased risk to health and safety. If it does, additional control measures should be implemented, and information provided. See the plant position paper, WorkCover NSW *Use of plant for purposes for which it was not designed*.

5.4.4 Fuelling – surface and underground

Substances or articles such as fuel that have a hazard related to fires or explosions, rapid chemical reactions, or immediate health risks (such as poisoning) are dangerous goods.

Dangerous goods are regulated under the *OHS Act 2000* and the OHS Regulation. These set out obligations regarding the notification of dangerous goods being stored and handled and a risk management approach together with specific control measures such as storage, signage, labelling, material safety data sheets (MSDSs), monitoring, health surveillance, record keeping, training and emergency planning.

Advice on complying with this legislation can be found in the WorkCover NSW *Code of practice for the storage and handling of dangerous goods*. Appendix 8 of the code contains specific advice on the use of industrial trucks in hazardous zones as defined by the OHS Regulation.

Fuel used for diesel engines to be used underground should be of low sulphur content, ie should contain less than 0.25 per cent sulphur by weight. (See relevant material safety data sheet).

Safe fuelling procedures (see WorkCover NSW *Code of practice for the storage and handling of dangerous goods*) should be established and where practical, fuelling should be conducted on the surface. Underground fuelling should be at designated fuelling bays, unless it is impractical to bring the plant to the fuelling bay. Engines should be switched off in fuelling bays and there should be no naked flames, lights or smoking in the fuelling area.

Fuelling bays should be:

- adequately ventilated
- a safe distance from traffic and roads
- built of non-flammable materials
- constructed with a sill or bund to prevent fuel escaping
- separate from vehicle repair or servicing bays
- without any naked flame
- provided with suitable fire extinguishers
- provided with an anti-static hose and pump, with a self-closing nozzle and a shut off tap to prevent fuel leakage when unattended (gravity-method fuelling may also be considered).

For underground fuelling:

- stored fuel should be limited to minimum quantities required for efficient operations
- an oil-absorbent material should be available and used to clean spills (dispose of used material promptly)
- fuelling at other than a fuelling bay may be by hose and pump or for small quantities by manually pouring from appropriate containers.

For surface fuelling, the fuelling station should:

- meet EPA requirements
- be properly signposted
- be surrounded with traffic barriers
- be locked when not in use.

5.4.5 Man riding vehicles

Personnel should be transported in vehicles that are designed for such a purpose. These vehicles should be provided with:

- seating for each person
- overhead protection and an enclosure to prevent body parts protruding

- suitable access eg doors and steps
- means for passengers to signal the driver, particularly if the driver is unable to see the passengers
- enough space for a stretcher and ability to transport injured personnel.

If not self propelled, the vehicle should be towed by a locomotive or prime mover, rather than pushed.

Personnel should not be transported with explosives, spoil or construction materials, except where it has been assessed that there is no risk to passengers.

5.4.6 Rolling stock – locomotives and rail cars

In long tunnels, diesel and electric locomotives and rail cars are a common mode of hauling materials and personnel.

As well as the general issues that apply to all plant, the risk management process for rolling stock should consider the following issues:

- maximum grade
- power, diesel or electric
- fail-safe brakes with dead-man control
- speed limiters, governors
- couplings and safety chains
- signalling systems
- the rail track eg gauge, switchgear, passing zones
- pedestrian access
- appropriate rolling stock
- derailments, including prevention measures, recovery systems and equipment
- tipping systems
- buffer stops.

5.4.7 Conveyors

In tunnels, conveyors are used for the transport of spoil from the face to muck cars, or directly to the spoil stockpile or disposal area on the surface. A number of conveyor types are available for use. Conveyors should conform to *AS 1755: Conveyors – safety requirements,* which sets out the minimum safety requirements for the design, installation, guarding, use, inspection and maintenance of conveyors and conveyor systems.

The risk management process should identify and eliminate (or control) the hazards and risks associated with conveyors.

For tunnelling, the following controls should be considered:

- isolating conveyors from normal work areas to prevent entanglement of limbs or body
- preventing personnel from riding on conveyors
- using fire resistant or fire resistant anti-static conveyor belting
- providing fire extinguishers

- preventing of oversize material entering the conveyor system
- reducing spillage from overloaded conveyors eg regulate the conveyor's feed rate and belt speed
- suppressing dust
- implementing power isolation procedures to allow for maintenance, spillage clean-up, and clearing the rollers
- implementing maintenance systems that consider the increased risk, fire or falling objects, posed by failed bearings on idlers and drums
- implementing procedures after shutdown and maintenance.

5.4.8 Cranes, hoists and winders

This section refers particularly to lifting plant for materials and personnel, and includes cranes (eg elevating work platforms) and hoists (eg winders).

In addition to general plant issues, there are specific requirements for cranes and hoists, such as design standards, risk control measures, and registration requirements.

Note: Item registration needs to be renewed annually, even for plant designed prior to 2001.

Cranes and hoists must conform to the relevant parts of *AS 1418: Cranes, hoists and winches,* and their use should conform to the relevant parts of *AS 2550: Cranes, hoists and winches – safe use.*

5.4.9 Specialist plant

Control measures to prevent personnel being injured during the use and maintenance of plant must be provided and maintained as part of a safe system of work. This principle applies to all plant, whether generic equipment that is used industry-wide or specialist plant that is used in tunnel construction. All plant, even custom designed plant, is subject to the same requirements under the OHS Regulation.

Where specialist plant used in tunnel construction is moving plant, the recommendations set out in 5.4.2 also apply.

5.4.9.1 Shotcrete rigs, jumbos, road headers, TBMs and electric tunnel muckers

Significant issues regarding specialist plant include the following:

- having ventilation close to the face to remove dust
- locking-out the plant as per the manufacturer's instructions (eg isolating the power, discharging accumulators) before accessing the face or carrying out maintenance, repairs or pick changes
- not standing under unsupported ground, unless protected by overhead protection
- not standing near plant that is likely to move, or near movable parts of the plant (eg gathering arms, tail conveyors, booms) when the operator's vision is restricted
- avoiding falling objects eg from the tunnel, conveyors or booms
- avoiding rotating drill steels that catch clothing and hair.

5.4.9.2 Other purpose-built tunnelling equipment

Other purpose-built tunnelling equipment (eg formwork, liner-segment handling equipment and spoil-car tipping station) also fall under the definition of plant, and the designer and manufacturer have the same duties and obligations as those who manufacture and design any other plant.

5.5 Other common tunnelling risks

5.5.1 Noise

Construction in tunnels and associated construction work and the enclosed work environment, combined with the plant and tunnelling activity, can generate high noise levels.

Clause 49 of the OHS Regulation requires employers to ensure that appropriate control measures are taken if a person is exposed to noise levels that:

(a) exceed an 8-hour noise level equivalent of 85 dB(A), or

(b) peak at more than 140 dB(C).

The WorkCover NSW *Code of practice for noise management and protection of hearing at work* provides practical guidance on managing noise levels in the workplace. This code adopts the NOHSC *National code of practice for noise management and protection of hearing*.

All workplaces that exceed the noise levels prescribed in the OHS Regulation should be assessed, unless workers' exposure to noise can be reduced below these levels immediately. As a general rule, if it is necessary to use a raised voice to communicate with a nearby personnel (say, one metre away), it is advisable to carry out an assessment.

In the assessment of noise levels it should be noted that:

- hearing loss or damage may be related to both duration of exposure and loudness of the noise
- hearing loss may be permanent
- noise assessments should be carried out by competent persons.

Examples of relevant hazards and risks include the following:

- poor sound-insulated stationary equipment eg compressors
- high-noise activity eg rock drilling, air tools
- high-noise mobile equipment eg loaders, road-headers, shotcrete machines.

Controls for noise include the following:

- isolating the noise by an engineered solution, such as:
  - constructing sound-deadening structures around static plant
  - fitting sound-attenuating silences to fans
  - fitting and maintaining mufflers to exhausts
  - applying sound-proofing material to walls and around equipment
  - selecting low-noise equipment
- reducing effects of high-noise activity by:

    - fitting sound-absorbing material eg workshop walls
    - limiting personnel in high-noise areas eg at the face during drilling
    - initiating blasts from a distance eg from the surface
    - enforcing PPE hearing-protection use
    - limiting exposure times
- reducing effects of high-noise mobile equipment by:
    - selecting plant with lower noise output
    - increasing efficiency of silencers
    - fitting additional mufflers to exhausts.

As the risks to hearing are so widespread in tunnelling works, all persons underground should carry at least basic hearing protection (eg ear plugs) for use when appropriate. More task specific hearing protection should be provided at the relevant work locations.

5.5.2 Hazardous substances

As the first option to reduce risks associated with hazardous substances, consideration should always be given to using substances that are less hazardous.

Where hazardous substances are introduced into a tunnel (or into an enclosed space), care must be taken to reduce the chance of spillage or loss of containment, and the hazard that this may give rise to. Some of these contaminants may be hazardous substances for which established workplace exposure standards must be observed.

Chapter 6 of the OHS Regulation sets out the requirements for managing the risks arising from hazardous substances. The WorkCover NSW *Code of practice for the control of workplace hazardous substances* provides advice on meeting the requirements of the OHS Regulation.

It is recommended practice not to store hazardous substances below ground. Only sufficient quantities of these materials for use on one day or shift should be held below ground. Before a new substance is introduced to the underground workplace, a risk assessment should be conducted in order to determine if there is a potential for it to cause a hazardous contamination of the air or ground. Consideration should be made of the risk it poses during normal use, storage and if containment is lost.

The manufacturer's material safety data sheet (MSDS) will provide information on the hazards associated with the material, including how to deal with spillage, leaks and fires.

Written procedures for safe use and handling, including emergency procedures, should be prepared for all substances posing a significant risk. Training should be given to all personnel using these substances.

Where hazardous substances are used, employers must:

- prevent exposure beyond the standard exposure limits
- train employees in the safe use of the substance and ensure they have access to the manufacturer's MSDS
- ensure that any necessary PPE is available and used
- ensure that all containers are labelled, especially when a hazardous substance is decanted

- ensure that all containers are cleaned when empty
- keep a register of hazardous substances used and a record of training provided
- provide supervision by competent person
- undertake health surveillance and biological monitoring where there is a risk to employees of exposure to hazardous substances affecting their health and safety (See cl.165, OHS Regulation).

For information on dangerous goods see section 5.4.4. Advice on complying with the dangerous goods provisions of the OHS Regulation can be found in the WorkCover NSW *Code of practice for the storage and handling of dangerous goods.*

5.5.3 Visibility and lighting

Clause 46 of the OHS Regulation requires employers to ensure that lighting is provided that:

(a) is adequate to allow employees to work safely

(b) does not create excessive glare

(c) is adequate to allow persons who are not employees to move safely within the workplace

(d) facilitates safe access and egress from the place of work, including emergency exits.

Poor visibility can result in:

- collisions
- persons struck or run over by plant
- inability to assess conditions of ground, plant and the like
- trips, falls and other injuries
- fatigue.

Control measures that should be considered include the following:

- hard wired lighting at transformer installations, workshops or service bays, fuelling points, pump stations or sumps, stores areas, crib rooms, loading points, unloading points, shaft and tunnel intersections, plant rooms, and in the transition zone some distance into the tunnel
- additional lighting at the face area eg lighting on the platform of mobile equipment
- adequate lighting for detailed work, hazardous processes, and where machinery is being operated
- lighting of emergency egress.

Where cap lamps are provided, there should be:

- one cap lamp provided, charged and maintained for all underground personnel
- adequate lamps to allow each lamp to be fully charged each day
- spare cap lamps for other personnel that may be underground on any given day.

5.5.4 Compressed air

Compressed air systems include air compressors, receivers (pressure vessels) that may be stand-alone or contained within the compressor unit, water traps, and reticulation such as valves and hoses supplying compressed air-powered tools and equipment. These systems may represent hazards and risks during installation and use. The WorkCover NSW *Guide for Plant 2001* also provides information on controlling workplace plant-related risks.

Injuries can be caused by:

- a sudden release of pressure due to a failure with pressure vessels or pipes, flexible hoses and tools
- incorrect installation of pipes, inadequate pressure rating, stressed joints
- incorrect work methods eg pressure not bled before working on reticulation, checks not made before pressurisation, uncoupling hoses under pressure, not fitting clips or safety chains
- unsafe acts eg cleaning with compressed air without appropriate PPE
- absence of PPE, inappropriate PPE
- contamination of the atmosphere by oils or exhaust in compressed air.

Controls for eliminating the risk of compressed air include the following:

- installing isolation valves 200m apart and at intersections
- installing and maintaining pressure relief valves
- supporting pipes at each end before joiner, and to the wall or roof
- ensuring traffic has adequate clearance around plant
- using appropriate equipment eg correct pressure-rated equipment, such as hoses, valves and pipe work, and compressors that supply oil-free air
- maintaining equipment appropriately eg maintain lines, repair leaks promptly, place receivers in protected positions, clip hoses and chain joints for hoses more than 50mm diameter
- storing equipment safely
- conducting periodic checks as required eg check pressure gauges on receivers, check valves before turning on air, clear water traps and drains daily, bleed all pressure from systems before disconnecting, re pressurise slowly, check pressure fittings for tension or other loads, use compressed air appropriately
- using appropriate PPE eg use eye and hearing protection when blowing out holes.

5.5.5 Electrical safety

Clause 64 of the OHS Regulation requires employers to ensure that:

(a) Electrical installations at places of work

all electrical installations at a place of work are inspected and tested, after they are installed and prior to their energising for normal use, by a competent person to ensure they are safe for use, and

(a1) all electrical installations at a place of work are maintained by a competent person to ensure they remain safe for use

(a2) Electrical articles used in construction work
all electrical articles that are used in construction work are regularly inspected, tested and maintained by a competent person to ensure they are safe for use if the articles are supplied with electricity through an electrical outlet socket

(a3) Electrical articles that may be affected by hostile environment
all electrical articles that are supplied with electricity through an electrical outlet socket that are at a place of work where the safe operation of the electrical article could be affected by a hostile operating environment are regularly inspected, tested and maintained by a competent person to ensure they are safe for use

(a4) Electrical installations and articles found to be unsafe
all electrical installations and electrical articles at a place of work that are found to be unsafe are disconnected from the electricity supply and are repaired, replaced or permanently removed from use

(b) plant is not used in conditions likely to give rise to electrical hazards

(c) appropriate work systems are provided to prevent inadvertent energising of plant connected to the electricity supply

(d) if excavation work is to be carried out at a place of work, all available information concerning the position of underground electrical cables is obtained and disseminated to persons at the place

(e) persons at work, their plant, tools or other equipment and any materials used in or arising from the work do not come into close proximity with overhead electrical power lines (except if the work is done in accordance with a written risk assessment and safe system of work and the requirements of the relevant electricity supply authority)

(f) any electrical cord extension sets, flexible cables or fittings:
   (i) are located where they are not likely to be damaged (including damage by liquids) or are protected against any damage
   (ii) are not laid across passageways or access ways unless they are suitably protected

(g) adequate signs to warn of the hazards, and (if necessary) restrict access, are provided at or near any area in which there is a risk of exposure of persons to hazards arising from electricity.

In this clause, **hostile operating environment** means an operating environment at a place of work where an electrical article is in its normal use subjected to operating conditions that are likely to result in damage to the article, and, for example, includes an operating environment that may:

(a) cause mechanical damage to the article, or

(b) expose the article to moisture, heat, vibration, corrosive substances or dust that is likely to result in damage to the article.

Clause 41 of the OHS Regulation outlines particular risk control measures that must be observed by controllers of premises and clauses 207 and 208 prescribe a range of safety measures to be observed when conducting electrical work on electrical installations.

This section of the code on electrical safety should be read in conjunction with the following Standards and installation rules:

- *AS/NZS 3000: Electrical installations* (known as the Australian/New Zealand wiring rules), which is mandatory under the *Electricity (Consumer Safety) Regulation 2006*
- *AS/NZS 3012: Electrical installations – construction and demolition sites,* which has been adopted as a code under the WorkCover NSW *Code of practice for technical guidance*
- *NSW Service and Installation Rules: Section 7 – High voltage installations.*

5.5.5.1 Installation, inspection, testing and record-keeping

To ensure they are safe, all electrical installations associated with tunnel construction must be inspected and tested by a competent person after they are installed and prior to their energising for normal use. All electrical articles used in construction work must be regularly inspected, tested and maintained by a competent person to ensure they are safe for use if the articles are supplied with electricity through an electrical outlet socket. All electrical installations and electrical articles associated with tunnel construction that are found to be unsafe must be disconnected from the electricity supply and repaired, replaced or permanently removed.

These activities must be carried out in accordance with the OHS regulatory requirements contained in the WorkCover NSW *Code of practice for electrical practices for construction work* and theWorkCover NSW *Code of practice for low-voltage electrical work*.

5.5.5.2 Electric cables – reeling and trailing

There should be a cable management system in place specifying minimum installation requirements to ensure that reeling or trailing cables are protected from damage. Trailing cables must only be handled during normal operation using appropriate PPE such as hooks, tongs, slings, or other PPE and equipment designed for the purpose.

5.5.5.3 Cables – construction wiring

Construction wiring and switchboards should be supported and positioned at a height above the tunnel floor to prevent damage from passing vehicles, mobile equipment, falling rocks and the like.

Single and three-phase final sub-circuits must be protected by a residual current device (RCD) with a rated tripping current not exceeding 30 mA, which operates in all live (active and neutral) conductors. This includes construction lighting, socket outlets supplying hand-held or portable equipment, and relocatable structures.

Light fittings should be fitted with a cover to protect against moisture and dust.

5.5.5.4 Portable generators

Portable generators should not be used or placed in tunnels unless they are diesel-powered and fitted with exhaust scrubbers. Portable generators must comply with *AS 2790: 1989 (as amended) Electricity generating sets – transportable (up to 25kW)*. Depending on the type of generator, they should be connected to the wiring and equipment in accordance with *AS/NZS 3012: Electrical installations – construction and demolition sites* and *AS/NZS 3010: Electrical installations – generating sets.*

The following arrangements are permitted for single-phase generators:

- a generator connected to a site switchboard, which is fitted with socket-outlets and RCD protection. In this case the generator must be installed by an electrical contractor in accordance with the requirements of *AS/NZS 3000: Wiring rules* and AS/NZS 3010 and be inspected and tested by a licensed electrician prior to being introduced to service and after relocation
- a generator with integral 30mA RCD and socket-outlets to which portable equipment can be connected.

5.5.5.5 High voltage installations

High voltage means an operating voltage of more than 1000 V a.c. or 1500 V d.c. between phase conductors or between a phase conductor and an earth as defined in *AS/NZS 3000: Wiring rules*.

A qualified electrical engineer should design the high-voltage reticulation and earthing system for tunnel construction. They should also certify that the high-voltage earthing systems have been tested and that all the electrical protection will operate as designed should an earth fault occur. A **qualified electrical engineer** means an electrical engineer who is a charter member of the Australian Institution of Engineers, or a person who is recognised by WorkCover as being competent to exercise the functions of a qualified engineer.

An employer must ensure that personnel carrying out work on a high-voltage system hold a current certificate for high-voltage work, or are directly supervised by a person qualified in such work.

An access permit system must be in place to monitor all persons who access high-voltage installations.

Clause 32(3) of the *Electricity (Consumer Safety) Regulation 2006* requires electrical installation work to be carried in accordance with *AS/NZS 3000:2000 Wiring rules* and *AS/NZS 3000:2000 Electrical installations*.

A note at the end of Clause 32(3) of the *Electricity (Consumer Safety) Regulation 2006* requires persons carrying out work on electrical installations connected, or intended for connection, to a distribution system within the meaning of the *Electricity Supply Act 1995* to have regard to the *New South Wales Service and Installation Rules* published by the Department of Energy, Utilities and Sustainability from time to time.

Section 7 of the *NSW Service and Installation Rules* describes operating procedures and criteria that are to be followed when work is carried out on a high voltage electrical installation. Attachment A to section 7, under the heading 'Schedule of Minimum Operating Procedures and Safety Equipment', sets out a number of criteria for working on high voltage electrical installations. These include:

- staff and contractors are adequately trained to work on the installation
- operating procedures are established and safety equipment is provided to ensure the safe performance of all work on the installation.
- operating procedures are to comply with the procedures detailed in the supporting standard *AS 2467: Maintenance of electrical switchgear*
- electrical safety rules covering all aspects of operating the high voltage installation are to be documented and provided to all persons engaged in the work
- operators are to be trained in the use of high voltage earthing equipment
- testing equipment is to be provided to prove the installation is deenergised
- access permit forms are to be provided to facilitate the monitoring of all persons accessing isolated sections of the high voltage electrical installation.
- the provision of a live line indicator stick, which is tested at least once every 12 months.

Other aspects of safe work practices and procedures for work on a high voltage electrical installation can be found in the *NSW Service and Installation Rules.*

Signs indicating 'DANGER – HIGH VOLTAGE' should be in suitable positions along the entire length of the high voltage cable. They must be placed on the outside of the substation enclosure, and at each entry point. Appropriate signs must also be placed on all high-voltage plant and equipment. An 'AUTHORISED PERSONS ONLY' sign must be placed on all doorways and panels of the substation. High voltage switchgear and associated equipment must be clearly labelled to indicate the portion of the electrical installation that it controls.

5.5.6 Welding (and oxy cutting)

Part 7.3 of the OHS Regulation sets out particular risk control measures for welding, including exposure to atmospheric contaminants and other hazards, and ultraviolet radiation.

Section 187 of the OHS Regulation requires employers to ensure that:

(1) exposure of persons to atmospheric contaminants arising from welding, including fumes, gases and vapours emitted from materials consumed during welding and from materials being welded, is controlled by use of one or more of the following measures (in descending order of priority):

  (a) substituting a less hazardous process, material or procedure

  (b) using appropriate ventilation.

(2) persons directly involved in welding are wearing appropriate personal protective equipment

(3) adequate signs to warn of the hazards are provided at or near any area in which there is a risk of exposure of persons to hazards arising from welding.

Section 189 of the OHS Regulation requires employers to ensure that risks associated with exposure of persons to harmful levels of ultraviolet radiation at or near the site of welding are controlled by use of the following measures (in descending order of priority):

(a) using appropriate screens to provide protection from ultraviolet radiation

(b) ensuring that persons required to be in an area in which there is a risk of exposure to ultraviolet radiation are wearing appropriate protective equipment

(c) ensuring that persons who are not carrying out welding are not permitted to enter an area in which there is a risk of exposure to ultraviolet radiation and that adequate signs to warn of the hazards are provided.

Additional control measures that should be considered include the following:

- fitting flash back arrestors to gas-based welding equipment
- transportation and securing of cylinders to fixed supports or appropriate trolleys
- storing gas-based welding cylinders in ventilated areas
- limiting below ground storage, to prevent the build-up of explosive atmospheres
- providing additional extraction ventilation when welding
- fitting voltage-reduction devices to electric welders.

For further information, see Appendix 2.

5.5.7 Confined spaces

Tunnels under construction must be assessed for risks associated with confined spaces as defined in Cl 66 of the OHS Regulation. There may also be activities on the surface during construction that could constitute confined spaces.

Clause 68 of the OHS Regulation requires employers to ensure that no person enters a confined space, or work is not carried out inside or outside a confined space if:

(a) there is a risk to the health and safety of a person entering, occupying or working on the surface of the confined space, or

(b) there is a risk of fire or explosion, and the risk has not been controlled as required by this Regulation.

The OHS Regulation imposes restrictions on persons authorised to enter a confined space and on when those persons are allowed to enter. Clauses 66-78 of the OHS Regulation outline the requirements for working in confined spaces. Guidance can be found in *AS 2865: Safe working in a confined space*.

Examples of hazards and risks include entering shafts, tanks, pipes and pumping station sumps; extreme temperature; and poor air quality.

Examples of controls include the following:

- directing adequate ventilation flows into the work area
- standing personnel outside a confined space when a person is working inside
- directing gases to the open air, or using continuous air replacement systems
- using purging agents
- testing the air quality to determine areas of possible contamination
- providing appropriate emergency equipment
- planning, establishing and rehearsing emergency procedures.

5.5.8 Manual handling

Manual handling is any activity requiring the use of force exerted by a person to lift, lower, push, pull, carry or otherwise move, hold or restrain any animate or inanimate object. This may also include sustained and awkward postures or repetitive motions.

It is one of the main hazards that cause back pain and other musculoskeletal disorders.

Clause 80 of the OHS Regulation requires employers to ensure that:

(a) all objects are, where appropriate and as far as reasonably practicable, designed, constructed and maintained so as to eliminate risks arising from the manual handling of the objects

(b) work practices used in a place of work are designed so as to eliminate risks arising from manual handling

(c) the working environment is designed to be, as far as reasonably practicable and to the extent that it is within the employer's control, consistent with the safe handling of objects.

Further information about manual handling is available from clauses 79-81 of the OHS Regulation and from the *National Code of Practice for Manual Handling* (NOHSC:2008 (1990)).

Examples of manual handling controls for tunnels include the following:

- considering manual handling issues in the design, or suitability assessment, of plant
- modifying the design of the objects to be handled
- using mechanical aids or machines for lifting
- planning ahead, selecting correct equipment, redesigning tasks
- using team lifting
- mechanising ground support and other material handling operations
- introducing palletised or bulk-handling systems
- introducing pods for transporting materials with service vehicles
- purchasing materials in bulk or in smaller weight containers
- minimising double-handling by planned placement of materials
- limiting loads lifted and carried
- using waist-height storage areas
- using work platforms to avoid extensive reaching

- training personnel in manual handling techniques, correct use of mechanical aids and team lifting
- modifying the workplace, taking into account work design and work practice to avoid lifting, twisting, slips and trips
- rotating tasks to avoid prolonged repetition of handling.

5.5.9 Falls from heights

Clause 56 of the OHS Regulation requires employers to ensure that risks associated with falls from heights are controlled by provision and maintenance of:

(i) a stable and securely fenced work platform (such as scaffolding or other portable work platform), or

(ii) if (i) is not reasonably practicable – secure perimeter screens, fencing, handrails or other forms of physical barriers capable of preventing the fall of a person, or

(iii) if (ii) is not reasonably practicable – other forms of physical restraints that are capable of arresting the fall of a person from a height of more than 2 metres.

Employers are also required to provide safe means of movement between different levels.

Tunnels under construction present an increased risk of falls due to the wet, slippery or uneven ground, inadequate lighting, or inappropriate PPE. Areas where fall protection could be required include the following:

- shafts, pits, trenches and sumps
- cuttings and benches,
- elevated structures, working platforms, service platforms, ladders, stairs, formwork, lifts, scaffolding, bins, walls, roofs, portal walls and batters
- plant, bins and tanks.

In addition to the control measures specified in the OHS Regulation, the following control measures may be appropriate:

- improved lighting
- stairways instead of ladders
- signposting hazards
- housekeeping, such as removing trip hazards, grading roadways and rectifying slippery areas.

Separate guidance material is also available from WorkCover NSW in relation to safe work on roofs, use of fall arrest systems and portable ladders. Standards Australia has guidance material on industrial fall-arrest systems, portable ladders, fixed platforms, and scaffolding.

More information is available in the WorkCover NSW *Safe Working at Heights Guide 2006*.

5.5.10 Falling objects

Clause 57 of the OHS Regulation requires employers to ensure that risks associated with falling objects are controlled by the use of the following measures:

(a) provision of safe means of raising and lowering plant, materials and debris in the place of work

(b) provision of a secure physical barrier to prevent objects falling freely from buildings or structures in or in the vicinity of the place of work

(c) if it is not possible to provide a secure physical barrier, provisions of measures to arrest the fall of objects

(d) provision of appropriate personal protective equipment

(e) isolate danger zone to establish a ‘no go’ area.

Risk assessments should be performed to determine appropriate control measures to protect persons from accidental falls of objects, including rock, shotcrete, spoil, tools, plant and other construction materials.

The following are highlighted for the particular risk of falling objects, from or into:

- shafts, including working stages or platforms within them
- pits, trenches, sumps, benches
- equipment, bins, tanks, kibbles, spoil stackers, lifts, plant
- building of roofs or walls of the tunnel, cuttings, portal walls, batters
- elevated structures, such as conveyors, hoisting facilities, bins, tipping mechanisms for spoil, working platforms, formwork, ladders, scaffolding.

Controls that can reduce the risk of objects falling from heights include:

- modifying design eg kick (toe) boards, chutes, splash plates
- prohibiting work above other persons
- installing screens, overhead protection, protected walkways, isolating danger areas as ‘no go’ zones
- housekeeping floors and access ways, cleaning spillage, using lanyards or thongs on tools.

5.5.11 Vibration

In tunnels, the operation of certain tools and plant can expose persons to high levels of harmful vibration. The types of hand-held plant that can generate such vibration are rock drills, jack picks, concrete vibrators, air tools and the like. Mobile plant can also generate high vibration levels.

Controls that can reduce vibration include the following:

- replacing hand held machines with remote controlled systems eg rock-drilling jumbos or slide-mounted drills
- fixing out of balance items
- servicing plant to the manufacturer’s specifications to reduce vibration
- use of vibration absorbing handles or rubber type vibration insulating devices between the tool and the hands
- providing foot-pusher plates for sinking drills
- providing suspended or vibration absorbing seating in plant
- providing padded seating in man riding vehicles.

5.5.12 Eye injury

Projected objects or hazardous substances could cause eye contact. Some hazards may be physical, such as rock, metal shards, glass, mud and dust. Others may be chemical, such as acids, fuel, cement powders, oil and ammonium nitrate etc. Risks can also include high pressure water, acidic ground water, polluted water, or radiation from welding.

Risk factors should be considered when repairing plant and equipment, installing support, welding, working on pumps or water lines, turning on air and water, blowing out hoses, hammering steel, dropping objects, or handling substances.

Risks of eye injury can be eliminated or controlled by the following:

- using alternative methods such as tunnel machine methods (not drill and blast) or automatic drilling machines
- draining pressure from air lines before work
- covering substances when handling
- not pouring or improvising when handling hazardous substances
- using fitting guards and screens
- using engineering methods
- providing appropriate training, instruction and information
- using PPE during hazardous activities, and eye protection at all times regardless of the activities
- specialised eye protection (eg visors and goggles) where required.

As the risks of eye injury are so widespread in tunnelling works, all persons underground during the tunnel construction should carry at least basic eye protection, and use it when appropriate. More task specific eye protection should be provided at the relevant work locations.

APPENDIX 1 – WORKERS COMPENSATION INSURANCE

Anyone who employs workers, and in some cases engages contractors, must maintain a current workers compensation insurance policy. Penalties apply for failing to have a current policy in place.

All employers have a legal liability to pay workers compensation to workers who are injured in the course of their work, and employers are required by law to hold a workers compensation insurance policy from a licensed WorkCover insurer or Scheme Agent to cover that liability.

For workers compensation insurance purposes the *Workplace Injury Management and Workers Compensation Act 1998* (1998 Act) defines a worker, subject to certain specified exceptions to mean:

> *A person who has entered into or works under a contract of service or a training contract with an employer (whether by way of manual labour, clerical work or otherwise, and whether the contract is expressed or implied, and whether the contract is oral or in writing).*

In addition, the 1998 Act deems certain other persons to be workers for workers compensation purposes eg some types of contractors.

For assistance in clarifying your obligation contact your insurer, Scheme Agent or the WorkCover Assistance Service on **13 10 50.**

APPENDIX 2 – USEFUL PUBLICATIONS

WORKCOVER GUIDES

- *A guide to dust hazards*
- *First aid in the workplace guide* Cat No 121
- *Guidelines for writing work method statements in plain English* Cat No 231
- *HazPak* Cat No 228
- *High visibility clothing guide*
- *Plant guide* Cat No 233
- *Risk management* Cat No 425
- *Safe working at heights guide 2006* Cat No 1321
- *CHAIR safety in design tool guideline for building and civil projects* Cat No 976
- *Subby pack* Cat No 975
- *Use of personal protective equipment at work – a guidance note*
- *Work involving use of carcinogenic substances* Aug 2002

WORKCOVER CODES OF PRACTICE

- *Code of practice: Control of workplace hazardous substances* Cat No 153
- *Code of practice: Amenities for construction work* Cat No 317
- *Code of practice: OHS consultation* Cat No 311
- *Code of practice: Electrical practices for construction work* Cat No 301
- *Code of practice: Low voltage electrical work.*
- *Code of practice: Excavation (2000)* Cat No 312
- *Code of practice: Moving plant on construction sites (2004)* Cat No 1310
- *Code of practice: Noise management and protection of hearing at work* Cat No 150
- *Code of practice: Storage and handling of dangerous goods (2005)* Cat No 1354
- *Code of practice: Overhead protective structures* Cat No 17
- *Code of practice: Technical guidance* Cat No 962
- *Code of practice: Working in hot or cold environments (2001)* Cat No 309
- *Code of practice: Storage and handling of dangerous goods.*

NATIONAL OCCUPATIONAL HEALTH AND SAFETY COMMISSION (NOHSC) PUBLICATIONS

These publications can be obtained from the Office of the Australian Safety and Compensation Council (formerly NOHSC) or **www.ascc.gov.au**.

- *Adopted national exposure standards for atmospheric contaminants in the occupational environment* (NOHSC:1003)
- *Code of practice for the safe removal of asbestos* (NOHSC:2002 (2005))
- *Guidance note on the interpretation of exposure standards for atmospheric contaminants in the occupational environment.* 3rd Edition (NOHSC:3008)
- *Membrane filter method for estimating airborne asbestos fibres.* 2nd Edition (NOHSC: 3003)
- *NOHSC National code of practice for noise management and protection of hearing at work* (NOHSC:2009 (2000))

AUSTRALIAN STANDARDS

Standards may be purchased directly from Standards Australia, currently via SAI Global at **www.saiglobal.com/shop**

- AS/NZS 1200 — *Pressure equipment*
- AS 1269.3 — *Occupational noise management – Hearing protector program*
- AS 1270 — *Acoustics – Hearing protectors*
- AS/NZS 1336 — *Recommended practices for occupational eye protection*
- AS/NZS 1337 — *Eye protectors for industrial applications*
- AS/NZS 1338.1 — *Filters for eye protectors – Filters for protection against radiation generated in welding and allied operations*
- AS 1418 (Series) — *Cranes, hoists and winches (design series)*
- AS 1657 — *Fixed platforms, walkways, stairways and ladders – Design, construction and installation*
- AS 1668.2 — *The use of mechanical ventilation and air conditioning in buildings – Mechanical ventilation for acceptable indoor-air quality*
- AS 1674.1 — *Safety in welding and allied processes: Part 1 – Fire precautions*
- AS 1674.2 — *Safety in welding and allied processes: Part 2 – Electrical*
- AS 1742.3 — *Manual of uniform traffic control devices – Traffic control devices for works on roads*
- AS/NZS 1715 — *Selection, use and maintenance of respiratory protective devices*
- AS/NZS 1716 — *Respiratory protective devices*
- AS 1755 — *Conveyors – Safety requirements*
- AS 1891.4 — *Industrial fall arrest systems and devices – Selection, use and maintenance*
- AS/NZS 2161.1 — *Occupational protective gloves – Selection, use and maintenance*
- AS/NZS 2161.2 — *Occupational protective gloves – General requirements*
- AS/NZS 2161.3 — *Occupational protective gloves – Protection against mechanical risks*
- AS/NZS 2161.5 — *Occupational protective gloves – Protection against cold*
- AS 2187.0 — *Explosives – Storage transport and use (terminology)*
- AS 2187.1/Amdt1-2000 — *Explosives – Storage transport and use (storage)*
- AS 2187.2 — *Explosives – Storage transport and use (use)*
- AS 2225 — *Insulating gloves for electrical purposes*
- AS 2430.1 — *Classification of hazardous areas – explosive gas atmospheres*
- AS 2430.3.1 — *Classification of hazardous areas – examples of area classification – general*
- AS 2550 SEt — *Safe use of cranes, hoists and winches*
- AS/NZS 2604 — *Sunscreen products – Evaluation and classification*
- AS 2790 — *Electricity generating sets – Transportable (up to 25kW)*
- *AS/NZS 2802:200* — *Electric cables: Reeling and Trailing – for Mining and General Use (other than Underground Coal Mining)*

- AS 2865 — *Safe working in a confined space*
- AS 2985 — *Workplace atmospheres – Method for sampling and gravimetric determination of respirable dust*
- AS 2986.1-2003 — *Workplace air quality – Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography – Pumped sampling method*
- AS 2986.2-2003 — *Workplace air quality – Sampling and analysis of volatile organic compounds by solvent desorption/gas chromatography – Diffusive sampling method*
- AS/NZS 3010 — *Electrical installations – Generating sets*
- AS/NZS 3012 — *Electrical installations – Construction and demolition sites*
- AS 3640 — *Workplace atmospheres – method for sampling and gravimetric determination of inhalable dust*
- AS/NZS 3760 — *In service safety inspection and testing of electrical equipment*
- AS 3853.1 — *Fume from welding and allied processes – Guide to methods for the sampling and analysis of particulate matter*
- AS 3853.2 — *Fume from welding and allied processes – Guide to methods for the sampling and analysis of gases*
- AS 4343 — *Pressure equipment – Hazard levels*
- AS/NZS 4602 — *High visibility safety garments*
- AS 4774.1 — *Work in compressed air and hyperbaric facilities : Work in tunnels, shafts and caissons*

OTHER REFERENCES INCLUDING OVERSEAS STANDARDS

- **American Conference of Governmental Industrial Hygienists (1330 Kemper Meadow Drive Cincinnati OHIO 45240-1634)**: *Industrial Ventilation – A Manual of Recommended Practice*
- **NSW Roads and Traffic Authority (1998):**
  - *Traffic Authority Manual: Traffic control at worksites*
  - *Manual of Uniform Traffic Control Devices*
- **ISO 7243:** *Hot Environment – Estimation of heat stress on working man, based on the WBGT-index*
- **Welding Technology Institute of Australia:**
  - *Health and Safety in Welding*
  - *Guidelines on Fume Minimisation*
- **British Standard BS6164 (2001):** *Code of practice for safety in tunnelling in the construction industry*
- **International Tunnelling Association (ITA)**

  Guidance material can be ordered or downloaded from the ITA web site: **www.ita-aites.org** as follows: PATH : ITA-AITES > ITA ASSOCIATION > Products / Publications > Working Groups Publications > WG N° 5 – HEALTH AND SAFETY IN WORKS:

  - ITA booklets:
    - *Safe working in tunnelling* (2004)
    - *Guidelines for good tunnelling practice* (1993)

    - *Safe working in tunnelling* (1989)
    - *Guidelines for good tunnelling practice* (1987)
  - Articles:
    - *Guidelines for good tunnelling practice: Summary of the ITA working group report* (Tunnelling and underground space technology, Vol. 2, Nr. 2, pp. 217–218, 1987)
    - *Guidelines for good tunnelling practice* (Advances in Tunnelling Technology and Subsurface Use, Vol. 3, Nr. 4, pp. 169–193, 1983)
    - *Safety signs in tunnels* (Advances in Tunnelling Technology and Subsurface Use, Vol. 1, Nr. 2, pp. 183–190, 1981)
- **International Tunnel Insurers' Group (ITIG):** *A code of practice for risk management of tunnel works*
- **British Tunnelling Society and Association of British Insurers:** *A joint code of practice for risk management of tunnel works in the UK*

APPENDIX 3 – HAZARD CLASSIFICATION OF COMMON FUELS AND ATMOSPHERIC CONTAMINANTS IN TUNNELLING

Substance	**Hazardous substance classification**	**Dangerous Goods classification**	**Buoyancy in air** (as a pure substance at ambient conditions) ↑ = Buoyant ↔ = Neutral ↓ = Non-buoyant	**Origin or source of hazard and comments**
Acetylene	NA	Class 2.1 flammable gas	↑	Leak from gas cylinder, hoses or torch
Ammonia	Toxic, corrosive	Class 2.3 Toxic gas	↑	Evolved from concreting or grouting
Asbestos	Toxic (long-term), causes cancer	Class 9 miscellaneous	↓	Contaminated fill sites, old underground water pipes or conduit
Butane	NA	Class 2.1 flammable gas	↓	Leaks from cylinders of ‘rock gas’, butane torches
Carbon dioxide	Asphyxiant	Class 2.2 non-flammable non-toxic gas	↓	From combustion engine exhausts, filled ground, thermal areas
Carbon monoxide	Toxic	Class 2.3 Toxic gas, sub-risk Class 2.1 flammable gas	↔	Incomplete combustion from engines, higher concentrations if poorly tuned
Diesel fuel (distillate)	Harmful	Combustible liquid (included as a dangerous goods in OHS Regulation)	?	Leaks from storage tanks, pipes near petroleum installations, service stations or refuelling areas
Hydrogen sulphide	Very toxic	Class 2.3 Toxic, sub-risk Class 2.1 flammable	↓	Peaty ground, decaying organic matter eg from filled ground, thermal areas

Substance	**Hazardous substance classification**	**Dangerous Goods classification**	**Buoyancy in air** (as a pure substance at ambient conditions) ↑ = Buoyant ↔ = Neutral ↓ = Non-buoyant	**Origin or source of hazard and comments**
Kerosene and other low volatility solvents	Harmful	Class 3.3 flammable liquid	↓	Leaks from pipes or tanks near petroleum installations, service stations or refuelling areas. Leaks from storage
LP Gas	Depends on contaminants	Class 2.1 flammable gas	**?**	Leaks from tanks, pipes near petroleum installations, service stations or refuelling areas
Methane (natural gas)	NA	Class 2.1 flammable gas	↑	Leaking reticulation pipes, peaty ground, decaying organic matter eg from filled ground
Nitric Oxide			↔	
Nitrogen dioxide (and other oxides of nitrogen)	Very toxic and corrosive	Class 2.3, sub risk 5.1 oxidising and 8 corrosive	↓	Electric arc welding. Nitric oxide produced by combustion engines and explosive use quickly reacts with air to form nitrogen dioxide
Oxygen	NA	Class 2.2, sub risk 5.1 oxidising	↔	Leaks from gas cylinders or hoses (eg used with acetylene torches). Concentration in air is 21 per cent
Ozone	Hazardous	NA (not transported in cylinders)	↓	Electrical sparks and arcing (eg electric motors). Arc welding, especially of aluminium alloys. Respiratory irritant
Petrol and other high volatility solvents	Carcinogen, harmful and irritant	Class 3.1 flammable liquid	↓	Leaks from tanks, pipes near petroleum installations, service stations or refuelling areas

Substance	**Hazardous substance classification**	**Dangerous Goods classification**	**Buoyancy in air** (as a pure substance at ambient conditions) ↑ = Buoyant ↔ = Neutral ↓ = Non-buoyant	**Origin or source of hazard and comments**
Propane			↓	
Silica	Hazardous if particles of respirable size	NA	↓	Cutting sandstone rock. Cumulative exposure leads to lung damage and cancer.
Sulfur dioxide (sulphur dioxide)	Toxic and corrosive	Class 2.3 toxic gas, sub-risk Class 8 corrosive	↓	Thermal areas, combustion

Notes:

1. LP Gas is Liquefied Petroleum Gas, a mixture of propane and butane.
2. Use the above list to check the entries needed on your hazardous substances and dangerous goods register. As examples, all fuels kept at the site, gases used in cylinders and silica dust if cutting through sandstone should be included on the register.
3. Control measures required if exposure limits exceeded.
4. Buoyancy in air of a contaminant may be relevant when positioning detectors of monitoring exposures.

APPENDIX 4 – HEAT STRESS AND AIR COOLING

A table of air-cooling power as a function of air velocity (W/m2).

Air velocity	**Wet bulb temperature (°C)**					
(m/s)	20.0	22.5	25.0	27.5	30.0	32.5
0.1	176	153	128	100	70	37
0.25	238	210	179	145	107	64
0.5	284	254	220	181	137	87
1.0	321	290	254	212	163	104

Notes:

1. The values given in the above table are the clothing corrected air cooling power at varying wet bulb temperatures and air velocities.
2. The radiant temperature is taken to be equal to the dry bulb temperature, which is typically 10°C higher than the wet bulb temperature.

APPENDIX 5 – VENTILATION METHODS AND EQUIPMENT

In considering the design and capacity of a tunnel ventilation system, there are a number of configurations and types of equipment that may be used. The following is a brief outline of some of the principal alternatives.

Ventilation systems may be:

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

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

- single, double or multiple stage
- contra-rotating or non contra-rotating (normally in matched pairs)
- direct driven with motor within the fan casing, or driven with motor outside the fan casing
- flameproof type, suitable for use in hazardous atmospheres (including the motors used), 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 tunnel workings
  - may be centrifugal or axial
  - are electrically powered, sometimes adjustable and often monitored
  - often remain installed in a fixed position throughout the progress of the works.
- auxiliary fans:
  - located underground in the proximity of the workings providing the required flows at the active areas
  - used for regulating the airflows about the tunnel workings
  - 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
  - are generally axial flow and electric, but may be compressed air powered for small short-term air flow applications.

Fans are:

- usually fitted with an evase to increase efficiency and also with a shroud with a screen to prevent persons or materials coming in contact with the blades
- available for special circumstances, such as potentially flammable or explosive atmospheres, with very specific safety features, motor types and requirements
- selected for the duty required of them to meet the demands of the tunnel work, including equipment, smoke clearance, air velocity requirements, leakage losses, inefficiency, additional future needs and the like

- valued in terms of fan pressure and delivered air capacity against resistance or friction in the duct, the excavations or the workings as the case may be.

In any system, because the airflow will otherwise take the route of least resistance, the air flow is directed to the required tunnel areas by a combination of:

- ducting, including:
    - rigid ducting of steel or fibreglass for the main ventilation lines, used in the extraction system for lines under negative pressure (suction)
    - flexible ducting of canvas, polythene etc for face ventilation, sometimes the main flows for forced air flows under positive pressure (blowing)
    - flameproof, special ducting for hazardous (inflammable or explosive) atmospheres.
    - airways, including:
    - shafts, or ventilation rises conducting air to or from the surface
    - service drives or headings carrying ventilation intake or exhaust air.

The airflow may be regulated by a combination of any or all of the following:

- barricades built of timber, steel, concrete, bricks
- ventilation doors that can be opened or adjusted
- ventilation regulators that can be adjusted – usually fitted in a barricade
- booster or auxiliary fans to increase flows to selected areas
- brattice or fabric stoppings and brattice wings for directing (low pressure) flows to areas with little air movement – such as pump stations or refuges
- altering fans settings to change flows.

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 at any place in the tunnel
- a sling psychrometer to more accurately determine the relative humidity at any place in the tunnel
- a Kata thermometer to determine the cooling effect of air
- a water gauge for measuring air pressure differences (for example across a fan) and normally used with a pitot tube
- an anemometer (usually mounted on a stick) to measure the air velocity at any place in the tunnel
- continuous dust monitoring equipment (**Note:** the high humidity in tunnels can affect their accuracy)
- continuous gas monitoring equipment
- gas detection units or gas test tubes to determine the concentration of contaminants or other gases in the air etc.

In a **forced ventilation system** fresh intake air is drawn from the outside and pushed through ducting (or sometimes through other headings) via in-line fans, to the working face(s). This system has the following advantages, including:

- the air flow can be distributed through flexible ducting that is cheaper and easier to install than rigid ducting

- there is generally no need for an additional overlap system at the face, as a sacrificial section of flexible ducting can be used at the high wear section near the tunnelling activity
- activity behind the face such as trucking or service works in the access do not become a source of contaminants at the working face as the airflow is away from that face.

This system does have some significant drawbacks that have to be considered in meeting the obligations for proper ventilation, including:

- all the work activity, apart from near the fresh air discharge points, takes place in 'return' air that has been contaminated with dust, fumes etc from the working places
- the system relies simply on the dilution of the contaminants, heat etc to provide a safe environment
- the principle of capturing the contaminants as close as possible to the source is not possible
- flexible duct tends to suffer more damage and be higher maintenance than rigid ducting
- the system is not readily boosted with in-line fans
- auxiliary ventilation of other areas consists of forcing air with diluted contaminants into them, etc.

In an **extraction ventilation system**, contaminated exhaust air is drawn from the working faces or places through rigid ducting or headings to the surface via the fans either fitted in-line, into barricades or on shaft tops etc. This system has the following advantages including:

- the contaminants from the face tunnelling activity are captured into the ventilation system very close to the point of generation
- there is little contact with contaminants from the face activity
- leakage occurs into the duct only
- an overlap system is readily installed at the face to protect ducting and to allow face advance and ventilation extension
- can be incorporated with dust filter systems behind say, TBMs or roadheaders
- in-line boosting is readily done by fitting an axial fan in-line subject to power availability and pressure considerations
- auxiliary ventilation of other areas is possible by breaking into the ducting and installing *tee* or *y* pieces etc.

This system does have some drawbacks that have to be considered, including:

- the rigid ducting is harder to repair or replace than flexible duct
- installation rates are slower for rigid ducting
- costs are higher for rigid ducting
- more leaks are possible due to the greater number of joints and the need to align and sleeve each joint
- a forcing system or overlap is still required at the face generally to allow flexibility and to reduce the number of set ups to install rigid ducting that is ideally done from some distance behind the face
- The dust, fumes or gases from activity behind the face is drawn to the face first before being exhausted to the surface etc.

Note that combination systems of forced and exhaust ventilation are possible to design.

Other

Overlap is a description given to a system of:

- using a forcing fan and ducting with the forcing fan set behind the end of an extraction system
- ensuring that the forcing fan must have a lesser capacity than the extraction capacity at this point – if not, recirculation will occur
- ensuring that the forcing fan will push fresh intake air to the face where it will return with the contaminants to the exhaust duct and be removed to surface.

As ventilation fans are a major source of noise underground, the noise levels generated by the ventilation systems should be limited to those levels determined in the OHS Regulation. This states that employers must ensure that appropriate control measures are taken if a person is exposed to noise levels that exceed an 8-hour noise level equivalent of 85 dB(A), or peak at more than 140 dB(C).

In addition, common industry practice is to limit the noise levels associated with ventilation equipment to not exceed 100dBA for intermittent exposures.

Various silencers are available or can be built for noise abatement. Fans can also be mounted within sound reducing structures.

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