SAFETY IN NORWEGIAN DRILL AND BLAST TUNNELLING

NORWEGIAN TUNNELLING SOCIETY

PUBLICATION NO. 27

NORWEGIAN TUNNELLING SOCIETY



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SAFETY IN NORWEGIAN DRILL AND BLAST TUNNELLING

Publication No. 27

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Preface

The Norwegian Tunnelling Society (NFF) is a society open to individuals, companies, institutions and government services that are engaged in or associated with the construction industry where use of the underground and the related work tasks and disciplines are central.

The Society's members, both personal and corporate, come from every single segment in the industry chain. The publication *Safety in Norwegian Drill and Blast Tunnelling* is part of a series of publications published by NFF and has been produced under the direction of NFF's Development Committee.

In the text, reference is made to several Norwegian laws and regulations. We have explained the main intention of these legislative texts, but for a fuller understanding of the scope of their provisions, we recommend they be consulted in their entirety. Some already exist in English translation, others may need to be translated. This publication is intended to be used by qualified persons who understand the limitations of a concise publication.

Its content reflects the state of knowledge at the time of editing completion. Whilst every effort has been made to assure the quality of the publication, it may nevertheless contain errors and omissions. NFF and/or the authors are not liable for any errors and/or omissions in the publication or for the consequences thereof. Examples of forms that can be used for tasks specified in regulations are included in the appendices. For practical use, these forms can be downloaded from NFF's website www.nff.no.

The publication deals with matters related to safety in the performance of various types of work underground and provides recommendations as to how safety may be ensured, but the solutions must be adapted to each individual project.

The working group responsible for this publication was composed of the following members:

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Jarle Gausen	Secretary

NFF would like to thank everyone who has contributed to this publication. It is hoped it will be a useful resource in relation to safe operations during the construction of tunnels and rock caverns.

In particular, the working group would like to express their gratitude to all participants of the group interviews that were conducted in several tunnelling projects in Norway. Thank you for being willing to take part and share with us your experience, insight and knowledge of what it is like to be a tunnel construction worker.

Oslo, March 2018

Norwegian Tunnelling Society (NFF) Development Committee



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1. Introduction

The publication *Safety in Norwegian Drill and Blast Tunnelling* is intended to be a resource and a guide to promote safe operations from planning stage to completed project. The aim is that the book should help the owner or client, designer and contractor to:

- think safety throughout the planning, design and execution phases of a project
- prepare specifications and tender documents that are detailed and clear in regards to pricing of safety measures
- clarify specific requirements in Norwegian public laws and regulations in connection with project design and execution
- draw up SJA plans and HSE plans
- describe the risk factors for different types of work in tunnels and rock caverns
- provide information about the effect such factors may have on safety
- describe measures and good practice for ensuring safety underground
- carry out work in tunnels, rock caverns and shafts in a safe manner

The publication consists of two parts:

Part 1 (chapters 4 - 6), which primarily addresses clients, designers, coordinators etc; and

Part 2 (chapters 7 - 9), which describes "best practice" and is aimed at employers, foremen and tunnel construction workers.

The project participants mentioned above, all have in common an obligation to carry out risk assessment in all phases of a project. This assessment shall be made in keeping with Norwegian Standard NS 5815:2006 Risk Assessment of Construction Work.

This standard relates to risk assessment of the actual performance of construction work. Since the works may vary in scope and complexity from project to project, it is important to point out that the requirements for risk assessment laid out in the standard are minimum requirements.

The risk of personal injury, damage to the environment (including the external environment), material damage and any own-defined success factors and goals are all covered by the standard. This also extends to damage and inconvenience for third parties, for example, neighbours to the construction site. The standard is intended to be used for both large and small projects.

A number of laws and regulations relating to underground works are referred to throughout the text. The relevant documents are listed at the end of the publication.

1.1. Scope of the publication

This publication relates to underground rock works, which are described as:

All forms of rock breaking, including work on inspection, scaling and installing rock support. It also includes loading and transport of blasted rock within the workplace in connection with:

- building tunnels and rock caverns for railway projects, road projects, power stations, parking facilities, storage halls and other rock caverns
- shaftexcavation

The publication does not cover work in mines and work or driving tunnels with tunnel boring machines (TBMs).

1.2. Content

The publication describes:

- work in front of the tunnel face, at and behind the face
- transport of rock to an on-site deposit, or to the border thereof
- finishing works in the form of trenches, pipes, water and frost protection, elements and concrete works, where they are carried out simultaneously with the rock works at the tunnel face and where these works have an impact on each other

NFF's Publication No. 9 Arbeidsmiljø under jord ("The working environment underground") deals with matters relating to the working environment with a focus on health and the environment and therefore these issues are not discussed here.

2. Group interview and methodology

During the production of this publication, the working group chose to conduct group interviews with construction workers involved in various tunnel and/ or rock cavern projects in Norway. The purpose of the interviews was to gain a better understanding of the working day and the challenges faced by the workers during the different work operations. To gain necessary insight into the workers' work situation, four group interviews were conducted involving personnel from projects in Bodø, Mo i Rana and Sørkjosen, respectively.

Before the interviews, all participants were given an information letter and consent form (appendix 1). This document explains, among other things, the object of the group interview, the topic to be discussed, and how the workers' contribution was to be used in the production of this publication. Participation was voluntary and the participants could withdraw from the interview at any time. The topic and the questions, 11 in total, were directed at the workers' perceived risk during rock works in tunnels (for the complete interview guide, see appendix 2). The group interviews were conducted by two representatives from the publication working group.

The views expressed in the different group interviews were not very different, but rather a consensus of what was perceived as the greatest risks when working in a tunnel. In all the interviews, particular mention was made of the risk of rockfall, crush hazard and challenges presented by high pressure in connection with grouting. Furthermore, all the participants mentioned challenges related to communication (good communication systems were essential for communication within the shift team, and also between shift teams and truckdrivers as well as communication with those working at site outside the tunnel.

The interviews have provided an important contribution to the publication, and the findings from the interviews have been incorporated in the chapters below.



3. Definitions

3.1. Danger zone

Any area in which an employee's safety may be at risk due the nature of the work, including any area in or around work equipment.

3.2. Risk

A function of the probability of an undesirable event taking place and the consequences thereof for the employee's life or health.

3.3. Hazard source

An action or situation that could lead to an undesirable event.

3.4. Risk assessment

A methodical way of uncovering possible hazards/ risks, in order to take appropriate measures to reduce probability and or consequence.

3.5. Work permit

A work permit provides written authorisation to carry out a defined job, at a specific location in a project, under given conditions and in a safe manner. It allows the work to start once approval has been given, and as soon as a specific set of operating and safety requirements has been met and the measures taken to meet the requirements have been accepted, documented and approved.

A work permit is an operational safety barrier against undesirable events. It serves to ensure that normal barriers are not taken out of service without compensatory measures being taken. It also sets standards for different operational and safety preparations that are a prerequisite for clearing a job for execution.

Use of work permits will also ensure that simultaneous activities in a project are assessed to prevent unintended effects and avoid the escalation of undesirable events.

It is the duty of everyone involved in the planning, approval and execution of the work to assess whether there is a need for a work permit for the job in question. A work permit must be issued by a person given this authority on behalf of the project. This could be somebody working for the main contractor or the client.

See the template for a work permit in appendix 3.

3.6. Safe Job Analysis

A Safe Job Analysis (SJA) is a systematic review and assessment of hazards ahead of an activity during which hazardous situations may arise.

Everyone who is to take part in the activity in question must participate in the completion of a SJA.

The object is to evaluate whether adequate regard has been paid to safety through existing work procedures, instructions and plans, or whether there is a need to implement additional measures capable of eliminating or controlling the hazards. A SJA is also a tool for ensuring that the measures previously agreed are in fact implemented.

It is especially important to complete a SJA when:

- the work involves non-conformance with descriptions in procedures, instructions and plans
- the work operation is new and unfamiliar to those who are to perform it
- people who do not know one another are to work together
- equipment of which the workers have no experience is to be used
- the conditions have changed, for example, weather conditions, time available, altered sequence of tasks, difficult coordination with other activities
- accidents/undesirable events have occurred previously in connection with similar activities
- A SJA template and tips and advice can be seen in appendices 4 and 5.

3.7. Work instructions

Work instructions indicate how one or more persons are to act in a given situation or during the performance of an activity. The instructions may be in the form of a text, a checklist, a flow chart, pictures or video.



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DEL 1

4. The participants' tasks, responsibilities and obligations

To achieve a safe working environment underground, it is important to develop general competence and knowledge by providing all clients, designers, employers and employees with safety information relating to the site, equipment and work tasks.

The general risks that have to be controlled and the measures that are important in this connection are described in chapters 5 and 6.

Chapters 7, 8 and 9 give a description of the particular risks and relevant measures in the different work activities.

4.1. The client's responsibilities

The client has an overall responsibility to ensure that the project is planned and carried out in such a way as to give due regard to health, safety, and environment (HSE/OHS) on the building or construction

Organisation and responsibility for HSE in projects					
The owner or client has a general responsibility to ensure that projects are planned and carried out in such a way as to give due regard to health, safety and the working environment on the building or con- struction site.					
The designers mu	st identify the risk the describe specific n be p	y bring into neasures to planned out	the projec deal with t of the pro	t as a consequence o he risk that cannot ject.	f their choices, and
Enterprise 1	Enterprise 2	Enterp	orise 3	Enterprise 4	Enterprise 5
The individual en others (I	nployer is responsible into account and cont I n addition, one of the	for planning ributing to e nterprise	g, performin necessary s will be th	ng and checking their coordination vis-à-vis e principal contracto	own work, taking others. r.)
The principal cont	tractor is responsible f mon activities, wher	or coordina several en	ting the H terprises w	SE work, and for inter ork at the same site.	nal control of com-
The foremen shal and	I ensure that health ar d execution of the tasl	nd safety co ks belonging	nsideratior g to their o	ns are given priority d wn area of responsibi	uring the planning ility.
Employees shall help in the implementation of measures to provide a good and safe working environment.Safety representatives shall represent the inter- ests of employees in cases relating to the working environment.				represent the inter- ating to the working t.	
Table 1: Organisation and responsibility for HSE in projects					
 site. The client must also identify the risk factors that are created by their plans. During the planning and design phases, the client shall take special care to give due regard to HSE requirements in connection with: describing and taking into account risk factors pertinent to the works to be executed ensuring that sufficient time is set aside for detailed planning and execution of the different work operations 					
			D · ·		

- the architectural, technical or organisational choices made

During the execution of the works, the client shall give due regard to health, safety and working environment considerations when coordinating the work conducted by the enterprises on the building or construction site.

The Construction Client Regulations (BHF) basically relate to risk management and organisation. The client's HSE plan is a key tool, the purpose of which is to describe how the risk factors in the project are to be dealt with.

The HSE plan shall contain specific measures related to work that may involve a danger to life and health, and a description of specific measures required to deal with the risk factors identified during planning and design phases shall be incorporated in the tender documents.

In underground rock works, factors such as geological and rock engineering conditions have an impact on risk factors and safety. The client shall describe and take into account such factors during the planning and design phases and ensure they are later included in the tender material.

4.2. The designer's responsibilities and obligations

The designers are professional players whom the client either appoints directly or through an agreement with a contractor.

Their obligations, like those of the client, involve identifying the risk they bring into the project as a consequence of their choices, and describing specific measures to deal with the risk that cannot be designed out of the project.

Factors that the designers must take into special consideration are:

- work schedule
- location or design of the building or structure
- choice of building products
- choice of structures for foundation and bearing elements
- choice and location of installations and rigging areas
- choice of installations
- work in the vicinity of or close to other infrastructure, including traffic
- appropriate planning for operation, maintenance and cleaning

4.3. The principal contractor's responsibilities

If several enterprises work on the same worksite, and at the same time more than ten employees are employed on this site, one of the enterprises shall have the role of principal contractor with the responsibility of coordinating the health, safety and environment activities of the individual enterprises. The coordination work of the principal contractor shall include ensuring that the individual employers have the necessary information about each other's work to be able to prevent injury to the other workers. Such coordination is especially relevant in the case of work in common areas and use of shared resources such as cranes, lifts, scaffolding and portacabins.

Besides coordinating meetings, the principal contractor shall also exercise a certain form of control and supervision over common areas and shared resources. This shall in practice be done by means of inspections on the building or construction site (safety inspection rounds) and shall cover at least the basic conditions that have previously been found to have an impact on health, safety and the working environment.

The competence of the principal contractor places certain limits on the possibility of coordination. It is not a requirement that the principal contractor should become familiar with new disciplines in order to be able to check the work of others. Furthermore, the principal contractor's duty of coordination does not diminish the obligations of employers when it comes to safeguarding the health and safety of their own employees.

If a principal contractor leaves the workplace whilst the work is in progress, one of the remaining enterprises will have to take on the duty of principal contractor. The original principal contractor must give notice in good time to the remaining enterprises, such that it can be established who shall take over as principal contractor.

The difference between coordination under the Working Environment Act (AML) and coordination according to the Construction Client Regulations (BHF)

The client's coordination does not replace but comes in addition to the principal contractor's coordination. **Coordination under BHF** is a **paid, contractual task** the main purpose of which is to prevent unnecessary conflict between different enterprises and different work operations. **Focus on, and decisions as to simultaneity, sequence and time.**

Coordination under AML is an **unpaid duty** the main purpose of which is to ensure that the

individual employers have the necessary information about each other's work (when conflict cannot be avoided) so that they can take into account and prevent injury to the other employees. Focus on information and rules on use of common areas and shared resources.

4.4. The employer's responsibilities

In order to safeguard the health, safety and environment of their employees, all employers shall ensure that systematic management of health, safety and environment is implemented at all levels of the enterprise.

In addition, employers shall:

- ensure that their own activities and those of their employees are organised and performed in such a manner that persons other than their own employees, who are involved in work on the project, are guaranteed a thoroughly safe and sound working environment
- cooperate with other employers to ensure a thoroughly safe working environment
- ensure that the working hours of contracted workers are in accordance with the provisions in the Working Environment Act

See chapter 5 in this publication for a more detailed description of what systematic health, safety and environment activities entail.

4.5. The foreman's responsibilities and obligations

An employee whose job it is to supervise other employees must ensure that the due regard is paid to health and safety during the planning and execution of the work tasks that come under their own area of responsibility.

4.6. The employee's duty of participation

Employees shall participate in the development, implementation and follow-up of the enterprise's systematic management of health, safety and environment.

Employees shall take part in the organised safety and environmental work of the enterprise and shall actively contribute to the implementation of the measures intended to create a good and safe working environment.

Employees shall use protective equipment, exercise caution and notify the employer and safety repre-

sentative of any faults or defects found. Employees shall stop work if it is understood that the work cannot continue without involving danger to life or health.

4.7. The role of the safety representative

A safety representative shall be elected in all enterprises covered by the Working Environment Act. This will in practice apply to all organisations that work on construction projects in Norway.

In any enterprise with fewer that ten employees, the parties may agree in writing a different arrangement, including having no safety representative in the enterprise.

One of the tasks of the safety representative is to represent the employees' interests in matters concerning the working environment. This does not mean, however, that the safety representative should always act on behalf of his work colleagues if they have problems related to the working environment.

All problems should first be attempted to be solved by the person who best knows the problem, for example, by the individual discussing the case with their immediate superior. If the matter is not resolved, the next step is to contact the safety representative.

The safety representative shall ensure that the enterprise is organised and maintained, and that the work is carried out, in such a way that due regard is given to the employees' health safety and welfare in accordance with the provisions of the Working Environment Act.

The safety representative shall ensure in particular that:

- employees are not exposed to hazards from machines, technical apparatus, chemical substances and work processes
- protective devices and personal protective equipment are present in adequate numbers, that they are easily accessible and are in a sound condition
- the employees receive the necessary instruction, practice and training
- the work is otherwise organised such that the employees can perform the work in an appropriate manner as regards health and safety
- notification of any workplace accidents is to be sent to the appropriate authorities in accordance with the Working Environment Act, section 5-2

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- Military installations and hospital
- Mines
- Drop protection in road tunnels



5. Systematic approach to health, safety and environment management

A systematic approach to HSE management entails being one step ahead, identifying risks and implementing measures. It is a continuous process and should be an integral part of the culture of any enterprise.

The Norwegian Regulations on systematic health, safety and environment in enterprises (Internal Control Regulations) state that the person responsible for the enterprise has a duty to ensure there is systematic follow-up of health, safety and environment. This shall be done in cooperation with the employees and their representatives. The routines shall be set out in writing and shall ensure that problems are identified and dealt with promptly. Internal control is quality assurance, and entails that the enterprise shall:

- ensure that the laws and regulations in the health, safety and environment legislation that apply to the enterprise are available, and have an overview over the requirements that are especially important for the enterprise
- ensure that the employees have sufficient knowledge and skills in the systematic approach to the area of health, safety and the environment, including information about changes
- ensure that the employees participate so that collective knowledge and experience are utilised
- establish targets for health, safety and environment
- have an overview over the enterprise's organisation, including how responsibility, tasks and authority for the work on health, safety and environment are distributed
- identify dangers and problems and, on this basis, assess the risk, and also produce plans and measures for reducing the risk factors
- implement routines to identify, remedy and prevent contraventions of requirements laid down in or pursuant to legislation relating to health, safety and environment
- systematically monitor and review internal control to ensure it works as intended

Underground works are governed specifically by Regulations on the performance of work, chapter 27, Rock works, and in the Regulations on the handling of explosive substances, chapter 2, General provisions on the use of explosives, and chapter 10, Rock blasting.

In addition, the general provisions in the Working Environment Act, the Regulations on organisation, management and employee participation, the Workplace Regulations and other chapters in the Regulations on the performance of work all apply. The comprehensive rules and regulations that apply to this work represent important safety barriers for preventing accidents and injuries.

5.1. General risks in underground works

There are several sources that help to identify the risk factors, both general and specific, that are relevant during underground works. Statutory requirements as set out in the relevant laws and regulations are one source. Another is experience and learning from incidents. Last, but not least, the risk as experienced by the tunnel workers is a vital source of knowledge about these factors. Through the group interviews mentioned in chapter 2, more than 30 workers in three different contractor companies have made known what they believe to be major and relevant risk factors.

It became clear during the group interviews that a view shared by all the workers was that it is extremely unfortunate that different contractual requirements as regards safety in tunnelling work are set by the different clients. There is less respect for the importance of understanding and complying with the contractual requirements when the risk situation for the work operations is described differently from one client to another. The workers also clearly expressed frustration and resignation over some contractual requirements, which they see as inexpedient with respect to safety. This concerned in particular the ban on simultaneous drilling and bolting. It emerged that there are other work operations that the workers find to be far more hazardous, such as simultaneous bolting and charging, but which are not given the same degree of attention. The workers were very clear that it would have a huge impact on their working day and safety if there were more consistent and uniform contractual requirements in regard to safety in tunnels from client to client.

They also pointed out that there is far too much simultaneous work, for example during rigging, excavation and the transport of excavated material, or muck, which they regard as hazardous in relation to their own safety. The workers feel that there is little understanding of their safety when so many other types of simultaneous work take place in a tunnel.

Another topic the workers had fairly similar views on, was the construction time. They feel that they work increasingly against the clock and that they feel time pressure during their working day. Many sub-deadlines are perceived as being too short, and the workers feel that some of the work becomes stressful as the responsibility and time pressure are too great. It was mentioned in particular that bolt installation is a very heavy and physically demanding work operation, which is often carried out after blasthole drilling and/or parallel with the charging operation, which is also an extremely physical and laborious operation. The workers said they found that it made more sense to carry out bolt installation during blasthole drilling, as this causes less stress and strain, and in addition allows more time to inspect the rock to see whether anything has become loose during the drilling.

General risk factors during rock works in a tunnel can be summarised as follows:

Geological factors, design and location of the tunnel

- Loose rock
- Quartz, radon etc
- Cross-section
- Steep tunnels with a gradient > 14%
- Shafts
- Explosives remaining from earlier work

Conditions at the workplace

- Poor lighting
- Poor air quality, dust, gases and lack of oxygen
- Noise
- Live cables
- High-pressure water pipes and hoses
- Poor access routes
- Unsupported rock, danger of rockfall
- Fire hazard
- Explosion hazard, explosives

Conditions during work operations

- Work at a height
- Splatter hazard
- Crush hazard
- Heavy lifts

- Stress and time pressure
- Communication and culture
- Work methods
- Equipment used

Conditions resulting from sequential and simultaneous jobs

- Falling objects during simultaneous jobs at different heights
- Traffic speed of travel through work areas

Risk factors of varying degrees of seriousness can arise singly or as a combination of several factors that occur simultaneously. Rockfall at the face is probably the biggest risk factor with today's tunnel excavation methods.

How the above risks are to be controlled will be dealt with in the following chapters and sections of this publication.

5.2. Risk management

Risk management (conducting risk assessment and making decisions based on risk assessment) is central in creating safe work operations and safe end products in the building and construction industry. Risk management is a proactive approach in the sense that hazards and undesirable events are identified and handled before they potentially happen.

The goal of risk management is to make sound decisions concerning risk-reducing measures. Such decisions must be based on results of risk assessment.

Risk assessment is a combined process consisting of risk analysis and risk evaluation. These terms are explained in more detail below.

Risk analysis is systematic use of available information to identify hazard sources and estimate the risks associated therewith. The analysis is performed in three stages: 1) identify hazard sources and potential undesirable events; 2) frequency analysis (how often we think an event will occur); and 3) consequence analysis. The result of a risk analysis is often referred to as a risk picture.

Risk evaluation is a comparison of the results of the risk analysis with criteria for acceptable risk in order to assess whether the risk is tolerable or not.

As described in section 4.1, the owner shall ensure that due regard is paid to health, safety and environment on the building or construction site. The first risk assessment made for a project is carried out in the project development phase. In this



Figure 1: Risk management process (figure based on ISO 31000).

phase, risk assessments are made as a part of the feasibility study. The purpose of the feasibility study is first and foremost to find out whether the project can be carried out. The risk assessment made as a part of the feasibility study looks at all types of risks in a project, including the risk of accidents in an executing phase. An important stage in the identification of hazards in the project development phase is a preliminary examination of the site area, for example, in relation to geological dangers, risk of natural disaster, accessible infrastructure (road transport, ambulance services).

5.3. HSE plan for rock excavation works

A written plan for health, safety and environment (HSE plan) is required when rock excavation is to be carried out. The HSE plan must be prepared on the basis of a risk analysis and made available to the employees. Moreover, it should be updated regularly as required. An HSE plan for rock excavation should contain:

- measures for relevant risk factors (escape routes, rescue/refuge containers, personal ID tags)
- a description of how coordination will be addressed
- rules for safe use of methods and equipment
- a description of contingency plans
- a general outlay of the working area
- information about the ventilation system
- a description of measures for preventing explosions

- requirements pertaining to personal protective equipment and preventive measures against harmful gases
- contingency plans and measures for preventing and fighting fire
- identification and assessment of hazards
- information about safety assessments of workplaces and equipment

In the following chapters, the publication provides guidelines as to how central parts of the HSE plan for rock excavation works can be drawn up.

The HSE plan shall make it clear that the risks to which the workers are exposed at the workplace have been identified and assessed, and shall detail the measures that are to be implemented to prevent accident and injury. In particular, it shall be evident from the plan that the design, use and maintenance of workplace and equipment have been assessed for safety.

5.4. Organisation (appropriate planning) of rock excavation works

In addition to an HSE plan for rock excavation works, these works shall be organised so that the employees can perform their tasks without putting their own health and safety, or that of others, at risk. In the table below is a list of recommendations of how organisational requirements relating to rock excavation workscan be met.

Requirement that:	Can be met by:
• The workplaces shall be designed, construct- ed, equipped, put into operation, used and maintained.	 A good rigging plan, access to appropriate equipment and good routines for maintenance of equipment and facilities.
• The workplaces shall be kept in good order, and hazardous substances or deposits shall be removed or monitored.	 Good routines for order and maintenance, and measures for handling hazardous substances.
• The workplaces shall be designed and construct- ed in accordance with ergonomic principles.	 Access to appropriate equipment and resources.
• The employer shall provide necessary supervi- sion of work activities by persons with the req- uisite competence.	• Clear role descriptions for team leaders, fore- men and production managers that ensure they meet their responsibilities. Assess the need for additional supervisors.
• The employer shall ensure that there are a suf- ficient number of employees with the skills, experience and training required to do the jobs they are assigned.	 Overview of competence requirements, training and experience for the relevant work opera- tions/employees. Special focus on training in use of different types of equipment and han- dling of explosives.
 Workplaces for underground rock works shall be constructed, run, equipped and maintained so that the employees can work and move around with minimum risk. 	 Planned and maintained site roads and walk- ways that physically separate vehicular and pedestrian traffic to maximum extent possible and have good lighting. Continuous safety work. Good coordination of simultaneous activities.
• Particularly hazardous work, and work which in combination with another activity can give rise to a serious risk, shall only be carried out by employees who have been given a special permit by the employer and who have specialised skills in the area. The permit shall specify the conditions to be met and the precautions to be taken, before, during and after the work.	• Use of routine for work permit.

Table 2: Organisation of rock works

5.5. Contingency measures

This section gives an example of how contingency measures for rock works can be described.

System for overview over personnel underground	 A system shall be established that keeps track of which workers are below ground at any given time, and their probable location. There must not be more personnel inside the tunnel/rock cavern than there is capacity to evacuate to the surface or rescue chamber in an
	emergency situation.

Communication	 Communication shall be established between the personnel working underground and personnel on the surface so as to be able to raise the alarm in an emergency situation. In the event of insufficient communication equipment to safeguard the workers' health and safety, manned workplaces shall be checked every second hour. The responsibility for carrying out these checks must be defined. There shall be communication equipment/systems in all vehicles/ machines. 	
Rescue/refuge container	 The need for, and the number and location of rescue containers shall also be risk assessed when the tunnel length is greater than 500m, on the basis of the following conditions: Capacity of the rescue container (number of persons/size of gas cylinder bank). What walking distance is acceptable with the escape masks in question? Installations - where are electrical installations, machines and equipment located? Escape routes/rescue routes - connection to parallel tubes? Accessibility of the tunnel - area of the cross-section? Activities - what activities at what time? Rescue containers shall be maintained and ready for use at all times. A check shall be carried out at a minimum of every two weeks and shall be documented in the HSE logbook for rescue container checks. Location of the rescue containers shall be indicated on the rigging plan/map with profile number. If a rescue container is moved, the rigging plan shall be updated. 	
Marking of tunnel tubes and niches	 Tunnel tubes and niches shall be marked so that personnel can find their way in a rescue operation. The marking shall be indicated on plans/maps in the contingency plan with profile number. 	
Fire contingency measures	 Storage of inflammable material in tunnels shall be avoided. All mechanical equipment (cars, loaders, drilling jumbos, charging vehicles) shall be equipped with at least one 6 kg ABC fire extinguisher. Locations or structures that represent a particular fire hazard, such as cable reels and transformers shall also have fire extinguishers located by them. 	
Personal torch	All personnel who are below ground shall carry a personal torch.	
Self-rescuers, escape masks	 Self-rescuers/escape masks shall be available, inside the tunnel, for all workers who are in the tunnel during operations (eg, located in machines) - escape masks with long service life shall primarily be used. All personnel shall be given training in use of escape masks. 	
Information about con- tingency measures and escape routes	 Everyone on the work team shall be given the necessary information about contingency measures and escape routes, including information about changes in the rigging plan. Regular safety and escape practices proportionate with the risk on site shall be carried out. 	

Table 3: Description of contingency measures



Illustration 1: Rescue container (Photo: Skanska Norway)

5.6. Working environment measures This section gives examples of how working environment measures for rock works can be described.

Ventilation	 There shall be continuous and adequate ventilation to provide fresh air for the workers, adapted to the work methods used and the physical strain to which the workers are subjected. The ventilation system shall be checked and maintained continuously. Responsibility must be allocated. 	
Measurement of gases, dust and noise, plus requirements for personal protective equipment	 The need to measure gases, dust and noise shall be risk assessed (what measurements shall be made, where and how often, choice of measuring method). Depending on the conditions, it is recommended that the following be measured: total dust, quartz, radon, asbestos, CO, NO₂/NOX, noise. Based on the risk assessment, a HSE plan and documentation of gas measurements in the tunnel shall be prepared. A person responsible for the measuring instruments shall be placed where exposure is expected to be greatest and taken so as to obtain representative measurements of the exposure to which the workers are subjected throughout a working day. In the event of a change in tunnel driving routines and/or work methods, measurements shall be made more frequently until the exposure level is under control. Protective equipment (respiratory and hearing protection) must be adapted to the result of the measurements. 	

Table 4: Working environment measures

5.7. Reporting of non-conformances, incidents and accidents involving explosives

This section outlines recommendations as to how non-conformances, incidents and accidents involving explosives shall be reported.

In Norway there is a specific directorate responsible for public security and emergency planning, the Directorate for Civil Protection (DSB). This body is responsible for regulating matters related to the civilian use of explosives. Therefore, DSB has been included in the reporting routines given in the table below.

Who shall report?	• The enterprise that has executed the blasting work is under obligation to report all incidents involving explosives.
How shall reporting be done?	 Incidents and accidents involving the use of explosives shall be reported immediately to the Police and the Directorate for Civil Protection (DSB). Near misses shall only be reported immediately to the Police and DSB if they have a real potential to cause injury or harm. The threshold for reporting near misses is lower in, eg, built-up areas, although a real potential of injury or damage is still required if such incidents are to be reported immediately. Serious hazard situations in connection with rock works shall also be reported to the Norwegian Labour Inspection Authority. Notification or an accident report form shall be sent as soon as possible and, at the latest within eight days of an accident, incident or near accident, to DSB at postmottak@dsb.no. Alternatively, notification may be filed electronically using the form http://www.dsb.no/skjema Accidents with explosives. In addition to a copy of the blasting plan, charging plan etc that must be included, the notification also contain the enterprise's own evaluation of the cause of the incident and what has been done to prevent repetition. DSB shall be notified immediately if it is suspected that an explosive is defective. By defective is meant that there is a product defect, material defect or other defect of the product that is assumed to be due to production, storage or distribution conditions that have occurred prior to delivery to the end user.

Table 5: Reporting

5.8. Conduct in the event of fire in a tunnel/ rock cavern during construction work

Recommendations for conduct in the event of a fire in a tunnel or rock cavern during excavation are

provided in this section. The recommendations are based on a report from the Norwegian Fire Research Laboratory on 1/10 scale experimental tests on fire in tunnels during tunnel construction.

Ventilation fan	 The fans shall not be stopped as this causes the absolutely most adverse situation for trapped personnel (supplying air/oxygen accelerates the fire thereby avoiding smoulder fire). This also applies if the ventilation ducting has collapsed and the air passes directly to the location of fire. 	
Conduct at the face and behind the face	 When the fire prevents the crews from moving past the location of fire, the following measures shall be implemented: alert crews at the surface via telephone/radio. prepare escape masks. if possible, seek refuge in a rescue container. 	
Conduct at the surface	Alert rescue personnel, authorities and personnel within the enterprise.Establish contact with the crews underground.Obtain a list of the crews that are below ground.	

Table 6: Recommended conduct

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DEL 2

6. Preparatory works – rigging and operation

The preparatory works and continual mobilisation and operation are important for safe and efficient production when the actual tunnelling work is to be carried out. This involves:

- preparing a remobilisation plan and site layout plan
- preparing a work schedule
- securing the areas for third parties
- establishing a workshop
- establishing an access control system
- establishing communications systems
- preparing contingency plans
- establishing a tunnel water treatment plant
- preparing plans for and establishing ventilation, pump lines, lighting
- establishing power and water supply to the tunnelling jumbo

These tasks will be discussed in more detail under the respective work activities in chapter 7.

6.1. High-voltage and other electrical works

Requirements

High-voltage installations:

Installations with a nominal voltage higher than 1000V alternating voltage or higher than 1500V direct-current voltage.

Low-voltage installations:

Installations with voltage of up to 1000V alternating voltage or up to 1500V direct-current voltage.

Qualification requirements:

Workers involved in the design and maintenance of electrical installations must have a relevant electrical trade certificate (license).

Project design and execution:

Electrical installations shall be designed, executed and maintained so as to ensure that they perform their intended function without posing a hazard to life, health or material assets.

The contractor responsible for the electrical installations shall meet the requirements given in the Regulations on electrical enterprises and the qualification requirements for work related to electrical installations and equipment.

Special risk factors

These may include:

- short circuits because of technical faults
- collisions into installations and cables
- damage to cables when unreeling/reeling
- earth faults
- damage to cables during behind-face work, finishing works and in particular bolt drilling for water and frost protection
- rockfalls on installations and cables
- dust, water and exhaust gases

Measures

- Installations that carry high voltage must be labelled "High voltage – danger to life", whilst low-voltage installations shall be marked with nominal voltage.
- Installations shall be protected by earth fault protection with trip settings.
- Transformers must be suitably located so that they do not cause a major danger in the event of fire.
- Transformers must not be located too close to rescue containers or objects that represent a fire hazard.
- All cables and electrical installations must be suspended so as to prevent damage during ordinary tunnelling operations.
- Cables and installations must be protected from mechanical stress with protective pipes or other durable protection.
- Work on or close to electrical installations shall be carried out as per the safety regulations for electrical installations and be risk-assessed in accordance with these regulations.
- Frequent and planned cleaning of electrical installations.

General measures for parallel electrical installations

These measures may include:

• instructing persons who are familiar with the risk factors

- allowing only qualified persons to work with electricity
- designing electrical installations
- protecting installations from collision by correct placement, physical barriers and reflectors
- providing lighting on transformer stations and cable reels
- establishing good grounding
- keeping cabinet doors closed and locked
- shielding installations from water leaks
- mounting strain reliever on the cable to the jumbo and establishing good routines for handling it (laying it to the side, checking the residual current device RCD)



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7. Work activities

This chapter describes the different activities involved in underground works.

7.1. Tunnel entrance – initial approach

The tunnel entrance must be planned and constructed on the basis of the local conditions and the contract. In the planning phase, when positioning the entrance, it is essential to map and assess conditions in the surrounding environment (buildings, wells) and the geological conditions, and determine whether there is sufficient rock cover. In addition, every effort shall be made to ensure that the tunnel entrance face is as perpendicular as possible to the tunnelling direction.

Furthermore, it is imperative to assess the need for inspection, preliminary investigations and support of the area above the entrance to protect against falling rocks, rockslides and collapse.

The first round is normally split into pilot heading, bottom heading and top heading, with a length of up to three metres. Usually two three-metre long pilot rounds are blasted putting the pilot heading ahead (if shorter rounds are blasted, the time interval between them should not be too long). This is repeated at least twice with a new single row of holes with spiling bolts. Based on geological conditions, it is determined whether stitch drilling is appropriate. If it is decided that this method is suitable for contour drilling, holes are drilled 35 cm apart from centre to centre and every other hole is loaded with contour explosive (pipe charge).

If another contractor has carried out the preparatory works in connection with establishing a cutting/tunnel entrance, they must hand over blasting plans, blasting round reports and drilling logs in order to pass on information about how the work has been done, and what explosives and detonators have been used.

Typical features Challenges		Important to remember
Tunnel entrance must be planned and constructed on the basis of local conditions. Geological conditions and adequate rock cover are key factors.	 Falling rock, rock- slides and collapse 	 Secure area above entrance. Scaling, bolting, wire mesh and straps Rockfall netting, landslide control wall and sprayed concrete may be relevant safety measures
	 Drilling on explosives (especially in invert from bench drilling) 	 Check entrance face and floor for remaining explosives Check blasting round report/drilling log for rounds in cutting
	Flyrock from blasting	 Each round must be covered with blasting mats with good overlap Consider stitching the mats together; building rock banks in front of the mats is a good measure
Table 7: Tunnel entrance	Crush hazard	• Avoid presence in danger zones and blind zones around machines with moving components or machines in motion

Measures

- Review of blasting round plans for blasting of the cutting, especially if this has been done by another contractor or before workers with tunnel competence were present on the site.
- Prepare a blasting round plan for entrance rounds (containing drilling, charging and detonation plans).
- Prepare a blasting plan for the entrance rounds that comprises covering, warning and posting plans.
- Secure the entrance face (and any cutting in towards the entrance). Determine the scope of necessary support with bolts, bars, wire mesh, strips and sprayed concrete on the basis of geology/rock conditions. It is usual to install double spiling bolts around the tunnel contour in the opening round(s). Spiling is usually done using 6-8-metre long, 32-mm diameter rebars that are grouted. The bolts are spaced at about 80 cm from centre to centre in the innermost row and at about 90 cm from centre to centre in the outermost row when the distance between

the rows is about 50-80 cm. The bolts in the two rows are staggered so that a bolt in second row comes between the bolts in the first row. Rock straps are placed between the rows, and the holes are grouted. To compensate for lack of abutment on the air side of the spiling, it is important to ensure that the cooperating arch does not fall out. This is normally done using four-metre long cross-bolts (ca. 45° radially upwards or outwards) with centre-to-centre spacing of 1.5-2 metres.

• Each round must be covered with blasting mats that are suspended from bolts across the tunnel profile. The mats must cover the whole round and have a good overlap. Consider the need to stitch the mats together depending on the surroundings. Building rock banks in front of the mats (not on top of) is a good measure. It may also be sensible to have additional mats on mobile units.

See also measures under section 7.3.1 Blasthole drilling.



Illustration 2: Entrance (Photo: Hæhre Entreprenør)

7.2. Work ahead of the tunnel work face

Works ahead of the work face as discussed here include drilling probe holes, control holes and grout holes, core drilling and grouting. These are activities whose purpose is to gather information about the rock conditions ahead of the face or render the rock impervious to water ahead of the face. The personnel involved in this work are located at the face, and the safety risks they may encounter are in general the same as those involved in work at the face (see section. 7.3), although there are also some special risk elements ahead of the face.

7.2.1. General considerations

Typical features	Challenges	Important to remember
• With extension rods using a drilling jumbo to investigate conditions ahead of the face	Rockfall from tunnel crown	 Rock support work shall be carried out before the start of drilling All bolts shall be grouted before injection work starts On the basis of identified risks, risk assessment and instructions from the jumbo manufacturer, a horizontal and vertical plane shall be defined which indicate the limits of the danger zone
• The rods must be extended	 Proximity to rotating components Noise Presence between booms Handling of heavy drill rods Travel along tunnel floor Spray from flushing water Splinters from collaring and possible failure of drill string 	• Use of automatic rod han- dling is recommended

Table 8: Long-hole drilling

Typical features	Challenges	Important to remember
 Drilling done with separate core drilling rig to extract drill cores for analysis and documentation of the rock conditions ahead of the work face Performed from the face or a niche 	Often performed by a subcontractor	 Secured and orderly rigging area Lighting of rigging area Ventilation that ensures air quality at the face Communication with other activities in the tunnel

Table 9: Core drilling

Typical features	Challenges	Important to remember
Rockfalls of varying sizes	• If grouting material flows into the fracture plane that lies parallel to the established rock cavern, the pressure could open new fractures, resulting in decreased rock stability - at worst, such frac- tures could cause rockfall	 It is recommended that sprayed concrete be applied prior to start of grouting work Observe rock cavern to check whether grouting material exits behind the face; check whether cracks arise in the rock or sprayed concrete
Packer and injection rods are pushed out of holes	 The packer may be placed in poor rock The hole can be "lubricated" by grout before the packer is placed The packer may have a wrong diameter The packer may be of too low a pressure rating The packer may be inadequately tightened because of poor threads The packer may be inadequately tightened because of inadequate make-up torque Packer and outer injection pipe do not match 	 Rods shall be secured to prevent them from coming out of the hole - they can be secured to the face by bolts or by chains between the rods Air pockets under high pressure can occur in grouting holes and can result in the injection rod being ejected from the hole if the grip between packer and borehole fails
• Grout spill	 Spill from worn couplings, hoses or taps Spill from couplings under pressure during connection Spill from taps Spill from mixer vessels Spill as a result of misunderstandings 	 Rout spill is a frequently occurring incident during grouting Sealed safety goggles shall be prescribed, and there shall be easy access to eyewash at the workplace Product data sheets must be readily accessible Communications system integrated in helmets would facilitate communication at the face
Placement of packers	 Poor rock conditions/high static water pressure 	 Grout steel pipes in the injec- tion hole prior to drilling long holes (better anchoring of packers)

Table 10: Grouting work

Special risk factors

Rod change during long-hole boring can be carried out both mechanically and manually. Mechanical rod change is recommended. Manual rod change requires thorough risk assessment, and measures in the form of, for example, work procedures so as to ensure the personnel handling the drill rods are not exposed to unacceptable risk. The following is a non-exhaustive list of special risk factors:

- rockfall from the tunnel crown, walls or work face
- crush hazard between booms
- risk of tripping on coarse rubble when moving between booms
- proximity to rotating drill rods
- handling heavy drill rods
- spray from water flushing
- rockfall and rock splinters from collar area
- communication with drill operator and personnel at the drill string

Measures

Rock support of tunnel crown and walls must be put in place before long-hole drilling or grouting can start. In particularly poor rock conditions, the face shall also be provided with support. Support with sprayed concrete will help to reduce the risk of rockfall.

To increase safety, separate work instructions shall be drawn up for long-hole and grout hole drilling.

Ensure that the tunnel floor is properly levelled ahead of the face, such that personnel can move without the risk of tripping on rubble and uneven ground.

Ensure that the equipment is maintained and is in working order, such that rod change can be carried out safely, preferably without manual handling.

7.2.2. Drilling of probe and control holes

Drilling of probe and control holes involves the drilling of long individual holes to examine the rock conditions ahead of the face and to check the effect of grouting. Drilling is done using the tunnelling jumbo.

Usually, two to six 24-metre long holes are drilled for every third round. The holes are often placed far down in the walls and in the shoulders.

Drilling of probe and control holes is carried out sporadically and can exceptionally be done using manual rod handling procedures.

7.2.3. Grout hole drilling

Grout hole drilling is done using the jumbo to form a grout umbrella around the whole or parts of the rock cavern. In comparison to probe drilling, grout hole

drilling involves significantly more drilling. A grout umbrella along the whole tunnel profile can contain over 1000 drill metres.

7.2.4. Core drilling

Core drilling is done to extract samples (core samples) from the rock ahead of the face. The drilling is done using a core drilling rig and is normally carried out by personnel who do not participate in extraction of the rock. The drill holes may be several hundred metres long, and for each core sample that is taken out, the whole drill string must be mounted and dismantled. For this reason, a well-organised rigging area must be established with good access paths around the drilling rig such that handling of the drill rods and drill cores can be done without any risk of tripping. Core drilling is often done by one to two persons, and at faces or in niches where there is no other activity. Before the start of this operation, it would be natural, in a risk analysis, to consider the following:

- need for rock support of crown, walls and face
- design of rigging area to ensure good access paths between drilling rig, drill bit magazine and core boxes
- appropriate ventilation and lighting
- communication/warning routines to responsible foreman and those running other activities

7.2.5. Grouting

Requirements

Equipment designed for correct grouting pressure must be used. This includes pumps, hoses, couplings and packers.

Special risk factors

Pre-excavation grouting using high-pressure equipment is a normal sealing method during tunnel construction. It is not uncommon to use pressures as high as 80 bar, and in some cases 100 bar. This high pressure involves a significant risk, both directly and indirectly. There have been many serious incidents associated with grout spill, including a large number of eye injuries. The high pressure can represent danger to life if it causes compression of air. Air pockets can be trapped in a hole and if the packer blocking the hole fails, the packer will shoot out of the hole.

The major risk factors in grouting are related to grouting at high pressure:

- Rockfalls of varying sizes:
 - If grout flows into a fracture plane that is parallel to the established rock cavern, the pressure could open new fractures and result decreased rock stability. At worst, such fractures could result in rockfall.

- Packers and rods are pressed out of holes:
 - The packer may be placed in poor rock.
 - The hole may be "lubricated" by grouting material before the packer is placed.
 - The packer may be of the wrong diameter.
 - The packer may have too low a pressure rating.
 - The packer can be inadequately tightened due to poor threads.
 - The packer can be inadequately tightened due to inadequate make-up torque.
 - The packer and outer pipe do not fit each other.
- Grout spill:
 - Spill from worn couplings, hoses or taps.
 - Spill from couplings under pressure during connection.
 - Spill from taps.
 - Spill from mixer vessels.

Measures

- Use products of the correct pressure rating.
- Secure the rods such that they cannot be forced out of the hole.
- Use packers of the right dimension.
- Establish routines to avoid misunderstandings, ensure that the grouting line is not under pressure before it is connected (bend the hose to check that it is not under pressure).

- Replace worn components.
- Use sealed safety goggles and suitable gloves.
- Have eyewash readily available and prioritise washing the eye well and continuously in the event of grout splatter.
- Always have easy access to HSE product data sheets for grouting materials.
- Communication between the person driving the grouting rig and the person connecting the hoses can be ensured by using communication equipment.
- To increase safety, separate work instructions should be drawn up for grouting and a SJA should be carried out before the start of grouting work.

See also:

NFF Handbook No. 01: *Berginjeksjon* ("Rock Grouting"), revised 2002

NFF Handbook No. 06: *Praktisk berginjeksjon for underjordsanlegg* ("Practical rock grouting for underground works"), 2010

NFF Technical Report No. 08: *Sikkerhet ved berginjeksjon* ("Safety during rock grouting"), 2008



Illustration 3: Grouting (Photo: Veidekke Entreprenør)

7.3. Work at the face

Work at the face includes drilling and blasting rounds, loading blasted rock material, scaling and installation of rock support. The area is often defined as extending from the tunnel face back towards the ventilation ducting, or about 50 metres from the face.

In Norway it is a requirement that the employees working at the face with charging and blasting, need to be certified as rock blasters. This is quite an extensive education, and it is DSB that issues this certificate. In addition, the rock blaster needs to work in a company where at least one fulltime employee is certified as a rock blasting manager. This certification is also issued by DSB. This extensive requirement for competence is one of the most important measures in order to keep a safe working place regarding this part of tunnelling.

For all tunnel excavation, it is essential to have control over the personnel who are in the tunnel (access control). This is important both in the case of fire or accident but also for preventing undesirable events. Furthermore, there must be satisfactory radio communication between workplaces in the tunnel and the crew at the surface. Self-rescue masks shall also be available in all vehicles and machines used in the tunnel. The tunnelling jumbo shall have a minimum of three such masks. There shall also be fire extinguishers in all vehicles and machines, and close to all objects that present a fire hazard in the tunnel (cable reel, transformer, pump container etc). The establishment of a fire water outlet on water lines in niches and breakdown bays should also be considered.

7.3.1. Blasthole drilling

Prior to the start of drilling, the face shall be checked visually and any undetonated explosives removed. The removal of old explosives shall be done by flushing out with water. If there is any doubt, the rock blasting foreman shall be called in for assessment. Drilling in old holes must never take place. The blasting round plan shall be followed precisely.

Work at the face represents a major safety risk and requires:

- assessment of risk factors
- assessment of safety measures
- good routines
- continuous monitoring and good communication

Typical features	Challenges	Important to remember
 Drilling shall be carried out as indicated in the blasting plan The work shall be led by personnel with relevant experience and competence 	Rockfalls of varying sizes	 Inspection, mechanised scal- ing, manual scaling, bolting, sprayed concrete
	Fallout of fresh sprayed concrete	Check that the concrete has sufficient strength
	Crush hazard	 Avoid presence in danger area and blind zones
	• Fire	 Self-rescue masks for everyone Fire extinguishers in all vehi- cles, machines and by all objects that present a fire hazard in the tunnel Good cleaning and maintenance
	Drilling on explosives	 Never drill in old holes; flush the face and check for remaining explosives

Table 11: Blasthole drilling

The employer must ensure that:

- only personnel who have been given the necessary training are used
- the work is led by personnel with relevant competence and experience

It is a regulatory requirement that "the employer shall ensure that nobody is in the danger zone during drilling with jumbos for production in drifts and tunnels, and the operator shall be adequately protected against flying rock fragments."

Based on the above, it is generally prohibited for anyone to be in front of the boom attachment. However, it is permissible to define the danger zone in the horizontal and the vertical plane. This is understood to mean that the upper part of the face can be outside the danger zone. An example of this is given the figure below, where the danger zone is defined as the area below the red line. For someone to be allowed in the area above the danger zone, there must be a work permit based on a risk assessment.

The risk assessment and the work permit must be prepared by competent trained workers who are involved in the project. The client must also give permission.

The work that is allowed to be done whilst drilling takes place is scaling after the bolt holes have been drilled and the bolts installed. Since there may be misfires in the floor, it is imperative that drilling in the "footwall" be completed before anyone moves in front of the boom.

A template for a work permit can be seen in appendix 3.

Defining the danger zone in the blasting plan

The main object is that booms shall not come into the vicinity of the man-basket during work at height.

Bolt drilling and drilling of face/contour/other contours shall be carried out before a basket is put into operation, ie, personnel are not allowed to move in front of the boom before this drilling work has been done, unless all boom movements are stopped.

Today, technology exists that can be installed on some jumbos which, when baskets on a tunnel rig are activated by an operator, causes a drilling boom height limit to be set in the blasting round plan (see the suggested height limit below). In the event that booms are moved above a defined safety height, the operator must indicate acknowledgment of this on a screen.

The red horizontal line marks a division of the danger zone for drilling when the man-baskets are in operation above this line.

For each new round/blasthole array, it shall be assessed and documented (for example by acknowledgement in a foreman's report) that conditions at the face are safe as regards risk factors.



Figure 2: Division of danger zone


Illustration 4: Blasthole and rock bolt drilling (Photo: Skanska Norway)

Continuous assessment of geological conditions, good scaling of the crown, walls and face as well as a manual inspection before the start of drilling are very important in order to reduce the risk of rockfalls.

For inter-shift and intra-shift communication, it is recommended that a communication system mounted in all helmets be used – with specially fitted earphones/microphones.

7.3.2. Charging

Charging of rounds in the tunnel shall follow a prepared charging plan.

It is preferable to use an emulsion-based explosive (slurry) delivered in bulk, non-electric or electronic detonators (NONEL) and primers with about 15-25 gram cartridged explosive (pentrite/dynamite). Contour and other blastholes with reduced charging potential are charged with emulsion by spring charging with an automatic hose extraction system. String charging is obtained by using a retraction system that pulls the charging hose out at a certain rate such that a string of emulsion remains with a charge concentration that is adapted to the type of charging hole so as to give the desired blasting results.

Exceptionally, other types of explosive (pipe charges, dynamite) and electronic detonators are used. Electronic detonators may have some advantages as regards precision, fragmentation of rock in a blasting round, and pollution in water. The shock tubes of non-electric detonators are a source of environmental pollution (plastic that floats and remains on beaches when dumped in the sea).

Typical features	Challenges	Important to remember
• Today, it is preferred to use emulsion-based explosive, non-electric detonators (NONEL) and primers with 15-25 gram cartridged explosive		 Do not start charging from the floor before bolting and scaling have been completed Detonators shall not be put in the priming cartridge/ primer before it is to be run into the borehole
	 Rockfalls from tunnel crown and face Work at several levels in the vertical plane 	 Thorough scaling and rock support Avoid working below the person charging the top round
 Charging may not be carried out whilst blasthole drilling is in progress Charging may not be started before blast- hole drilling has been completed 	 Spill from charging hose/ borehole Incorrect handling of explosive and equipment 	 Use eye protection Everyone who charges shall either have the Rock Blasting Certificate, be registered with DSB as undergoing training or registered as apprentice
	Unattended round	 There must always be a guard on a round that is not blasted immediately after completed charging

Table 12: Charging



Illustration 5: Charging (Photo: Veidekke Entreprenør)

7.3.3. Warning prior to blasting

If there are several outlets, faces or connecting tunnels to the area that is to be blasted, these areas shall be checked and personnel warned. If there are works in progress in the vicinity of the face (distance to face < 200 metres), a warning shall be given prior to blasting.

7.3.4. Blasting

Black powder fuse and percussion cap are used where safe. The fuse shall be laid double, and it shall be at least one metre long (two metres laid double). Otherwise, a round is fired using an ignition device. The advantage of an ignition device is that it allows control of the blasting time.

When blasting is carried out, there shall always be two persons present. Vehicles used to evacuate the tunnel shall be parked facing the exit before the work operations commence. It shall be checked that the vehicle is in order and that it is not stuck. When a black powder fuse is used to initiate the blast, the engine shall be running and one of the persons present shall be at the wheel ready to drive out of the tunnel.

Check that all explosives have detonated and that there are no misfires, especially in connection with finishing works such as mechanised scaling and muck loading and drilling a new/next round.

7.3.5. Handling of partially detonated rounds (misfires)

The rock blaster shall check all detonated rounds. If a round is partially detonated, or if it is suspected that there is still explosive in the rock, the following actions shall be taken:

- the area must immediately be closed off and secured
- the rock blasting foreman must be advised of the situation
- the work instructions that have been drawn up must be followed and a SJA prepared by the following participants: blaster, shift manager and site manager

7.3.6. Storage, temporary placement, transport and handling of explosives

Requirements

The Norwegian Directorate for Civil Protection (DSB) sets special requirements for storage and handling of explosives. This is governed by the Regulations on the handling of explosive substances, section 7, which relates to storage, and section 11, which relates to handling and temporary storage. The working environment requirements with respect to

fire and explosion hazard in connection with rock works can be seen in particular from the requirements in the Regulations on the performance of work, sections 27-18, 27-20 and 27-22.

Special risk factors

- unintentional detonation
- fire
- theft

Measures

- For transport of explosives and detonators on public roads, vehicles must be ADR-approved when more than 50 kg of explosive is to be transported. The driver of the vehicle must have an ADR certificate. ADR does not apply to closed site areas. The vehicle shall nevertheless be suitable for transport of explosives, and there must always be a fire extinguisher, minimum 2 kg, in the vehicle during transport. Mixed loads are not allowed on either public roads or closed construction sites.
- A list must be kept of the explosives that at any time are in approved storage sites (type and amount of explosive and detonator). This means that the explosives must be monitored, both at the location where they are permanently stored and at the location to which they are transported for use. Temporary placement at the user location has a time-limited duration of 12 hours maximum. This does not need any special approval, but the explosives must either be under constant supervision or properly locked up.
- Limit temporary placement of explosives and detonators on the blast site. As a general rule, explosives shall not be transported to the blast site before it is ready to be charged.
- Always store/place explosives and detonators separately.
- Separate safety plans and risk assessments must be established for handling of misfires. There are special requirements as to how this shall be done in the Regulations for the civilian handling of explosives.
- Establish good and safe routines for proper handling of explosives.
- Implement measures to prevent fire.
- Training of personnel who transport explosive goods on public roads (ADR-certificate).
- Everyone who handles explosive goods shall have special in-house training provided by the company with which they are employed.

7.3.7. Loading

Loading at the face, in a niche behind the face or from an intermediate store is carried out using different types of machines (wheeled loader, tracked loader, scooper loader, front acting shovel or loadand-carry machine). The rock can be loaded onto the vehicle or carried to an intermediate store behind the face or out to a tip. There may also be work arrangements where two loaders are used that load and carry to an intermediate store in the tunnel. To achieve an optimum/lowest possible loading time, the size of the loaders is adapted to the tunnel cross-section.

If the rock quality is considered too poor for loading to continue, the site management shall be notified immediately, and measures implemented.

Requirements

- The loader must be equipped with a fire extinguisher, self-rescue mask and communications equipment.
- Safety approved roof on the operator's cab (ROPS/FOPS).
- The operator must have a licence to operate loaders.
- The loader must be equipped with either an audio-visual system, a sound or a light signal. Thorough cleaning is important. The use of light signals is recommended in tunnels.

Special risk factors

- Rockfall from crown and face.
- Unwanted movement in the danger and blind zones of machines.
- Collision with other vehicles.
- Fire on the machine.
- Handling of blocks.
- Unauthorised persons at the face.

Measures

A good rule is to minimise movement in tunnels when loading takes place. If there is to be an inspection of the tunnel work face when loading is in progress, it must be ensured that visual contact is established with the operator of the loader and drivers in transport vehicles. All activity must be



Illustration 6: Loading (Photo: Pon Equipment)

stopped before anyone moves into the danger zone of the machines.

It may be a challenge for the loader operator if there are many large blocks in the muck pile. This requires extra handling, which entails a risk when moving/"splitting" blocks or loading on dumpers or trucks. It may be advisable to change the blasting plan if this is a reoccurring problem.

7.3.8. Transport of excavated material

Transport of rock from the face is done using dumpers, tippers, trucks, load-and-carry machines, wheeled loaders or conveyor belts on which the rock is moved either to a site for intermediate storage, a depot or directly to a tip.

Requirements

All operators of machines in a tunnel must have the relevant licence and training.

Special risk factors

There will always be a risk during loading and transport in tunnels. During loading at the face, there may be a danger of rockfall from the walls, crown or face. All machine operators must be aware of this.

Conflict between man and machine is one of the biggest risks during work in tunnels. It is therefore important that care is always taken when driving. All personnel in a tunnel, including machine operators, must be aware that rock may fall from the transport unit and cause damage to machines and equipment and, at worst, injury to personnel. The operator of a loader and the driver of a transport unit must ensure that the risk of rockfall from the box is minimal.

Sometimes visibility will be poor in the tunnel due to dust and exhaust gases during loading. If, in addition, lighting is poor, the personnel involved in loading will need to show extra vigilance. Should fire break out in a vehicle in the tunnel during the loading process, it is imperative to try to extinguish the fire immediately. If the fire is not extinguished, an alarm shall be given over the radio communication system and the tunnel must be evacuated, either to the surface or to a rescue container.

There are special challenges in connection with long, steep tunnels that have a gradient of up to 20 % (1:5) in regard to engine and brake capacity of the machines and equipment.

Other risk factors are:

- running into/over personnel
- rockfall from truck/dumper
- collisions
- no or poor visibility

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- high speed must be adapted to visibility and driving conditions
- driving off the road on the way to the tip because of slippery road surface
- poor road surface
- driving too far out on the edge of the ditch
- fire in the machine
- rocks that become stuck between tyres of dual wheels
- overturning of dumper / truck at the tip
- steep tunnels gradient of up to 20 % (1:5)

Measures

There shall be no pedestrians in the tunnel whilst loading and transport take place. If, in exceptional circumstances, this is necessary, special arrangements must be made. Operators must not move outside their vehicle at the face during loading. There shall be a special focus on keeping windows and lights clean at all times to improve visibility in the tunnel when driving.

To increase safety during transport, a risk assessment must be made before it commences, and this assessment shall be updated before each change in the transport plan. Such changes may be, for example, a new tip, relocation of an intermediate store or the arrival of winter. Routines for maintenance of the road surface in the tunnel and the roads outside (gritting) are very important and shall be a part of the risk analysis. Maintenance of the road shall be carried out by the enterprise responsible for the transport of rock. It is this company that is most dependent on a good road surface.

The transport equipment must have approved lights, reversing alarm and fire extinguisher, and planned, correct maintenance must be carried out. Cleaning of lights and brakes is an essential part of daily maintenance.

For long tunnels, ventilation/airing may be a challenge. Vehicles can in such cases be equipped with fresh air masks.

Planning of long and steep tunnels should be avoided, as it entails greater HSE risks. Steep tunnels have led to many accidents on various power plants. Maximum gradient should be around 14 % (1:7). If steep tunnels are built, special requirements must be made with regard to brake systems on machines and equipment – and specific training on the equipment must be provided.

7.3.9. Tip site

Tip sites shall be illuminated when it is dark, but in such a way that operators are not blinded. The tip

area shall be kept level, and when it is slippery it shall be cleared and gritted. A permanent tip site and other areas where use of vehicles may entail a particular hazard shall have barriers to prevent vehicles running off the road. When using tippers, loads shall be tipped into the tip, and then spread outwards. If a tip is higher than 3-4 metres, a tipper should always be used.

Special risk factors

Special risk factors in connection with tipping arise when both delivery and removal of material take place simultaneously at the tip. One special case is when crushing takes place on the tip area. Good routines and responsibility must be established as well as good communication. In addition, everyone must have a common understanding of the risk picture.

Risk elements are:

- ground failure at the tip or landfill, especially a landfill in water
- overturning of a dumper/truck at the tip
- danger of material "getting stuck in the box"
- reversing over the tip
- poor lighting
- several activities at the tip (crushing)

Measures

- Everyone must be familiar with the safety rules at the tip, and any changed circumstances during operation.
- Ground surveys are particularly important when tipping in water. Be aware of any fracturing or settling in the ground.
- Good routines for tipping and correct positioning of vehicles (avoid jack-knifing truck and trailer, do not park askew).
- If a tipper is used, the operator of the tipper is responsible for giving a stop signal.
- Material should be tipped at a safe distance from the tip edge, physical barriers should be established.
- If there is any doubt about the conditions, go out of the vehicle to check.
- Ensure there is adequate lighting.

7.4. Rock support work

Work instructions are required for all rock support work.

- Continuous checks must be made of the rock and the support work already done.
- Loose rock that presents a rockfall hazard must be removed as quickly as possible or stabilised in a safe manner. The method used to remove loose rock and secure it in place must be assessed continuously.

Appropriate methods may be:

- mechanised scaling, based on profile and geology
- manual scaling (scaling using crowbars and scaling rods)
- use of sprayed concrete
- bolting

In general, the following applies to support work:

- mechanised scaling shall always be followed by manual scaling (scaling using crowbar or scaling rod)
- no unauthorised persons may be in the vicinity of the scaling work.

Special conditions that impact on the rock support work must be passed on to the next shift and recorded in writing. Documentation shall be kept at the workplace as long as the work is in progress.

7.4.1. Mechanised scaling

This is performed using a purpose-designed scaler. The machine usually has an impact hammer (about 500 kg) mounted on a pivoting telescopic arm and a lifting/tilting cabin on a wheeled or tracked chassis.

In tunnels in competent rock, it is often preferable to use a small to moderate high-frequency hydraulic hammer adapted to the strength of the rock mass instead of a larger low-frequency hammer, so that only loose rock is cleared, and new fractures and cracks are not caused by excessive hammering on clinker rock masses.

7.4.2. Manual scaling

Manual scaling is done with a scaling rod or crowbar from a certified work platform mounted on a certified mobile base machine or from a certified man lift.

Manual scaling shall be done by a crew with the necessary experience and insight into the work (at least one member of the crew must be very experienced in this technique). The number of persons on the work platform shall always be assessed on the basis of space and need.

Challenges	Important to remember
 The size of the machine in relation to the tunnel cross-section is not adequate Comes too close to the scaling area thereby presenting a rockfall hazard via the scaling boom and in the worst case impact damage to the operators cabin 	Must have a sufficiently large machine
 Must avoid boom impact, as this damages the scaling hammer 	 The equipment must be used carefully/ properly, huge forces are involved

Table 13: Mechanised scaling

Challenges	Important to remember
Poor lighting	• There must be adequate lighting to be able to carry out the work in a safe manner
Crush hazard	Agreed and good communication between personnel on the work platform and operator of base machine
Uncontrolled rockfall	 If the geological conditions are such that it is not sufficient/ safe to carry out manual scaling after mechanised scaling, the rock must be supported with sprayed concrete Manual scaling must always be done from a secured area, and with the work platform positioned so that rock that is prised off falls outside the platform
Unwanted traffic in danger zone	• No unauthorised personnel must be in the vicinity when the scaling work is in progress

Table 14: Manual scaling



Illustration 7: Mechanised scaling (Photo: Veidekke Entreprenør)



Illustration 8: Manual scaling (Photo: Skanska Norway)

7.4.3. Bolting

Bolting is done to provide both temporary support and permanent support in order to prevent rockfall.

• Preliminary bolting at the face (grouted reinforced steel bolts, bars etc).

Challenges

- Rockfall
- Grout spill
- Crush hazard
- Rotating machine parts
- Installation of bolts in the face during blasthole drilling

Table 15: Bolting

- Rock bolts on the face (expansion, polyester, combination bolts etc).
- Rock bolt behind the face (grouted bolts, combination bolts).

Important to remember

- The work operations involved in bolting must be included in the risk analysis, and work instructions must be drawn up for the bolting work
- There must be a work permit see template for work permit for simultaneous bolting and drilling, appendix 3



Illustration 9: Bolting (Photo: Skanska Norway)

7.4.4. Sprayed concrete

Sprayed concrete is used for both temporary and permanent support, and both before and after bolting.

An accelerator is added to the concrete in the nozzle such that it hardens and adheres quickly to the surface, and fibres are also added to take up tension and sag.

The rock is flushed with water before concrete is sprayed on to give the concrete good adhesion to the surface, and the thickness is dimensioned according to need.

Challenges	Important to remember
 Rockfall from unsupported rock Blockages Unwanted traffic in danger zone Spill from concrete discharge Spill from concrete jet and aggregate rebound Collapse of non-hardened concrete Crush hazard between concrete truck and spraying rig 	 The work operation involving sprayed concrete must be included in the risk analysis, and work instructions must be drawn up for sprayed concrete The need for a SJA must be assessed prior to the start work at each shotcreting location
Health hazard associated with both handling of cement and addition of accelerator (corrosive)	 Choose accelerator that represents minimum risk (non-alkaline) Choice of spraying rig (type) that causes minimum personal exposure/risk (remote control) Use breathing apparatus (preferably fresh air supply), face mask and skin protection when working with or in proximity to shotcreting Avoid presence of persons in polluted atmosphere (during and immediately after spraying) in areas where there is a risk of falling material

Table 16: Sprayed concrete work

7.4.5. Heavy rock support

Heavy rock support is used to stabilise rock with poor stability, little rock cover or which for other reasons requires heavier support than bolts and sprayed concrete.

Support measures may be:

- spiling
- pipe umbrellas
- sprayed concrete arches or lattice girders
- concrete linings (if the tunnel profile is "lost")

In recent years, the tendency has been towards more use of the combination of spiling and sprayed concrete arches and less use of full linings. There has been good experience with the use of pipe umbrellas (inlaid casings as spiling) in projects where the whole or parts of the cross-section are characterised by weak rock or soil-like masses.

When there is a need for heavy support, the rock conditions are often extremely poor, with a great danger of rockfall prior to rock support work. Normal rock support in the form of sprayed concrete and bolts should be installed if the conditions do allow before heavy support work is started. If support with sprayed concrete arches can be carried out some way behind the face, this will give much safer working conditions. Spiling bolts combined with rock straps can then be installed as temporary support at the face, prior to installation of sprayed concrete arches.

If the conditions require heavy support work at the face, special care must be taken. It may be necessary to sprayed concrete the face prior to the start of installation work starts in order to prevent rock face fall-out towards personnel on the floor. In extreme cases, full lining must be carried out at the face. If collapses develop it may be necessary to close the face with concrete.

It is essential to carry out risk analyses in which the prevailing geological conditions are considered prior to the implementation of these measures. The support work must perhaps be carried out in several stages (often with a SJA), but it is an absolute requirement that personnel at all times remain in a safe area.

See also:

NFF Handbook No. 05: *Tung bergsikring i underjordsanlegg* ("Heavy rock support in underground works"), 2008.

7.5. Work behind the face

Different types of work involving a risk of undesirable events are carried out behind the face. These jobs include the installation of ventilation ducting, water pipes and electricity, and the maintenance of pump systems, water supply and lighting. The work is usually done when there is no transport in the tunnel, but may also take place as a parallel activity.

Requirements

The workplace must be provided with adequate lighting and air quality. During work at a height, a certified and approved work platform and tools must be used.

Special risk factors

The major risk elements associated with work behind the face are:

- crush hazard
- "loose" compressor hoses
- falling objects
- falls from a higher level
- unintentional start of fans
- work close to ongoing transport
- dust and gas

Typical features	Challenges	Important to remember
 Drilling and installation of suspension bolts Advance of suspension wire Suspension of ventilation ducting Patching of ventilation ducting 	 Dust and rock particles from drilling Setting up, fastening and cut- ting wire. Danger of impact from tensioned wire Crush hazard if tunnel fan is started during installation work Dust and rock particles can loosen from the ducting 	 Dry drilling must not be done in tunnels Drilling should be done using the jumbo Wire must be secured before cutting Fan control should be locked during installation work Use protective goggles and dust mask

Table 17: Installation and maintenance of ventilation

Typical features	Challenges	Important to remember
 Drilling and installation of suspension bolts Connection and disconnec- tion of drill head Running of water pipe 	 Dust and rock particles from drilling Work must be carried out when loading or scaling is in progress 	 Dry drilling shall not be done in tunnels Drilling should be done using the jumbo The area around the work- place should be closed off and illuminated.

Table 18: Routing of process water

Typical features	Challenges	Important to remember
 Connection and disconnection of pump hose Running of pump piping 	 The work has to be carried out when loading or scaling is in progress Pump pipes can be heavy to handle 	• The area around the work- site should be closed off and illuminated

Table 19: Running pump piping

Typical features	Challenges	Important to remember
 Connect cable reel to transport unit Disconnect reel and move it forwards towards the face 	 Avoid damage to the cable Ensure that the reel is loose and that the cable is not pulled with the reel 	 Use adapted equipment Disconnect from voltage Ensure that the reel spins freely The cable is suspended in accordance with approved electrotechnical standards Should not be done when there is transport in the tun- nel; must be done when there is no need for power at the face

Table 20: Running power supply to the face

Typical features	Challenges	Important to remember
 Drilling for suspension bolts Suspension of ferraline Suspension and marking of cable 	 Dust and rock splinters from drilling Suspension and cutting of wire Attachment of cable to suspension wire 	 Drilling is done using tunnelling jumbo Is placed at a level with the centre of the ventilation screen Wire is fixed prior to cutting Crush hazard during routing of cable Traffic past suspension site should be avoided

Table 21: Running high-voltage cable

Typical features	Challenges	Important to remember
 Disconnection of cables Transport of transformer Connection to cables that have been run into place 	 High voltage Careful transport High-voltage connection 	 Disconnection of power prior to connection -use high-voltage electrician Transformer should be equipped with robust trans- port hook Use high-voltage electrician Should be done when there is no need for power at the face

Table 22: Relocation of transformer



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8. Work requiring coordination (during tunnel excavation)

Finishing work in this context includes all activities that take place in an underground construction site in the period between completion of rock support and handover of the site to the owner or client. Rather than making a detailed assessment of each individual activity, we will examine the risk factors the different additional works may entail as a result of simultaneity and the consequences for other activities.

In many projects, the requirement of progress means that many activities further back in the tunnel must be carried out before breakthrough of the tunnel. This makes it imperative that everyone is fully informed of what is happening in the project, and that the work sequence and routines are made clear. It is important that new information is provided when there is a change in arrangements or work operations. For all such works, it may be a challenge to have adequate ventilation of the workplace. All works that take place in parallel with tunnel driving result in lower productivity and must as a rule be carried out because of time pressure.

Activities that may take place at the same time during tunnel excavation include:

- trenching and road building
- installation work
- various concrete works

Trenching is the first activity to be done in order to develop the tunnel after it has been excavated. This involves placing drainage and cable draw pits, laying drainage pipes and ducts for electricity. The road structure has sometimes also been completed in this phase of the project. Choice of equipment is crucial in regard to the risks, and to how this work affects other activities in the tunnel.

Installation works in road and railway tunnels consist primarily of installation of bolts, concrete elements, PE foam, membranes, vaults, mesh reinforcement and technical equipment. There are several types of concrete elements that are installed in underground works, for example, wall and ceiling elements in road and railway tunnels and prefabricated elements in caverns, such as columns and flooring in parking facilities. In recent years, technical rooms have been built in transport tunnels on the basis of prefabricated solutions. Installation is often carried out in parallel with other activities and with passing traffic. These works require special machines and equipment, which must be certified and whose drivers must have machine-specific training.



Illustration 10: Element machine (Photo: Skanska Norway)

During tunnelling, concrete works are often carried out in parallel with the tunnel excavation. These may be works related to tunnel portals, concreting of OPI ducts (routing for electric cables etc), work on technical buildings and pumping stations. When time is short, concrete barriers (New Jersey) and shoulders may be slip formed. This activity will as a rule take place after breakthrough of the tunnel.

In the case of twin tube tunnels, it is possible to carry out works in one tube whilst transport takes place in the other. This requires some of the cross connections between the tubes to be blasted to a size which would allow construction machines to be driven through. The biggest challenge with this method is to establish a good ventilation system. This can be solved with a well-designed ventilation system, which includes tight walls and doors between the tunnel tubes.

The owner or client and designer have a special responsibility to identify the risk that is added to the project when a great deal of simultaneity is planned. Specific risk-reducing measures must be considered and described. The client must in addition have strong focus on coordination between participants.

Typical features	Challenges	Important to remember
• Works involving completion of/internal work in the tunnel	 Unwanted traffic in the dan- ger zone Passing vehicles, danger of collisions Polluted air Noise and light conditions 	 Planning of additional work to allow sufficient time with- out conflict with other works Risk assessment of all activi- ties with all participants Barriers of concrete blocks between activities Correct dimensioning of ventilation Extra lighting where activities take place High-visibility clothing (cl.3) Good hearing protection (personal)

Table 23: General works between tunnel work face and tunnel entrance

Typical features	Challenges	Important to remember
 Establishing pits or basins/ laying of pipes 	 Site access road Rock falling off vehicles Crush hazard Reversing/running into people Collision between vehicles Undetonated explosives 	 Systematic checking of loads on vehicles Acoustic reversing signal and camera on all vehicles Marker signs Check of blasted surfaces before drilling/picking

Table 24: Trenching/road building in tunnels

Typical features	Challenges	Important to remember
 Installation of concrete elements Installation of PE foam or membrane Fireproofing of PE foam Membrane with sprayed concrete 	 Crush hazard Falling objects Collision between vehicles Fire in plastic materials Intermediate storage of plastic materials in tunnels and rock caverns Special problems with dust during sprayed concrete work 	 Special signposting/closing off of work area Special risk assessment - heavy lifts/vacuum. Visibility marking lights. Reduce speed when passing. Use of fire close to plastic materials must be prohibited. Minimise exposure of plastic materials, under- ground (unsprayed/stored) Use dust masks, tunnelling jumbo with enclosed cab

Table 25: Installation work

Typical features	Challenges	Important to remember
 Portals Technical buildings SOS telephone booths Slip forming (NJ) 	 Lack of approved scaffolding, rail- ings, barriers, warnings etc Falling objects Many activities in the tunnel 	 Protect scaffolding and slip forms from collision Reduced speed Minimise work in the tunnel – consider prefabricated solutions

Table 26: Concrete work

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9. Rehabilitation of existing tunnels and rock caverns

Rehabilitation of existing transport tunnels normally consists of some of the following activities:

- removal of existing tunnel installations
- removal of waterproofing
- removal of existing rock support
- removal of any remaining old explosive material

After this, new caverns are established, and new and/or supplementary rock support is installed, as is new water and frost protection. This is followed by the assembly and installation of new ventilation, electrical equipment and communication equipment. The existing fill and drainage system are then removed from the tunnel floor, a larger drainage ditch is blasted, and a new road surface and drainage system are established, together with conduits for electric and communication cables. Work on electrical installations often starts before rock works and the installation of water and frost protection have been completed.

During rehabilitation work in existing underground facilities, the risk picture may be far more complicated than when corresponding work is performed in new constructions. The reason for this is that in addition to the rock and production engineering conditions, there are also operational considerations to be taken. Examples here include road tunnels with short windows of available work time, old waterways in power plants or sewage tunnels. Rehabilitation work where there is a short distance to installations in operation or to high water pressure etc is another example.

During rehabilitation work in road tunnels conflicts arise between traffic flow and a safe working environment for the tunnel workers. In general, it is the workers' safety that must be given priority. Good planning and early warning of closure will allow rehabilitation work to be carried out as efficiently and safely as possible.

Traffic flow should be defined in the specification and there should be clear requirements as regards performance of the work. It is important to be aware that rehabilitation work can be carried out with much more efficiency and safety by stopping all traffic throughout the work period. Experience has shown that in tunnels where traffic flow is maintained, the production capacity will be 30 to 50 % of the capacity that can be achieved in tunnels that are closed.

Requirements

The developer or client shall risk assess the work that is to be done with a view to safety and working environment.

The employer shall risk assess safety and working environment prior to start-up and monitor the HSE situation during the performance of the work.

Special risk factors

- Ahead of rehabilitation works, steps shall be taken to map occurrences of, for example, radon, asbestos and quartz in the bedrock.
- During the rehabilitation of existing road tunnels, it has been discovered that rock drilling, installation of water and frost protection, asphalt milling, and asphalting are jobs that generate a particularly high exposure to dust and gas. A connection has been established between quartz dust and lung damage and between exposure to radon/asbestos and lung cancer.
- During work in road tunnels, highly stressful situations arise when traffic is to pass at frequent intervals in convoys.
- The rigging and dismantling of equipment with transport in and out of the tunnel each day.
- Damage to important installations can occur as a result of, e.g., ablasting work, and thereby worsen the work situation. Importance should be given to protecting installations, and plans should be drawn up for maintaining traffic flow without safety installations.
- Emergency vehicles do not respect roadworks warnings or escort vehicles and can cause dangerous situations. Notification of the need for emergency responses through roadworks warning areas should be given to the workplace via road traffic information centres.

Measures

- Operations shall be planned so as to avoid simultaneous performance of works that have a particularly heavy impact on the working environment.
- Dust-producing works should be avoided, or dustdamping measures implemented. Dry drilling must be avoided. However, in the winter a cold draught can result in ice formation when wet drilling.

- Ventilation of the tunnel must be ensured throughout the work period. Gas readings for control of CO, NO and NO₂ should be carried out and documented continuously.
- Where it is possible to divert traffic, the work should be carried out in the daytime without any traffic flow.
- If work is to be done in tunnels carrying traffic, it is important that the traffic is made to flow at low speeds with a guide vehicle.
- Robust safety barriers shall be erected between traffic and the work area in the tunnel.

Risk	Possible physical barriers	Possible organisational barriers
Traffic in convoys (frequent convoys have a particularly stressful effect)	 Avoid convoy driving where possible Possible diversions should be considered Diversions must be used where possible; in the case of subsea tunnels, the use of ferries should be considered More consideration should be given to full closure for longer periods It must be possible to close tunnel for longish periods 	 Define convoys to fixed times, and at long intervals; important that the convoy avoids "elastic band effect" Convoys at fixed times are better than continuous convoys Provide information about closed roads at night well in advance of the start of the work - the traffic will then be able to adapt
Injury to a third party	• Traffic must not be admitted to the work area before it has been declared safe	 Sufficient time must be allowed for proper protection in connec- tion with blasting work The client must take responsibility here - means such as using fines to make traffic wait can have an adverse effect on the safety of the workers
Lack of information to road users	• Light panels should be used that provide information on the move- ment of traffic	• Requirements in this regard are established in contracts
Transport in and out of heavy special equipment for each work session	• Arrangements should be made to allow storage of equipment in the tunnels	• A contract should clearly define the equipment that is allowed to be used
The roadworks warning plan does not safeguard the safety of the workers adequately	Workers' safety comes before requirements for traffic flow	 Safety assessment conducted by the client must not only consider input from the sign authorities Sign authorities, client and con- tractor should have dialogue in order to find good solutions for guaranteeing the safety of the employees Roadworks warnings should not be subject to tender
Emergency vehicles through the road- works warning area	Communication system between traffic watch and the work crew	 Information about emergency responses should be given via the road traffic information centre

Table 27: Special risk factors and proposed measures to deal with them

10. Relevant Norwegian laws and regulations

- LOV-2005-06-17-62 Lov om arbeidsmiljø, arbeidstid og stillingsvern mv. (arbeidsmiljøloven AML) Act relating to working environment, working hours and employment protection etc (Working Environment Act)
- FOR-2011-12-06-1356 Forskrift om utforming og innretning av arbeidsplasser og arbeidslokaler (Arbeidsplassforskriften) - Regulations on the design and layout of workplaces and premises for work (Workplace Regulations)
- FOR-2009-08-03-1028 Forskrift om sikkerhet, helse og arbeidsmiljø på bygge- og anleggsplasser (Byggherreforskriften) - Regulations on health, safety and working environment on building or construction sites (Construction Client Regulations)
- FOR-2011-12-06-1355 Forskrift om organisering, ledelse og medvirkning Regulations on organisation, management and employee participation
- FOR-2011-12-06-1357 Forskrift om utførelse av arbeid, bruk av arbeidsutstyr og tilhørende tekniske krav (Forskrift om utførelse av arbeid) - Regulations on the performance of work, use of work equipment and technical associated requirements (Regulations on the performance of work)
- FOR-2017-06-15-844 Forskrift om sivil handling av eksplosjonsfarlig stoff (Eksplosivforskriften) -Regulations on the civilian handling of explosive substances (Explosives Regulations)
- FOR-2006-04-28-458 Forskrift om sikkerhet ved arbeid i og drift av elektriske anlegg Regulations on safety in work on and operation of electrical installations
- FOR-2013-06-19-739 Forskrift om elektroforetak og kvalifikasjonskrav for arbeid knyttet til elektriske anlegg og elektrisk utstyr Regulations for electrical enterprises and qualification requirements for work related to electrical installations and equipment
- FOR-1996-12-06-1127 Forskrift om systematisk helse-, miljø- og sikkerhetsarbeid i virksomheter (Internkontrollforskriften) - Regulations on systematic health, safety and environmental work in enterprises (Internal Control Regulations)

11. Literature list

NFF Handbook No. 01	Berginjeksjon (2002)
NFF Handbook No. 02	Engineering Geology and Rock Engineering (2000)
NFF Handbook No. 03	Arbeidsmiljø under jord (2000)
NFF Handbook No. 05	Tung bergsikring i undergrunnsanlegg (2008)
NFF Handbook No. 06	Praktisk berginjeksjon for underjordsanlegg (2010)
NFF Handbook No. 07	Håndbok for bestiller av bergsprengningsarbeid (2012)
NFF Handbook No. 08	Håndbok for utfører av bergsprengningsarbeid (2014)
NFF Handbook No. 09	Håndbok for arbeidsmiljø under jord (2015)

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12. Appendices

Handbooks published by NFF

No. 1:	Fjellinjeksjon. Praktisk veiledning i valg av tettestrategi og injeksjonsopplegg.	(NOK 200)
No. 2:	Engineering Geology and Rock Engineering. NBG	(NOK 500)
No. 3:	Arbeidsmiljø under jord.	(NOK 200)
No. 4:	Håndbok for skytebas.	(NOK 200)
No. 5:	Tung bergsikring i underjordsanlegg	(NOK 200)
No. 6:	Praktisk berginjeksjon for underjordsanlegg	(NOK 200)
No. 7:	Håndbok for bestiller av bergsprengningsarbeid	(NOK 200)
No. 8:	Håndbok for utfører av bergsprengningsarbeid	(NOK 200)
No. 9:	Håndbok for arbeidsmiljø under jord	(NOK 200)
No. 10:	Håndbok for sikkerhet ved arbeid i tunneler og bergrom	(NOK 200)

Technical reports published by NFF (NOK 100 each)

- No. 01: Redningskammer for underjordsdrift
- No. 02: Diesel under jord. Sluttrapport fra forprosjektet.
- No. 02E: Diesel Underground a project report.
- No. 03: Sikker sprengning i dagen.
- No. 04: Plastmaterialer i tunneler og bergrom sikker håndtering i anleggsfasen.
- No. 05: Informasjon, takk! Råd og tips om kommunikasjon i en anleggshverdag.
- No. 06: Sikker boring gjennom ylte.
- No. 07: Diesel under jord
- No. 08: Sikkerhet ved berginjeksjon
- No. 09: Behandling og utslipp av driftsvann fra tunnelanlegg
- No. 10: Rescue chamber for underground work. Translation of Technical Report 1
- No. 11: Nøyaktig boring
- No. 12: Konturkvalitet i sprengte tunneler
- No. 13: Ventilasjon ved tunneldrift
- No. 14: Gruvedrift under jord
- No. 15: Støy fra bygge- og anleggsvirksomhet
- No. 16: Anbefalte retningslinjer for utarbeidelse av miljøbudsjett og miljøregnskap for tunneller
- No. 17: Kort innføring i bruk av TBM

Publications from the Norwegian Tunnelling Technology

- No. 1 Hard Rock Tunnelling
- No. 2: Tunnelling Technology
- No. 3: Hydropower Tunnelling
- No. 4: Road Tunnelling
- No. 5: Tunnelling Today
- No. 6: Geology of Norway (a map)
- No. 7: Tunnelling Reviewed in the International Press
- No. 8: Subsea Tunnelling
- No. 9: Underground Storage
- No. 10: Urban Tunnelling
- No. 11: Hard Rock TBM Tunnelling
- No. 12: Water Control Tunnelling
- No. 13: Health and Safety in Norwegian Tunnelling
- No. 14: Norwegian Tunnelling
- No. 15: Sustainable Underground Concepts

- No. 16: Underground Constr. for the Norwegian Oil and Gas Industry
- No. 17: Underground Openings Operations, Maintenance and Repair
- No. 18: Subsea Tunnels
- No. 19: Rock Support in Norwegian Tunnelling
- No. 20: Rock Mass Grouting
- No. 21: Contracts in Norwegian Tunnelling
- No. 22: Norwegian Hydropower Tunnelling II
- No. 23: Norwegian Tunnelling Technology
- No. 24: Health, Safety and Environment in Norwegian Tunnelling
- No. 25: Norwegian Rock Caverns
- No. 26: Principles of Norwegian Tunnelling

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- TBM excavation
- Rock stability assessments and reinforcement techniques
- Analytical and numerical analyses







NFF, Publication no 27

Appendix 1.

Information letter and consent form for group interview participants

We hope that you will take part in the focus group interview organised by the Norwegian Tunnelling Society's (NFF) Development Committee, in connection with their work on a new handbook entitled Safety in tunnel and cavern construction work.

Who are we?

We are the NFF working group behind the production of the handbook and represent the Norwegian Labour Inspection Authority, Hæhre Entreprenør, the Norwegian National Rail Administration, the Norwegian Union of General Workers, Skanska Norway, the Norwegian Public Roads Administration/ Directorate of Public Road and Veidekke Entreprenør. Two representatives from the working group will conduct the interview

What do we want?

We believe that to prepare a handbook on safety in tunnel and cavern construction work it is essential to find out what those of you who work in tunnels every day think about safety and the risks you encounter. Therefore, to gain a better understanding of what this handbook should contain as regards recommended practice in tunnel and cavern construction work, we wish to learn more about your daily working life and how you see all the challenges that arise during tunnelling work.

We want to listen to what you have to say so as to be able to form as accurate a picture as possible of the real working day in tunnels and ensure the handbook contains appropriate guidelines and recommended practice with the correct focus.

What is a focus group interview?

To gain necessary insight we need to speak to you, the people who actually perform this work. We therefore wish to interview some of you in what is called a focus group interview. This is an interview form in which we gather six to ten tunnel workers (in this case a shift team) in one group and discuss different topics that we and you believe to be of importance in tunnelling work: how you perceive the risk associated with the different work operations and the surroundings, and the challenges that you yourselves experience.

Where will the interview take place?

The focus group interview will be held at the end of a shift and after a meal (eg, the afternoon shift will be interviewed after dinner). The interview will last at most 60 minutes and will be held close to your workplace.

Can I be anonymous?

As this is an interview in a group together with others in your shift team, it will not be possible to conceal your identity during the interview. However, the information you give in the course of the interview will be anonymised during our work on the handbook and will not be traceable back to you. It is up to you whether you wish to use your name during the interview or not. The interview will be audiotaped, and then played back and transcribed so that we can carefully review what you said. The recordings will be deleted as soon as transcription has been completed.

Participation is voluntary

Participation in the focus group interview is of course voluntary. If you do not wish to participate, it will not have any consequences for you or you relationship with your employer.

Should you find anything unclear or would like further information, please do not hesitate to contact us.

Marie Halvorsen Facilitator, focus group interview Tel. 932 10 005

Declaration of consent

I wish to take part in the focus group interview for the NFF Development Committee's handbook on safety in tunnel and cavern construction work. I am aware of what the interview involves, and what it is to be used for.

I am familiar with my rights as a volunteer.

PARTICIPANT'S NAME:

PARTICIPANT' SIGNATURE:

Interview guide

NFF, Publication no 27 Appendix 2.

Focus group interview: Perceived risk in underground construction work

Topics (highlighted/underlined) for discussion during the interview:

1. Perceived risk when working in a tunnel (general)

- a) What do you perceive as the greatest risk or risks when working in a tunnel?
- b) What undesirable events are most commonly reported?
- c) What is the effect of cross-section and incline versus decline? (the geometry)

2. Work ahead of the face (long-hole drilling and grouting)

- a) What do you perceive as the greatest risk in connection with long hole drilling and grouting?
- 3. Work at the face (scaling, shotcrete, drilling, charging and blasting, simultaneous drilling and bolting, loading)

a) What do you perceive as the greatest risk in connection with work at the face?b) How do you feel about different operations being carried out simultaneously?

- b) How do you reel about different operations being carried out simultaneously?
- 4. Work behind the face (behind-face work/service work, installation work simultaneous with tunnel driving)
 - a) What do you perceive as the greatest risk in connection with work behind the face, such as, eg, suspension of ventilation ducting, water and pump pipes?
 Simultaneity?

5. Transport (muck transport, tip work (overturns), road maintenance)

a) How do you feel that the transport of excavated rock, or muck, affects your safety?b) How do you think the drivers see the situation?

6. Concluding question

a) What in your view should be the major focus of this handbook on safety in tunnel and cavern construction work?

Template/Example Work Permit

Risk assessment, work permit and instructions for simultaneous work in front of the boom attachment on a drilling jumbo NFF, Publication no 27 Appendix 3.

Risk assessment, work permit and instructions for simultaneous work in front of the boom attachment on a drilling jumbo

The Norwegian Regulations concerning the performance of work (703), section 27-16, stipulates the following with regard to drilling with drilling jumbos: *"The employer shall ensure that nobody occupies the danger zone during drilling with rock drilling rigs for mine and tunnel excavation, and that operators are adequately protected against flying rock fragments."*

The comment to section 27-16 explains that: "What constitutes the danger zone should be determined specifically by identifying risks, conducting a risk assessment and having regard to instructions from the rig manufacturer."

Based on the above, no one as a general rule is allowed to be in front of the boom attachment on the drilling jumbo. Moreover, simultaneous drilling and charging is not permitted.

The division of the danger zone can be defined in the horizontal plane and the vertical plane on the basis of a risk assessment. This means that the upper part of the face could be defined as outside the danger zone as indicated in the figure

Figure – Division of the danger zone in the horizontal plane



The red horizontal line marks the division of the danger zone for drilling in a horizontal plane. Simultaneous drilling and rock support work in the form of bolting and scaling, from man-baskets above the defined danger zone in the horizontal plane, may be allowed through a work permit and instructions.

Risk identification/assessment: What can go wrong, and what can we do about it?				
Possible hazards/ risk – control questions	Νο	Yes	If yes, how should the hazards/risks be controlled?	Responsible
Is the tunnel cross-section (height) a risk for the performance of the work?				
Is there a need for measures/protection against rockfall from the crown and face?				
Is there a need for measures in connection with shotcrete applied (NB! Must have adequate strength)?				
Is there a risk of encountering high water pressure?				
Is there a risk that rockfall/rockslide can be triggered as a result of drilling in adjacent rock?				
Is there a risk of drilling into old explosive material, fragment spray produced by possible detonation of explosives that lie hidden in the face after a previous blasting round?				
Is there a risk associated with rotating drill bits and moving booms (proximity to them)?				
Is there a risk of splinters from the drill string and rock loosening and hitting personnel?				
Are there noise problems, vibrations, risk of hearing damage and accidents as a result of high noise level from boring machines in opera- tion? (Consider hearing protection, time spent in work area)				
Are there special chemical exposure hazards (dust, oil fog)				
Is there experience from previous reports of undesirable events at the face? (Findings and measures)				

- ✓ I confirm that this risk assessment has been carried out with the support of personnel who have a fundamental knowledge of rock engineering, skills in rock support work, and an adequate knowledge of HSE.
- \checkmark I confirm that bolt drilling and face/contour/other contour drilling has been completed.
- \checkmark I confirm that the floor has been checked for misfires and that the "footwall" has been drilled.
- ✓ In my view, the measures described are satisfactory to provide safety when support work is to be carried out in front of the boom attachment on the drilling jumbo at the same time as drilling.
- ✓ I also confirm that I have gone through this work permit/set of instructions with everyone who will be involved in the work operation.
- ✓ I confirm that I have gone through "Requirements that must always be met in order to control possible risk and prevent/reduce the crush hazard between moving booms and rock" with everyone involved in the work operation.

This work permit is given for the following period of time: ____

Date: _____ Name: __

Representative for employer (signature)

Signature:

Rock drill operator:	
Worker(s) in basket:	
Other workers:	
Possible representative for client	

Signed document will be filed for the project in accordance with the project's filing key.

Requirements that must always be met in order to control possible risk and prevent/reduce the crush hazard between moving booms or between boom and rock:

- ✓ Double hearing protection, frequent replacement of protection (at least every third month). Noise measurements must be carried out, and a reduction in time spent at drill rig/face considered.
- ✓ An employee who carries out work in front of the boom attachments on the drilling jumbo should do this work from an approved man-basket with railings.
- \checkmark The man-basket on the jumbo must have an emergency stop that is in working order.
- \checkmark The operator should be protected against flying rock fragments.
- ✓ There must at all times be a minimum distance between the man-basket in which the operator is positioned and the booms on the jumbo.
- \checkmark No one must be under the basket or the drilling activity
- ✓ Drilling must be carried out manually (not automatically) whilst simultaneous work is carried out in front of the boom attachments.
- ✓ Drilling should be monitored with regular mapping of the conditions, assessment of risk, implementation of measures and routines to maintain or increase safety.
- ✓ All non-conformances that are identified at the face must be registered in the enterprise's nonconformance system so that they can be used as indicators of "hazards", and at the same time ensure that necessary measures are implemented.
- ✓ Everyone involved in this work operation must have full focus and through their signature undertake to perform the measures that are described in this work permit.

Safe Job Analysis (SJA) - tips and advice What is a SJA?

NFF, Publication no 27 Appendix 4.

A SJA is a systematic review and assessment of hazards ahead of an activity during which hazardous situations may arise.

Risk should as, a general principle, be mitigated through analyses and choices made in early project phases, but changes to plans and unforeseen circumstances can necessitate reassessment of safety and implementation of measures "there and then".

When should a SJA be conducted?

It is particularly important to conduct a SJA in the following situations:

- The work results in non-conformance with specifications in procedures and plans.
- The work operation is new and unfamiliar to those who are to perform it.
- People who do not know each other are to work together.
- Equipment of which the workers have no experience is to be used.
- The conditions have changed, eg, weather conditions, time available, changed sequence of tasks, difficult coordination with other activities.
- Accidents/undesirable events have occurred previously in connection with similar activities.

Often it will be the workers themselves - those who are in the thick of it - who will discover the need for a SJA.

Some advice

• Involve the workers

Those who are to carry out the work have a unique insight into how to find practical solutions. Therefore, the workers are a key resource for the performance of a JSA. At the same time, involvement will increase awareness of the hazards and create ownership of the measures implemented.

• Be open to all input

All involved parties should be given the opportunity to comment and make suggestions if they think that major factors have not been given sufficient attention. No question or suggestion is too stupid.

			SJA – Safe Job /	Analysis				
Project (no. and name)		Person re	esponsible for SJA	(name, sign)			ă	ate:
Brief description of activity		Responsi	ble for activity (co	mpany)			_	
A SJA is being conducted becau The work results in non-conformancu The activity is new and unfamiliar. People who do not know each other	ise (cross off c e with specificati are to work toge	ne or more of the follov on in procedures and plans ther	ving): Equipment c The conditio sequence of Accidents/u	of which the wor ons have change f tasks, other act ndesirable even	kers have no experience is to d (eg, weather conditions, av tivities being carried out nearl ts have occurred previously in	be used. ailable tim by)	e, on with similar a	activities.
What tasks give cause for concern?	Hazards – v (See examples	vhat can go wrong? :in list below)	Do we have cor the hazards? (cr Yes Partly	ntrol over ross off) Little	Measures How should the hazards be o	controlled	- K	esponsible
			:)	:(
			:)	:(
			:)	:(
			:)	:(
			:)	:(
What can be learned: (To be filled	l in by person res	ponsible for SJA <u>after</u> the job l	as been done: What c	an be done diffe	ere ntly/better next time? wha	at positive	findings are imp	oortant to remember?)
Possible hazards								
1 Crashes/collision	9	Falling objects	11	High pressu	re, splatter hazard	16	Neather conditi	ions (wind, cold, fog)
2 Structural failure	7	Falls	12	Noise, vibra	tion	17	Vatural events (flood, landslide)
3 Fire, explosion	8	Heavy lifts/heavy material	5 13	Radiation		18	Work in tanks/la	ack of oxygen
4 Moving objects/crush hazard	<u>о</u>	Surfaces with high/low ter	nperature 14	Dust, smoke	e, gases, toxic substances	19	Drowning hazar	d
Sharp objects (cuts/perforations)	ΠT	KISK OT ELECTRIC SNOCKS	CT	Inadequate	lighting	70	Other, specity:	

SJA - Safe Job Analysis

NFF, Publication no 27 Appendix 5.

Norwegian Tunnelling Society NFF International Support Group

NFF, Publication no 25 Appendix 6.

The Norwegian Tunnelling Society NFF has some 1200 members, among those approximately 70 corporate members covering private sector, governmental agencies, research and education. Their representatives are active in the various permanent committees. One of these - The International Committee responsible for this publication - is specially supported by the core group presented below:

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