

# HEALTH, SAFETY AND ENVIRONMENT IN NORWEGIAN TUNNELLING



NORWEGIAN TUNNELLING SOCIETY

PUBLICATION NO. 24



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# **HEALTH, SAFETY AND ENVIRONMENT IN NORWEGIAN TUNNELLING**

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**NORWEGIAN TUNNELLING SOCIETY**

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Apprentice of the year 2014 flanked by mentors and tunnelling colleagues.

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## FOREWORD

The present publication, No. 24 in the English language series from the Norwegian Tunnelling Society NFF, has – as always – the intention of sharing with colleagues and friends internationally our latest news and experience in the use of the underground, this time with focus on health, safety and environment.

In 2004 NFF issued the Publication No.13 called Health and Safety in Norwegian Tunnelling. During the period 2004-2015 laws, regulations and critical threshold values were modified followed by controls, measurements and enhanced attention from owners and society on HSE-matters.

While preparing publication 24, the NFF Development Committee issued its Handbook 09 “Arbeidsmiljø under jord” (Work Environment Underground, April 2015). Several papers in Publication 24 are re-written selections from this handbook. Sincere thanks to the special work group. Also thanks to the Editorial Committee of Publication 24.

Finally, our sincere thanks to Authors and Supporters. Commitment and competence are the bases for the continued development of new publications.

Oslo, May 2015

**Norwegian Tunnelling Society  
International Committee**

## THE AUTHORS

Among the priority issues of the Norwegian Tunnelling Society NFF, is the sharing of information. That takes place in a variety of meetings, as proceedings from national conferences or workshops. Technical Reports, Handbooks or the English language series on matters related to tunnelling and underground work.

Without Authors no books, without willing experts no publications from NFF. Usually the Author(s) name is linked to the paper, usually some further details as to background etc is included in an appendix. For Publication No 24 called HSE in Norwegian Tunnelling, the society is indebted to some 25 authors.

The society hereby express its sincere thanks and appreciation for their efforts. In appendix IV you will find information as to background and contact options. Here are the faces behind the names



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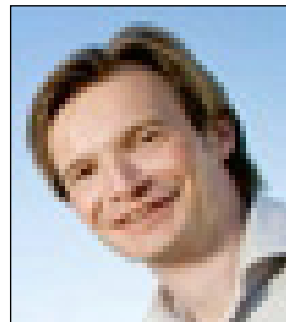
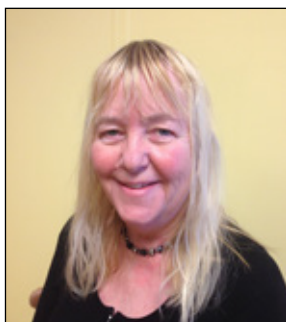


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***From left, Tom Myran and Bente Ulvestad honoured for outstanding scientific HSE research. Previous NFF Presidents Eivind Grøv and Jan Kristiansen handling diplomas and flowers.***





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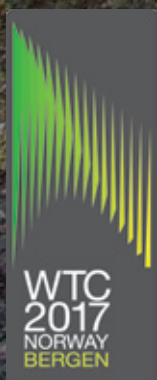
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## 01. INTRODUCTION

HAUG, Ruth G.

### HEALTH, SAFETY, ENVIRONMENT

HSE is constantly given more focus and attention in tunneling and mining works. Norway can show a positive record over the last 25 years counting accidents and fatal results. Nevertheless there are too many injuries and deaths in our industry world wide. Construction and underground works has been and will be a hazardous workplace. Taken seriously at all levels, it is possible to improve even more, in order to take care of the health in a long term perspective, get people home safely every day, avoid negative effects on our surroundings and improve the overall environment. HSE is seen as an important element in the Norwegian method of tunneling.

Norwegian Tunnel Society has over years, been looking into HSE- works for underground operations. In 2004, we introduced Publication No. 13. The issue is still of urgent importance. Underground works are more and more mechanized, the drilling operation is performed with fewer people, charging is taking place with fewer people, the explosives are more safe, and accidents are dropping. The personal responsibility is focused on each individual, where the peoples safety is given the high-

est priority. In the context of rock stability the skill and experience of the individuals are still an important part. This publication is a collection of views and experiences with HSE from several participants in the construction industries. We have made an effort to let owners, contractors, miners, suppliers and consultants be heard in order to focus on the wide variety that all includes perspectives of HSE. They are all asked to participate because we think they have experiences and knowledge we think is worthwhile sharing. We do hope you as a reader find some useful advice or input to improve the HSE in your daily work. We wish to provide the reader with a broader understanding of the legislation, regulations, practical work and improvement related to HES in Norwegian underground works.

We are grateful to all our colleagues who share their knowledge. Our national competence is growing in such way. We hope it will be fruitful also internationally. It is all about getting people home safe and sound every day!

Oslo, May 2015





***Subsea tunnel***

*Freezing zone, roof sprayed concrete supported, ready for another round. Photo NPRA*



## 02. EXPOSURE TO AEROSOLS AND GASES IN MODERN TUNNELING OPERATIONS AND LUNG FUNCTION DECLINE

BAKKE, Berit  
ULVESTAD, Bente

### ABSTRACT

#### *Objective*

Personal air measurements of aerosols and gases among tunnel construction workers were performed as part of an 11-days follow-up study on the relationship between exposure to aerosols and gases and respiratory effects.

#### *Methods*

Ninety tunnel construction workers employed at 11 construction sites participated in the exposure study. The workers were divided into seven job groups according to tasks performed. Exposure measurements were carried out on two consecutive working days between the two health examinations. Ninety tunnel workers and 51 referents were examined with lung function tests and questionnaires before their work period started and again 11 days later.

#### *Results*

The GM air concentrations for the thoracic mass aerosol sub-fraction,  $\alpha$ -quartz, oil mist, organic carbon (OC), and elemental carbon (EC) for all workers were 561  $\mu\text{g}/\text{m}^3$ , 63  $\mu\text{g}/\text{m}^3$ , 210  $\mu\text{g}/\text{m}^3$ , 146  $\mu\text{g}/\text{m}^3$ , and 35.2  $\mu\text{g}/\text{m}^3$ , respectively. Statistical differences of air concentrations between job groups were observed for all contaminants, except for OC, EC, and ammonia ( $p > 0.05$ ). Air concentrations of OC were correlated to air concentrations of oil mist ( $r_{\text{Spearman}} = 0.56$  ( $p < 0.0001$ )). The shaft drillers, injection workers, and shotcreting operators were exposed to the highest levels of thoracic dust (7061  $\mu\text{g}/\text{m}^3$ , 1087  $\mu\text{g}/\text{m}^3$ , and 865  $\mu\text{g}/\text{m}^3$ , respectively). The shaft drillers and the support workers were exposed to the highest levels of  $\alpha$ -quartz (GM= 844  $\mu\text{g}/\text{m}^3$  and 118  $\mu\text{g}/\text{m}^3$ , respectively). Overall, the exposure to nitrogen dioxide and ammonia were low (GM=120  $\mu\text{g}/\text{m}^3$  and 251  $\mu\text{g}/\text{m}^3$ , respectively).

After 11 days of work, lung function declined significantly in the tunnel workers, not in the referents. Lung function decline was associated with exposure to organic carbon.

#### *Conclusion*

The current study strengthens previous findings that use of emulsion explosive has reduced exposure to  $\text{NO}_2$  in all jobs compared to using ammonium nitrate fuel oil which was previously used. Diesel exhaust air concentrations seem also to be lower than previously assessed (as EC). Nevertheless we conclude from the study of lung function that the air exposure in today's tunnel work still appears to have a detrimental impact on the airways. We can only speculate that repeated, short-term loss of lung function, probably due to inflammation caused by exposure, still may be linked to the risk of developing chronic lung disease.

### I INTRODUCTION

Studies in the 1990ties revealed that tunnel construction workers are exposed to aerosols and gases while operating drilling machines and through detonation of explosives in confined spaces. In addition to particulate matter, diesel exhaust,  $\alpha$ -quartz, nitrogen dioxide ( $\text{NO}_2$ ), ammonia ( $\text{NH}_3$ ), oil mist and oil vapour are air contaminants that dominate in tunnel construction work. Associated health effects include airway inflammation, lung function decline and chronic obstructive pulmonary disease (COPD) (Ulvestad *et al.*, 2000; Bakke *et al.*, 2001; Bakke *et al.*, 2001; Ulvestad *et al.*, 2001; Ulvestad *et al.*, 2001; Bakke *et al.*, 2002; Ulvestad, 2002).

During the last decade efforts have been made to reduce occupational exposure to aerosols and gases among tunnel construction workers through careful planning of the work and improved ventilation of the tunnels. Today most construction projects use emulsion explosives because of its higher resistance to water. Such explosives have been shown to generate less gases following detonation compared to the former first choice Ammonium Nitrate Fuel Oil explosive (ANFO) (Bakke *et al.*, 2001). Electrically powered drilling equipment and machines are preferred to reduce the emission of diesel exhaust. In addition, new technologies such as diesel exhaust particulate filters and catalytic converters have been implemented in this industry. Also, there has



been focus on use of personal respirators when performing known high-risk tasks such as spraying of mineral oil and wet concrete.

Demands for reducing the construction time increases the number of parallel activities and amount of traffic movements within the tunnel. This may introduce new risks for the workers.

The aim of a recent study was to characterise and assess exposure to aerosols and gases among tunnel construction workers in modern tunneling operations as part of a 11-days follow-up study on the relationship between exposure to aerosols and gases and possible respiratory effects in tunnel construction workers.

## 2 MATERIAL AND METHODS

### *Work characteristics*

These tunnel construction workers work 12 days consecutively and are then off for nine days. A typical work shift lasts 10-12 hours and includes two breaks of 30 min each. Tunnel construction workers are engaged in rock drilling, charging of explosives, and various support - and finishing work. Occupational job groups in tunnel construction work have previously been described (Bakke *et al.*, 2001). Briefly, the excavation process starts off with drilling and charging of explosives. After blasting, the rock is loaded and transported out of the tunnel using dump trucks. Finally, removing of loose rocks using a scalar and various types of rock support is carried out. Rock support includes, e.g., fastening of unsafe rock with steel bolts and sealing of the rock by spraying wet concrete onto the excavated surface. Other important tasks during excavation are mounting ventilation ducts, maintenance and repair of machines, and installation of electrical power supply. If the risk of water leakage into the tunnel is considered high, injection workers carry out rock consolidation with micro concrete to prevent leakage. All tunnels investigated in this study had forced ventilation systems using fans and ventilation ductings to dilute aerosols and gases for workers in all areas of the tunnel. Excavation of the shaft followed the same sequence as for tunnels, however, instead of using an underground drilling rig, pneumatic hand held equipment for rock drilling and a raise climber were used. The only ventilation in the shaft was from pressurized air used to power the drills.

### *Study design*

All tunnel construction workers (n=91) employed at 11 available tunnel construction sites in Norway were invited for this study in 2010-2011. Participation was

voluntarily. One worker decided not to participate. Health effects assessments were performed shortly before the work shift on the first day back on site after nine days off. After 11 days of work, the medical tests were performed again at the same time of the day. In total, ninety tunnel workers and 51 referents were examined with lung function tests and questionnaires.

The workers were stratified into job groups according to tasks performed. Job groups included in this study were drill and blast workers, drill and blast mechanics (a subgroup of the drill and blast workers), support workers, loaders (a subgroup of support workers), injection workers, shotcreting operators, and shaft drillers. Personal air measurements were carried out on two consecutive working days prior to the day of the second health examination. Each worker was sampled twice. Thoracic dust, elemental carbon (EC), organic carbon (OC),  $\alpha$ -quartz, and  $\text{NO}_2$  were measured in all workers. Oil mist, oil vapour, and  $\text{NH}_3$  were measured in a subsample of workers from all job groups (N= 57), except shotcreting operators and injection workers. All samples were collected in the breathing-zone outside personal protective respirators. The sampling time varied between 270 and 855 minutes (arithmetic mean (AM) =569 minutes).

Sampling methods and analysis of the samples are described elsewhere (Bakke *et al.*, 2014)

## 3 DATA ANALYSIS

The frequency distribution was examined visually using probability plots and indicated that a log-normal distribution provided a better fit to the exposure data. The data were therefore ln-transformed before statistical analysis. The measured air concentrations were used without further adjustments. Air concentrations were summarized by geometric means (GM), geometric standard deviations (GSD), minimum concentrations (Min) and maximum concentrations (Max) using maximum likelihood estimation (MLE). Arithmetic mean was estimated from the expression  $\text{EXP}[\ln \text{GM} + 0.5 \ln \text{GSD}^2]$  (Seixas *et al.*, 1988). The SAS procedure NLMIXED was used to perform MLE for repeated measures data subject to left censoring for all contaminants except for  $\text{NH}_3$  where the SAS procedure LIFEREG was used because there was no repeated measurements (Jin *et al.*, 2011) 2011.

Correlations between exposure variables were evaluated using Spearman's correlation coefficient. No correlation coefficient exceeded 0.6. The highest correlations were between air concentrations of OC and oil mist, and between EC and  $\text{NO}_2$  ( $r_{\text{Spearman}} = 0.56$  and  $0.60$ , respectively ( $p < 0.0001$ )).

Statistical analyses were carried out with SPSS 21.0 (SPSS Inc, Chicago, Illinois, United States) and SAS version 8.2 (SAS Institute Inc., Cary, NC, USA).

#### 4 RESULTS

A total of 90 tunnel construction workers carried personal sampling equipment in the exposure study, and all workers were monitored twice. Few workers reported use of personal protective respirators, except shotcreting operators who partly used disposable half-masks with filters for particles (3M™) during sampling. In total, six samples of  $\alpha$ -quartz and 20 samples of EC and OC were discarded because of technical failures.

In total, 79 samples of  $\text{NO}_2$  using direct reading instruments were evaluated. Only 8 of these samples of  $\text{NO}_2$  were above the LOD of  $376 \mu\text{g}/\text{m}^3$ . The median  $\text{NO}_2$  concentrations of the samples above LOD were  $565 \mu\text{g}/\text{m}^3$  (range  $376$ – $1317 \mu\text{g}/\text{m}^3$ ). However, in 17 of the measurements maximum observed peak value incidents of high air concentrations of  $\text{NO}_2$  were detected ( $>3764 \mu\text{g}/\text{m}^3$ ). The GM air concentrations for the thoracic mass aerosol sub-fraction,  $\alpha$ -quartz, oil mist, OC, EC,  $\text{NO}_2$ , and  $\text{NH}_3$  for all workers were  $561 \mu\text{g}/\text{m}^3$ ,  $63 \mu\text{g}/\text{m}^3$ ,  $210 \mu\text{g}/\text{m}^3$ ,  $146 \mu\text{g}/\text{m}^3$ ,  $35.2 \mu\text{g}/\text{m}^3$ ,  $120 \mu\text{g}/\text{m}^3$ ,  $251 \mu\text{g}/\text{m}^3$ , respectively. Statistical differences of air concentrations between job groups were observed for all contaminants, except for

OC, EC, and  $\text{NH}_3$  ( $p>0.05$ ). On average, OC accounted for 76 % of the total carbon measured, and total carbon accounted for 49 % of the thoracic aerosol mass. Also, statistical differences of air concentrations of  $\alpha$ -quartz between construction sites were observed ( $p<0.05$ ). The arithmetic mean (AM) percent of  $\alpha$ -quartz in the thoracic mass aerosol sub-fraction ranged from 3 to 40 percent between sites. The shaft drillers, injection workers, and shotcreting operators were exposed to the highest air concentrations of thoracic aerosol mass (GM= $7061 \mu\text{g}/\text{m}^3$ ,  $1087 \mu\text{g}/\text{m}^3$ , and  $865 \mu\text{g}/\text{m}^3$ , respectively). The shaft drillers and the support workers were exposed to the highest concentrations of  $\alpha$ -quartz (GM= $844 \mu\text{g}/\text{m}^3$  and  $118 \mu\text{g}/\text{m}^3$ , respectively). Shotcreting operators were the highest exposed workers to  $\text{NH}_3$  (GM= $2927 \mu\text{g}/\text{m}^3$ ). The highest levels of  $\text{NH}_3$  were found during loading of mass following detonation of the explosive. An example is shown in Figure 1.

#### Respiratory effects

After 11 days of work, lung function, measured by mean forced expiratory volume in one second ( $\text{FEV}_1$ ), had declined 73 ml (SD 173),  $p<0.001$  in the tunnel workers, compared to 6 ml (SD 33),  $p=0.9$  in the referents. Also forced vital capacity (FVC) had declined significantly. Decline in both FVC and  $\text{FEV}_1$  were significantly associated with exposure to organic carbon (Ulvestad *et al.*, 2014).

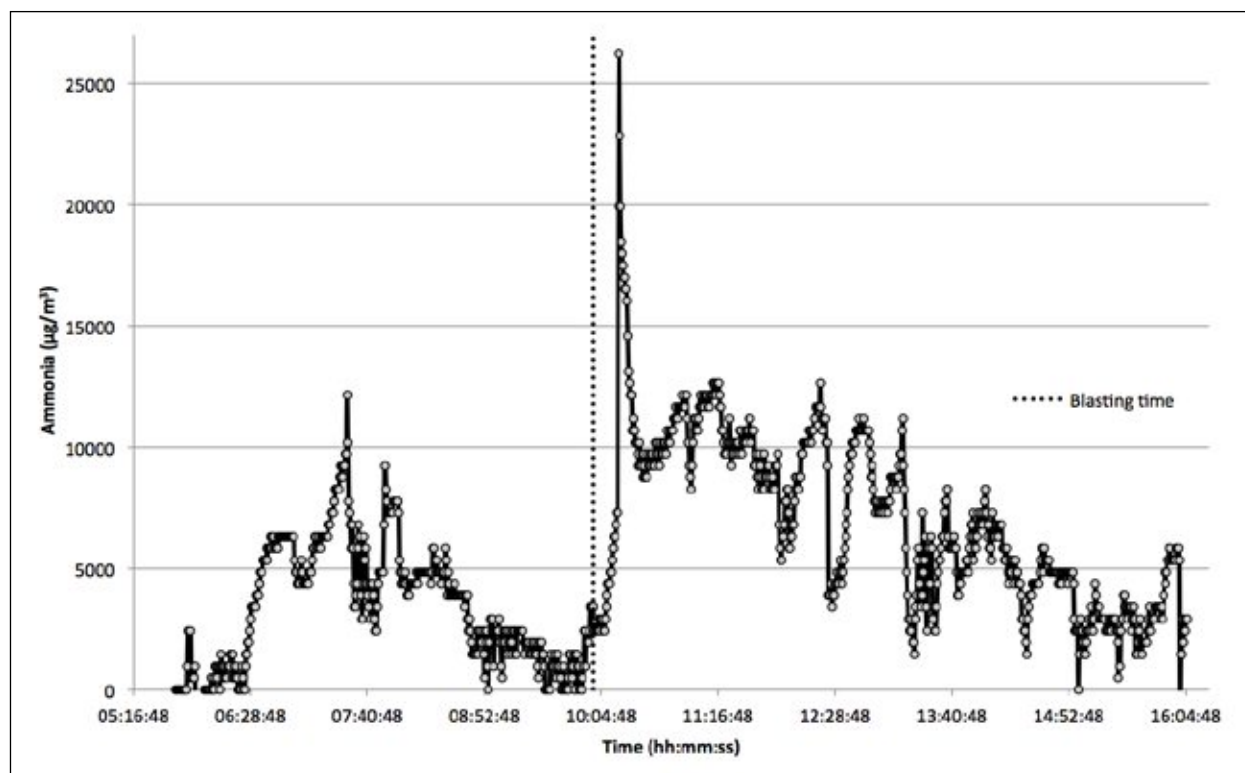


Figure1. Example of personal real-time measurement of ammonia while loading of blasted rock

## 5 DISCUSSION

As part of an 11 days follow-up study on the relationship between personal exposure to aerosols and gases and possible respiratory effects in Norwegian tunnel construction workers, an exposure survey was performed in 2010 and 2011. Tunnel construction workers are a mobile workforce, who perform a number of tasks and are in contact with many different materials at different worksites. These characteristics challenge the exposure assessment process and measurements performed at a single worksite may not be valid at other sites or time periods. In this study we measured air concentrations of selected contaminants at 11 different worksites. Overall, the results indicate that the air concentrations have slightly decreased for some contaminants and have been reduced for some jobs compared to measurements in this industry 10-15 years ago (Bakke *et al.*, 2001). However, challenges remain especially with regard to airborne dust concentrations. Particles are generated by drilling, blasting, crushing, grinding, shotcreting, and transport operations. The mass of particles in the thoracic aerosol sub-fraction was substantial during shaft drilling (GM= 7.1 mg/m<sup>3</sup>). Among other jobs, the GM air concentration varied between 0.42 and 1.1 mg/m<sup>3</sup> (drill and blast and injection workers, respectively). In former studies of shaft drillers and drill and blast workers we found that the GM of “total” dust was 6.1 and 2.3 mg/m<sup>3</sup>, respectively, and the GM of respirable aerosol sub-fraction 2.8 and 0.91 mg/m<sup>3</sup>, respectively (Bakke *et al.*, 2001). This indicates that focus on better ventilation and work practices have resulted in decreased air concentrations.

The thoracic aerosol mass sub-fraction was chosen because it is considered the most relevant health-related aerosol sub-fraction with regard to studying cardiovascular and respiratory effects (Vincent *et al.*, 2001). This aerosol sub-fraction, which penetrates below the larynx gives a better estimate of the dose to the lung than the inhalable-, respirable- or “total” dust (Brown *et al.*, 2013). Alpha-quartz was measured in the thoracic aerosol sub-fraction. The main work task, in which exposure to  $\alpha$ -quartz occurs, is rock drilling. In addition, inhalation of the aerosol generated during blasting may also increase  $\alpha$ -quartz exposure. The air concentration of  $\alpha$ -quartz during shaft drilling was very high (GM=0.84 mg/m<sup>3</sup>). The support workers who works about 100 meters from the tunnel face, also experienced high air concentrations of  $\alpha$ -quartz (GM=0.12 mg/m<sup>3</sup>). Statistical significant differences in air concentrations of  $\alpha$ -quartz between construction sites were observed, probably due to differences in geology. Underground project planning requires detailed geological documen-

tation. Information in these reports could be used in risk assessment of geological hazards, such as  $\alpha$ -quartz. Alpha-quartz may cause serious pulmonary diseases (Hnizdo and Vallyathan, 2003; Tjoe and Heederik, 2005).

The solid particle fraction of diesel exhaust is predominately composed of EC. EC has been proposed to be the most reliable marker of this particle phase of diesel exhaust (NIOSH, 2003). Few countries have regulated occupational exposure to diesel exhaust particulate matter, measured as EC. In Austria the occupational exposure limit (OEL) is 100  $\mu$ g/m<sup>3</sup> (Austria Arbeitsinspektion, 2013). In our study the overall GM air concentration of EC varied from 31-54  $\mu$ g/m<sup>3</sup> for all job groups. This is considerably lower than what was previously reported where we found an overall GM of 160  $\mu$ g/m<sup>3</sup>, and 340  $\mu$ g/m<sup>3</sup> among drill and blast workers (Bakke *et al.*, 2001). This indicates that diesel exhaust exposure have considerably been reduced among workers in these jobs. Other studies in Sweden and Switzerland among tunnel construction workers have reported EC levels of 80 - 90  $\mu$ g/m<sup>3</sup> (Sauvain *et al.*, 2003; Lewne *et al.*, 2007).

Particulate emission rates of EC and OC from diesel engines may vary greatly depending on the mode of vehicle operation. Typically EC/OC ratios under normal operating conditions are approximately 2.5 (Shah *et al.*, 2004). In our study, OC constituted on average 76 % of the total carbon and the main source is therefore probably not diesel exhaust. The air concentrations of OC were moderately correlated to the air concentrations of oil mist ( $r_{\text{Spearman}}=0.56$ ), and OC may therefore partly be an expression of exposure to oil mist in tunneling. Oil mist was, however, only measured for 2 hours during drilling. This also explains why the measured air concentration of oil mist is higher than the air concentration of OC. Alternatively, since the sampling duration of EC/OC was eight hours it is also possible that OC to some extent may have evaporated from the filter.

Machines used for drilling of shafts and tunnels require that the cutting head is lubricated. Oil mist and oil vapour may therefore be released into the work atmosphere. The GM air concentration of oil mist varied between <50 and 9100  $\mu$ g/m<sup>3</sup>. The highest GM air concentrations of oil mist were measured during shaft drilling using pneumatic drilling equipment (9100  $\mu$ g/m<sup>3</sup>). Such levels are known to affect lung function and should be prevented (Skyberg *et al.*, 1992). All individual measurements of oil vapour was < 620  $\mu$ g/m<sup>3</sup>, indicating that the oils in use were of low volatility.



The main sources of NO<sub>2</sub> during tunnel construction are blasting and exhaust from diesel powered machinery and vehicles. The amount of gases released during blasting depends on the type of explosive used (Bakke *et al.*, 2001). In this study emulsion explosive was the explosive of choice in all construction sites, and this may explain the relative low levels of NO<sub>2</sub> (GM= 120 µg/m<sup>3</sup>) which was similar to findings in former studies where the same emulsion explosive was used (GM=226 µg/m<sup>3</sup>) (Bakke *et al.*, 2001). However, the analytical methods were different and as shown in this study direct reading instruments do not have the sensitivity that is required for measuring full-shift NO<sub>2</sub> air concentrations during tunnel construction.

Use of respirators was not mandatory and was not used on a general basis, except among shotcreting operators who partly used respirators. The actual inhaled air concentrations may therefore be lower than measured among workers in this job.

In conclusion, the current study strengthens previous findings that use of emulsion explosive has reduced exposure to NO<sub>2</sub> in all jobs compared to using ANFO which was previously used. Diesel exhaust air concentrations seem also to be lower than previously assessed (as EC). Nevertheless we conclude from the study of lung function that the air exposure in today's tunnel work still appears to have a detrimental impact on the respiratory system. We can only speculate that repeated, short-term loss of lung function, probably due to inflammation caused by exposure, still may be linked to the risk of developing chronic lung disease such as COPD.

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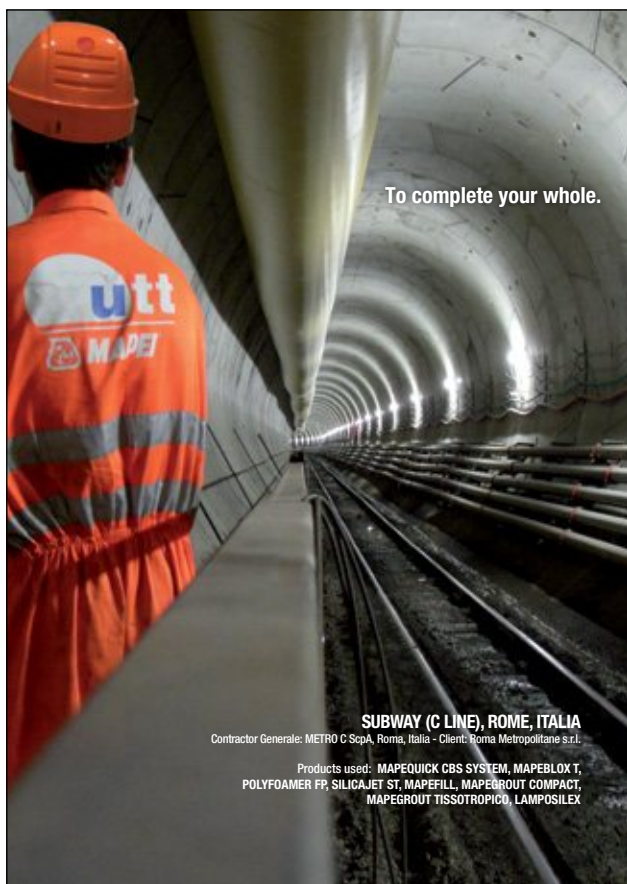
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***Snohvit/Snow White/Schneewittchen, a French-Norwegian LNG-development***

*The first oil & gas developmet on the Norwegian shelf in the Barents Sea with onshore facilities on a small island off Hammerfest (710 North). The island is connected to the mainland by a subsea road tunnel and the pipelines shore approach also through subsea tunnels. Photo: Statoil.*

### 03. OCCUPATIONAL HEALTH CHALLENGES IN DIFFERENT TYPES OF UNDERGROUND OPERATIONS

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In a tunnel many types of activities may take place simultaneously, and the workers are affected to a greater or lesser extent by the same working environment factors. This chapter describes chemical and physical factors in the underground working environment in general, and the gaseous and particulate pollutants in particular.

#### I CHEMICAL FACTORS IN UNDERGROUND OPERATIONS

The table below shows the major chemical environmental factors that may be found in a tunnel environment:

These working environment factors and the risk associated with them will be described in more detail under each type of operation in sections 4.1 – 4.8.

*General measures for reduction/limitation of chemical environmental factors:*

- Measures at the source:
  - Type of explosive
  - Type of equipment
- Organisational measures:
  - Good planning, organisation and preparation of the work
  - Carry out polluting work in ventilated areas, or provide mobile extraction
  - Limit who/how many is/are affected
  - Organise the sequence of the work
  - Limit simultaneous work, working hours, and time spent in polluted zones etc.
  - Routines for operation, maintenance etc.
  - Certified and documented training
  - Preparedness for incidents

<b>Chemical environmental factors</b>		<b>Intervention and limit values (some)</b>
Pollutants in different forms: Gas (G) Particulate (P)	Gases (G)	Depends on type of gas
	Dust/aerosol (P)	Irritating dust: 10 mg/m <sup>3</sup> Respirable dust 5 mg/m <sup>3</sup>
	Mineral dust/fibres (P)	Depends on type of dust, otherwise
	Asbestos	0.1 fibre/ml
	α-quartz (crystalline) (P)	Total dust: 0.3 mg/m <sup>3</sup> , Respirable: 0.1 mg/m <sup>3</sup>
	Concrete dust (P)	Irritating dust
	Oil mist (aerosol, P)	1 mg/m <sup>3</sup>
	Diesel exhaust (G, P)	Limit for diesel particles under consideration
	Welding fumes (G, P)	5 mg/m <sup>3</sup>

Table 1: Overview over chemical environmental factors underground



- Collective physical measures
  - Ventilation and process extraction
  - Enclosing processes (e.g. welding in separate ventilated enclosed area)
- Personal measures such as personal protective equipment etc. (do not replace physical measures)

Climatic conditions and radiation are physical factors in a tunnel which, as a rule, are virtually unaffected by engine technology, maintenance and fuel quality. In addition, fuel consumption increases with engine speed and when driving on a porous surface, draughts may lead to muscular stiffness, arthritis or other health problems. The sensation of draught is dependent on air velocity and temperature.

### 1.1 Gaseous pollutants and health hazard

Table 2 below shows an overview over the most common gases and where they are normally generated.

Equipment exists for continuous monitoring of the main gases. Such equipment can be installed for recording gas levels throughout the construction period, including any installation phases. Normally, the requirements for such continuous measurements will come from the owner. Action plans should be drawn up to deal with situations where intervention values are exceeded.

Typical measures for gas reduction are:

- Choosing emulsion explosive (NO<sub>2</sub> is reduced)
- Use of electrically powered equipment (reduces diesel exhaust emissions)

- Avoid staying in the blasting cloud
- Routines for operation, maintenance and repair of diesel-powered equipment
- Modern engine technology
- Ventilation
- Efficient loading up and transport
- Respiratory protective equipment

Where the use of personal protective equipment is concerned, it should be noted that for some gases (e.g. CO) there is no suitable respiratory protective equipment other than air equipment. We also refer to NFF's **Technical Report No. 7, Diesel power underground.**

### 1.2 Particulate pollutants and health hazard

Particulate pollutants such as mineral dust, organic and inorganic particles are major environmental factors in underground operations. The health effect of these substances depends on the composition, type (including particle form and size), concentration and exposure time.

The International Agency for Research on Cancer (IARC) has classified diesel exhaust as a group 1 carcinogenic substance. Crystalline quartz produces carcinogenic particulate pollutants, and the carcinogenic mineral asbestos can also occur in some rock types. Welding fumes, too, may contain carcinogenic metal compounds (in organic oxides). However, the fumes only present a hazard if welding of stainless steel is carried out below ground. Stainless steel contains chrome and nickel which, in addition to representing a cancer risk, may be allergenic.

Gas	Sources	Characteristics	Intervention value [ppm]
Nitrogen dioxide (NO <sub>2</sub> )	Diesel exhaust and blast gas from nitrogenous explosive	Reddish brown gas with pungent smell	0.6
Carbon monoxide (CO)	Diesel exhaust and blast gases	Colourless, odourless gas	25
Ammonia (NH <sub>3</sub> )	Blast gases and when nitrogenous explosive comes into contact with cement	Colourless gas with irritating and pungent smell	15 50 (S)*
Radon	Bedrock	Odourless, colourless and heavy	100 Bq/m <sup>3</sup> (day average indoor environment)
Sulphur dioxide (SO <sub>2</sub> )	Blast gases, welding, flame cutting	Colourless gas with sharp smell	0.8

\*(S)=Short-term value

Table 2. Gases – incidence and characteristics.

Aerosols	Sources
$\alpha$ -quartz in <u>respirable dust</u>	Bedrock and road fill
Asbestos fibres	Bedrock
Concrete dust	Spraying of wet concrete
Diesel particles	Diesel-powered machines and equipment
Welding fumes	Welding
Oil mist	Hydraulic motors, oil in compressed air

Table 3. Aerosols and incidence

For information on welding see the **Norwegian Labour Inspection Authority's Brochure Order No. 581**.

For general information on asbestos see <http://www.arbeidstilsynet.no/fakta.html?tid=78164>.

Aerosols are finely dispersed particles of solid matter, liquid or a mixture of solid matter and liquid in the air. *An aerosol therefore comprises all types of particulate air pollutants such as dust, fumes, mist etc.* The term "fumes" refers to aerosols of very fine solid particles that are generated from physical and chemical processes.

The blasting cloud contains both aerosols and gases. Spending time in areas that are exposed to the blasting cloud should therefore be avoided.

Aerosols can be formed by:

- Mechanical degradation of solid materials
- Swirling up of particles already formed
- Formation of mist particles through decomposition of liquid via nozzles, leakage, spray of liquids under pressure etc.)
- Condensation from combustion, welding, soldering, degreasing etc.

Dust is a generic term used to describe particles that are formed by mechanical action on solid matter. This takes place through different activities and work processes, such as:

- Blasting and drilling work
- Dumping of rubble
- Different forms of processing of rock material (crushing of masses etc.)
- Loading and transport operations
- Cement work, e.g. injection and grouting
- Concrete spraying/shotcreting

In addition, the movement of air can result in a piston effect that may cause spread of dust.

*Respirable dust* consist of particles < 5 micrometre ( $\mu\text{m}$ ), which are so small that they penetrate deeply into the lungs down to the alveoli. The fine dust that is

potentially hazardous to health, i.e., particles of less than 5  $\mu\text{m}$ , remains suspended in the air for a long time and is carried airborne over long distances. The smaller the particle size, the more hours/days it takes before they fall to the ground, and they can also easily be swirled up. The danger with fine dust is also that it often cannot be seen, unless light sources are used which show the pollutants. This means that the pollution level cannot be assessed by smelling or seeing the components.

Gases can be adsorbed to the surface of dust particles, which allows readily soluble gases to be transported further down in the airways than would otherwise be the case.

Fibres are particles with a length > 5  $\mu\text{m}$ , a diameter < 3  $\mu\text{m}$  and a length to diameter ratio of > 3: 1. With these fibre criteria, there is in total 250 minerals that may be fibre generating. However, of these it is asbestos which to some extent may represent a risk during work underground. Asbestos fibres are found in the form of the minerals chrysotile, crocidolite, amosite, antophyllite, tremolite and actinolite, which present different degrees of hazard, depending in part on their solubility and fibre form.

The health hazard of dust in general is therefore related to the composition or content of the dust, and the shape, properties and size of the particles. This must therefore be taken into consideration when the risk assessment of exposure is to be carried out.

Different types of measures must be implemented based on the type and degree of exposure to the different pollutants.

Typical dust damping/dust reducing measures are:

- Adapted ventilation
- Introduction of water:
  - Watering the muck pile
  - Water flushing installed on pneumatic pick hammer and loader
  - Watering the tunnel walls
  - Wet drilling

- Maintenance of the roadway, salting
- Functioning road drains and drained roadway
- Drilling with water flushing
- Good work and maintenance routines on diesel-powered construction machinery and transport equipment
- Routines for use of protective equipment (correct equipment, proper use)

### 1.3 Other chemical substances and compounds

Chemical substances/compounds other than those mentioned above may also be used in tunnels. Safety data sheets for each product used below ground should be available at the work site; cf. the requirements in the Working Environment Act, §3.2: *Employees shall be made fully aware of the content of the substances before they are put to use.*

### 1.4 Risks of chemical exposure in connection with the use of equipment

Different types of work involve the use of different types of equipment (machinery) that is electric or diesel-powered. Petrol-powered vehicles or machines cannot be used below ground, except when renovating tunnels where simultaneous renovation and traffic is allowed (see section 4.7).

#### *Diesel exhaust*

Pollutants from diesel-powered equipment constitute a health hazard. Diesel exhaust gases, when fully combusted, consist primarily of less noxious components such as carbon dioxide, nitrogen, water vapour and oxygen. With regard to potential health hazard related to diesel, the focus today is on NO<sub>2</sub> and soot in particular. Diesel exhaust is classified as carcinogenic.

The exhaust gas emission from a diesel engine is affected by engine technology, maintenance and fuel quality. In addition, fuel consumption increases with engine speed and when driving on a poor or steep roadway. Elementary carbon is an indicator of the concentration of diesel exhaust gases and is determined by an appropriate sampling method and analysis.

Diesel-powered equipment is used mostly in connection with loading and transport, and measures in connection with this work (use of equipment) are described in more detail in section 4.2.4 below.

Ventilation of rock caverns is of paramount importance for the air quality in connection with the work and use of equipment (machinery and vehicles). Early installation of permanent ventilation equipment and maximum use of electric equipment also has a positive effect on the working environment in the installation phase.

#### *Measures for reducing exposure to diesel exhaust:*

- Choose alternatives to diesel power (substitution)
- Maintenance of diesel engines
- Use newest engine technology/equipment in all phases of the development
- Good ventilation also in the installation phase, and especially in areas where diesel-powered equipment is used

#### *Oil mist*

High concentrations of oil mist occur chiefly in connection with pneumatic system faults and hydraulic system leakages. High concentrations may also occur locally during the application of release oil to concreting equipment, or in the event of incorrect oil metering when, e.g., lubricating shank adapters on boring machines.

Measures employed against oil mist are to some extent the same as those used to reduce diesel exhaust: maintenance of equipment to limit sources of oil mist generation and use of mask when remaining close to boring machines in operation. It is also important to give the workers good information and data about oil mist, how to avoid it and how to reduce exposure levels.

#### *Measures for reducing exposure to oil mist*

- Avoid unnecessary presence close to boring machines in operation
- Use a dust mask
- Maintenance of pneumatic systems
- Information to all involved parties about the hazards
- When applying release oil, it is essential to move away from the oil mist.

## 2 PHYSICAL WORKING ENVIRONMENT FACTORS

The table on the right shows the major physical environment factors that can be found in a tunnel environment.

### 2.1. Climatic factors and health hazard

Temperature, moisture and draught are “comfort factors” that affect the worker’s experience of his working environment.

The atmosphere in tunnels is corrosive. This is due to the condensation of water from hot, moist air and salt. Water and moist air in the tunnel interior may be weakly acidic because of nitrous acid and nitric acid from nitrous gases in diesel exhaust. Inhalation of such polluted air could result in irritation of the airways.

Draughts may result in local cooling of the body. Maximum comfort air velocity at the work site in a tunnel should not exceed 2 - 3 m/s. Increased velocity can



also result in drying out and increased dust generation. Apart from discomfort, draughts may lead to muscular stiffness, arthritis or other health problems. The sensation of draught is dependent on air velocity and temperature.

Water intrusion can result in severe hypothermia if water flushes directly over personnel. Hypothermia can cause a paralysis-like state. Protection against hypothermia of the head is particularly important.

Ventilation should be adjusted according to need in the tunnel, and generally be adjusted down when exhaust gases from the transport of blasted rock masses are evacuated out of the tunnel.

#### Measures

- Appropriate work clothing
- Wetsuit if remaining for any length of time in cold water
- Ventilation with adjusted air flow

## 2.2. Noise

Noise is the most stressful environmental factor underground. The noise conditions in tunnels are also perceived as worse than when working above ground

because of the sound reflection from hard surfaces in the rock cavern.

The ear is a highly sensitive organ, and young people can hear sound between 20 and 20,000 Hz. However, hearing deteriorates with age, and in particular the ability to perceive sound of high frequencies (above 10,000 Hz). Hearing damage can occur at sound levels above 85 dB (A).

Effects of exposure to high-frequency noise are hearing damage at high sound levels, psychological and mental reactions, stress (nervous complaints), impacts on work performance and wellbeing.

Physiological effects of exposure to low-frequency noise can occur at noise levels of 40–60 dB (A), the effect increasing with the sound level (higher blood pressure, higher pulse rate, headache, fatigue and weakness, stomach problems).

An important thing to remember is that a 3 dB reduction in the noise level = halving of the sound level.

Noise also represents a safety risk, as sound signals cannot be heard.

<b>Physical factors</b>		<b>Intervention and limit values (some)</b>
Climate	Air humidity (RH)	Recommended: 20 < RH < 60 %
	Air flow (draught)	Recommended: < 0.15 m/s, depending on temperature / activity
	Temperature (T)	Depends on activity level etc. (min 10°C)
	Splashing water	Waterproof clothing, wetsuits
Noise	Noise level, frequency	Intervention value: Lower 80dB, upper 85dB ( $L_{EX,8h}$ ) Limit value: 85dB ( $L_{EX,8h}$ )
Vibrations	Whole body	Intervention value 0.5 m/s <sup>2</sup> , Limit value 1.1 m/s <sup>2</sup>
	Hand/arm	Intervention value 2.5 m/s <sup>2</sup> , Limit value 5 m/s <sup>2</sup>
Lighting	Light and visibility conditions	Recommended norms, different locations/work (lux)
Radiation	Ionising radiation	20 mSv (year average)
	Radon (radon daughters)	Norwegian Radiation Protection Authority: Limit value: 200 Bq/m <sup>3</sup> Intervention value: 100 Bq/m <sup>3</sup> (year average for both)

Table 4: Overview over physical working environment factors below ground

### 2.3. Vibrations

Vibrations are rapid, periodic movements that are transmitted to different parts of the body, and they are therefore divided into whole body and hand/arm vibrations based on the parts of the body they affect.

#### *Whole body vibrations*

Whole body vibrations are mechanical vibrations that are transmitted to the whole body and involve a risk of harm to health, in particular spinal health.

Factors associated with vibrations that affect health are:

- Frequency of the vibration
- Intensity of the vibrations (amplitude, velocity or acceleration)
- Exposure time
- Body position and body surface contact with the vibrating underlying surface
- Direction of the vibration

The vibration level for an operator is a consequence of:

- Use routines
- Machine type
- Operator's seat and suspension
- Roadway/surface

There are substantial differences between different types of consequence, and even within the same type. Adverse seat design can give resonance and amplify vibrations. A halving of exposure level results in a 50% reduction in the effect, whilst a halving of the exposure time gives a 30% reduction.

Good maintenance of the roadway in the construction period will reduce vibrations in connection with transport, and contribute to a better working environment.

#### *Measures*

- Vibration-damping seat
- Good roadway/smooth underlying surface during loading

#### *Hand/arm vibrations*

Hand and arm vibrations are mechanical vibrations that are transmitted from equipment to the hand and/or arm and entail a risk of injury to blood vessels, skeleton, joints, nerves or muscles.

Vibrations of the hand/arm represent a risk in connection with the use of vibrating equipment or where parts of the equipment vibrate (e.g. control units). This risk is most likely to occur when vibrating handheld equipment is used (e.g., drilling/boring equipment).

#### *Measures*

- Avoid use of handheld drills

### 2.4. Radiation and lighting

Tunnel workers are exposed to ionising radiation from a number of sources including the country rock. This is due to the occurrence of radioactive elements in the rock types, such as radon and radon daughters. Radon is a heavy radioactive gas found naturally in all rock and soil types. In Norway radon concentrations are high, and radon is the second major cause of lung cancer and hence is of great importance for health.

The radon concentration depends on:

- Rock type/country rock (largest from xenomorphic rock types and slate)
- Degree of size reduction of rock types and minerals (specific surface)
- Seepage of radon-containing water
- Ventilation

#### *Measures*

- Good ventilation, especially in pits/ditches throughout the construction phases.
- In rock caverns without ventilation, e.g., behind tunnel installation, radon content should be measured before personnel go into the cavern.

### 2.5. Lighting

Good lighting creates a safe and more secure working environment. When the lighting is planned, the following factors should be taken into account:

- Adequate work light, i.e., that the lighting intensity at the work site is high enough for the tasks that are to be carried out (use of lux charts/ recommended values as function of age/ expected wear and soiling of light fittings)
- Transition from light to dark
- Luminance distribution (the distribution of lightness of different surfaces/areas)
- Age of workers

The eye's ability to adjust to the transition between darkness and light (also called adaptation) takes a relatively long time. To prevent accidents from happening, it is essential to set requirements for the lighting conditions such that luminance differences are as small as possible.

Below ground the luminance differences can be large, and behind the face the lighting can be slightly inadequate. When carrying out tasks that require a lot of movement in and out of the tunnel, the tunnel workers can be subjected to physiological and psychological blinding. These factors can have a tiring effect and therefore impact on the reaction time and performance of the workers.

Visibility in the tunnel can also be reduced by water vapour and particles. Reduction of visibility is a func-

tion of light absorption and light dispersion, which are affected by the size and structure of the particles. Below ground there is better visibility during the winter than in the summer because hot incoming air gives more water vapour in the rock cavern than cold incoming air.

*Measures for better lighting:*

- Good lighting at all fixed work areas.
- Good lighting on all machinery and transport units, including reversing lights
- Machinery and equipment should be equipped with good light to ensure that sporadic work areas are sufficiently illuminated.
- The Norwegian Public Roads Administration requires light sources of 800 lumen spaced 10 m apart along the whole length of the tunnel and throughout all construction phases.



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***Bleikstunnel on a sunny summer day***

*Short, but important. Road fv 976 like many other roads through mountainous areas is severely exposed to rock fall and rock slides. Tunnels give protection. Photo NPRA*



## 04. SPECIAL UNDERGROUND RISK ELEMENTS

NILSEN, Bjørn - NTNU

### I INTRODUCTION

All underground excavation is connected with a certain degree of risk. The degree of risk depends on several factors, such as:

- Complexity of the geological conditions
- Dimension and complexity of the project
- Knowledge of the ground conditions
- Methods and procedures used for excavation and rock support
- Follow up and state of readiness during excavation
- Standard of HMS regulations

Rock support and HMS/HSE are covered in other chapters of this publication. Main focus in this paper therefore will be on discussing the main geological risk elements, and the significance of ground investigations, design considerations and construction control for reducing uncertainty and risk.

### 2 GEOLOGICAL RISK ELEMENTS

The stability, and hence the risk of underground excavation, mainly depends on characteristics of the following geological factors:

- 1) Fracturing
- 2) Faults/weakness zones
- 3) Rock stresses
- 4) Ground water

In addition, seismic effects (earthquake) may have influence on the stability. Seismicity is however not a significant problem in low-seismic regions like Scandinavia, and earthquakes generally cause less damage underground than at the surface. Weathering may be very deep and cause considerable problems in other parts of the world, but in recently glaciated regions like Scandinavia this is normally not a significant stability issue (although some exceptions exist).

Main focus in the following therefore will be on the 4 main factors listed above.

#### 2.1 Fracturing

The significance of fracturing for stability depends on several factors, such as orientation relatively to the excavation (strike/dip), spacing (degree of fracturing), continuity (length) and character (roughness, filling/coating; i.e. swelling clay).

In a tunnel or other type of underground excavation it is unavoidable that unstable blocks are released more or less frequently by unfavourable jointing, and if such blocks are not removed by scaling or left unsupported, block fall will occur. An example of block fall (wedge failure) from the roof at the tunnel entrance is shown in Figure 1, and examples of rock support against potential instability due to fracturing are shown in Figure 2.



Figure 1. Example of instability caused by intersecting joints (old, low traffic road tunnel).

To minimize the risk of rock fall, continuous engineering geological mapping during excavation is required. The final decision regarding support is taken at face, normally as part of “the owners half hour” (time span specifically allocated for inspection) which is today routine procedure in Norwegian tunnelling. Particularly important is to make decisions for rock bolting in blocky ground like to the right in Figure 1 before the contour is covered by sprayed concrete.

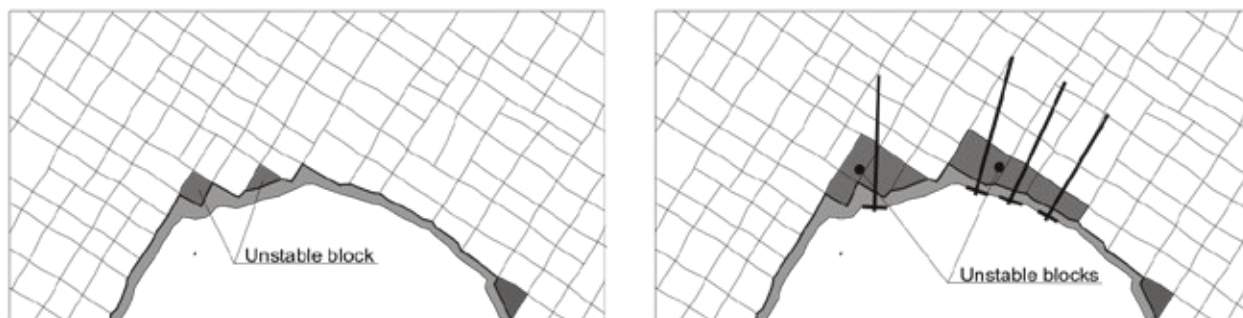


Figure 2. Principle sketches of unstable blocks caused by unfavourable jointing; small blocks stabilized by sprayed concrete (left), and larger blocks stabilized by combination of rock bolts and sprayed concrete (right). From NFF 2000.

## 2.2 Faults/weakness zones

Major faults and weakness zones may cause considerable stability problems and represent a major risk for underground excavation. Large features can normally be identified during pre-construction investigations, which are therefore very important for avoiding encountering such zones unexpectedly. For particularly challenging projects, such as subsea tunnels (and many other types of projects as well), probe drilling ahead of the face is used to minimize the risk of excavating into the zone before required measures such as pre-grouting and spiling are done.

In some cases, considerable stability problems and even cave-in have however occurred despite pre-construction investigation and investigations during tunnelling as described above. One such example is the incident during excavation of the Atlantic Ocean subsea road tunnel in 2008 (Karlsson 2008, Nilsen 2011). The instability occurred near the deepest part of the tunnel, at 225 m below sea level (the roof at the very deepest section is at 249 m below sea level), as sketched in Figure 3.

Comprehensive pre-construction investigations had been carried out for the Atlantic Ocean tunnel, and several distinct weakness zones were identified based on refraction seismic investigation. Several zones with similar seismic velocity as the cave-in zone were encountered before the incident, and had been successfully coped with based on pre-grouting and “traditional” procedures with sprayed concrete/radial bolting, spiling, reinforced ribs of sprayed concrete. One major difference was however that while the previous zones were relatively dry (mainly due to a high content of (swelling) clay), the cave-in zone was more permeable, and the combination of very poor rock mass quality and water seepage made rock support very difficult. Despite previous grouting and reduced round length, initial rock support based on spiling and sprayed concrete proved insufficient, and cave-in started developing. After a few

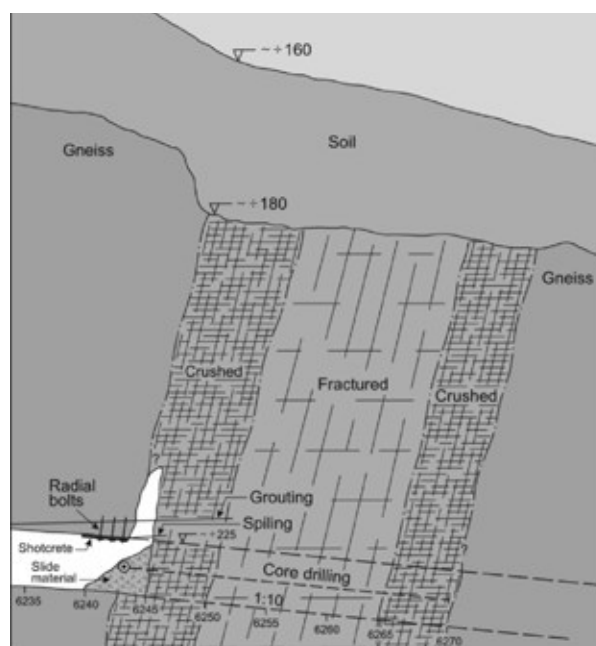


Figure 3. Cave-in at major weakness zone at 225 m below sea level, at a rock cover of approx. 45 m, near the deepest point of the Atlantic Ocean subsea road tunnel (from Nilsen 2011).

hours, a 5-6 m high cave-in of the roof had developed, covering the full tunnel width. Based on holes drilled later it was found likely that the collapse extended about 10 m above the tunnel roof as illustrated in Figure 3.

In order to stabilize the tunnel, excavated material was placed against the face, the space between the tunnel contour and the fill material was sealed with sprayed concrete, and concrete was also pumped into the cave-in hole. An approximately 10 m long concrete plug was then made to seal the tunnel. Later, based on extensive pre-grouting, supplementary investigation ahead of the face (including core drilling), reduced round length and extensive rock support, the section with the concrete plug and further into the weakness zone were carefully excavated. This process was very time consuming due



to extensive water inflow (up to 500 l/min in one single drill hole) at very high pressure (up to 23 bar), and it took about 10 months to complete excavation to a position 20 m ahead of the cave-in location. The rest of tunnelling through the weakness zone was done from the other side (with less problems).

A main lesson learnt from cases such as the Atlantic Ocean tunnel incident is that even when extensive ground investigations have been done, there is always a risk of encountering “unexpected ground conditions”. Great focus on engineering geological follow up and a high state of readiness during excavation are crucial for as far as possible to reduce the risk. In Norwegian tunnels, as a result of several serious past incidents, particular focus is on identifying potential zones with swelling clay (smectite), which often require very extensive support measures.

### 2.3 Rock stresses

Problems due to high rock stress are most common for deep seated underground excavations: i.e. tunnels and underground openings deeper than 400-500 m or located near the foot of a high mountain slope. For competent rock in such cases, rock spalling (fracturing parallel with the contour, sometimes quite violent) or rock burst (larger, very violent cave-in due to high stress) may occur. Rock spalling and rock burst are often very violent in hard, competent rocks like are often found in Scandinavia, and may be very dangerous. Although such incidents are particularly linked to certain topographical and geological environments, and often may be predicted based on pre-investigation and analysis, rock spalling may also come unexpected as result of high tectonic (or residual) stress, which is encountered in some regions of Norway.

Examples of rock spalling in a tunnel in gneiss, and more violent rock burst in a deep seated tunnel in granodiorite, are shown in Figure 4.



For minimizing the risk related to high rock stress, it is important that evaluations based on investigations and analyses prior to tunnelling are done and that indications of high rock stress during tunnelling are taken seriously. The most efficient measure for coping with high rock stress, and prevent spalling, is normally steel-fibre reinforced sprayed concrete immediately after round blasting combined with systematic rock bolting (end anchored, non-grouted bolts).

### 2.4 Ground water

Water inflow may represent considerable challenge and risk for tunnel excavation, particularly if large inflow occurs in a section with poor quality rock mass, i.e. related to a weakness zone. This was the case for the incident at the Atlantic Ocean tunnel described in chapter 2.2. For the cave-in zone in this tunnel, the challenge in the beginning was related to stability. Later, when excavating further into the weakness zone, the situation however more and more turned into a water inflow and grouting challenge. This combined stability and water inflow/grouting problem is illustrated in Figure 5.



Figure 5. Excavation through the cave-in zone at the Atlantic Ocean tunnel. Pre-grouting was done for coping with large water inflow, and the tunnel face reinforced with sprayed concrete, rock bolts and steel straps for ensuring stability and allowing for high grout pressure.



Figure 4. Examples of rock spalling (left) and rock burst (right) in deep-seated tunnels

More common than the situation illustrated in Figure 5 is that the major inflow is not in the central weakness zone, but rather in distinct single joints (sometimes located at the edge or boundary to the zone). In some cases the volume of water inflow may be very high, several tens of m<sup>3</sup>/min, and in deep-seated tunnels the pressure may be very high (more than 5 MPa, representing full hydrostatic pressure). In extreme cases tunnels may be lost due to heavy water inflow. Very high pressure or high temperature (i.e. >50°C like some places in Iceland) may represent considerable risk factors. In most cases, problems due to water inflow are however mainly related to stability reduction, difficulties for drilling and charging, damage of roadway, pumping, etc.

Water inflow in a planned tunnel is very difficult to predict based on pre-investigation or analysis. The best option for preventing water inflow is probe drilling ahead of the tunnel face, and pre-grouting if/when the inflow in the probe holes exceeds a preset limit.

### 3 INVESTIGATION AND DESIGN STRATEGY TO MINIMIZE POTENTIAL EFFECTS OF RISK ELEMENTS

As illustrated by the examples in Chapter 3, proper investigation and design may significantly reduce the geological risk elements of underground excavation. A basic philosophy in Norwegian underground excavation is that the extent of investigation as well as effort on geotechnical planning, design and construction control should always be adjusted to the complexity of the geology, and to the complexity and safety requirement of the project.

A recommendation regarding “proper extent of investigation” was published in 2003 based on a major research programme with broad participation from the Norwegian tunnelling industry. In this recommendation, a classification into Investigation class is made based on a) Level of engineering geological difficulty and b) Safety requirement for the project as shown in Table 1.

Safety requirement	Engineering geological difficulty		
	a1) Low	a2) Moderate	a3) High
b1) Low	A	A	B
B2) Medium	A	B	C
B3) High	B	C	D

Table 1. Classification of projects into Investigation classes A-D (after Palmstrøm et. al. 2003).

For each respective Investigation class, recommendations on how much should be spent on pre-construction investigation (as % of excavation cost) are given as function of tunnel length as shown in Figure 6. The basic philosophy of the system is that the effort on

ground investigation should be adjusted to the characteristics of the geology and the project and not be of the same extent in all cases. The system is recommended by the Norwegian public Road Authorities NPRA (2013) to be used for road tunnels, but has not yet reached a status of mandatory use. For more detailed description of the system, reference is made to Palmstrøm et. al. (2003) and NFF Publication No. 23 (Nilsen 2014).

Even when very extensive pre-construction investiga-

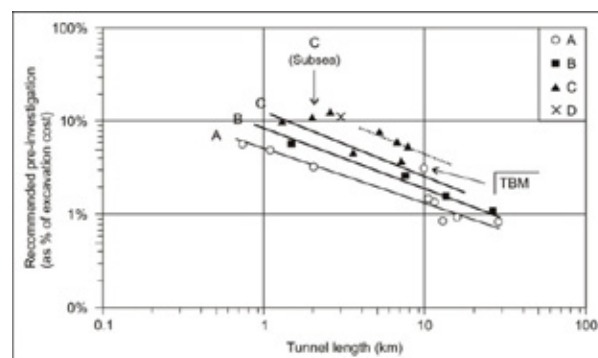


Figure 6. Recommended extent of pre-construction investigation as function of tunnel length for the respective Investigation classes (after Palmstrøm et. al. 2003).

tions have been carried out, some uncertainty regarding the ground conditions will always remain. Follow-up and supplementary investigation during tunnelling, such as continuous tunnel mapping, probe drilling and MWD, is therefore very important.

Rules and guidelines for geotechnical design are given by the Eurocode 7 (EC 7), which in 2010 replaced the Norwegian standard for geotechnical design (NS 3480) as official standard in Norway. Since the EC 7 is focusing more on soil than rock (and more on soft than hard rock), special guidelines regarding use of EC 7 for rock engineering design were published by NGB (Norwegian national group of ISRM) in 2011. A main principle in EC 7 is the classification into Geotechnical categories (which is similar to the classification into Geotechnical project classes in NS3480). NGB defines Geotechnical category as shown in Table 2.

Reliability class	Degree of difficulty		
	Low	Medium	High
CC/RC 1	1	1	2
CC/RC 2	1	2	2/3
CC/RC 3	2	2/3	3
CC/RC 4*	*	*	*

Table 2. Classification of projects into Geotechnical categories 1-3 as recommended by the Norwegian Group of Rock Mechanics (NGB 2012).

The Geotechnical category defines requirements regarding quality and efforts on all aspects of basis for design (maps, geotechnical data, etc.), investigation, planning and control. The higher geotechnical category, the more investigation, the more thorough planning and the more control are generally required. The extent of investigation is however to be finally decided by the owner, and this is one reason why the system in Table 1/Figure 6 has been found useful.

According to the technical rules of the Norwegian law for planning and design (PBL), the regulations of PBL can be considered fulfilled if methods and practice based on Norwegian Standard, including EC 7 are used (NBG 2011). Eurocode 7 is therefore a very important document which, when used properly, also contributes in reducing potential risk elements of tunnelling.

#### 4 CONCLUDING REMARKS

Underground excavation involves risk which may in worst case have fatal consequences and cause loss of the project. The geological conditions are often difficult to predict, and underground excavations are in many cases large and complex. Risk analysis and assessment of uncertainties are therefore very important.

In Norwegian underground excavation, the main geological risk factors are:

- Instability due to unfavourable jointing
- Cave in from major faults/weakness zones
- Rock spalling/rock burst due to high (and often anisotropic) stresses
- Large water inflow, sometimes with high pressure

In Norway, a combination of the poor rock mass quality of weakness zones and water inflow has often represented the biggest challenge, and in some cases swelling clay has caused major instability. All factors listed above may however represent serious risk, particularly if the knowledge of geological conditions is insufficient.

In order to reduce the risk to an acceptable level, and optimize planning and design, pre-construction investigations of sufficient extent and high quality are crucial. A sound principle for investigation is that the extent of investigation should always be adjusted to the geological complexity and type and safety requirement of the project. Because of the complexity of geological conditions it is crucial that pre-construction investigations are always followed up by continuous investigation during tunnelling.

Finally, it is important to be aware that “unexpected conditions” may occur at any time of excavation. In order to ensure safe tunnelling it is therefore crucial to have a high state of readiness and always being prepared to install the right type of stabilizing measure at short notice.

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Some 100 km north of Oslo, along Lake Mjøsa the implementation of a megaproject takes place. NPRA (the Norwegian Public Roads Administration) and NRA (The Norwegian Rail Administration) jointly reconstruct the major road E6 and the parallel main northbound railway line. Photo Hæhre Entreprenør; Svein-Magne Tunli.



## 05. PROJECT PARTIES AND RESPONSIBILITY ALLOCATION

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LIEN, Jan Erik

RØDSET, Knut Jarle  
HEGGHAMMER, Tone  
MESSELT, Hermann

Several parties are involved in the implementation of an underground project, each responsible for a defined part or phase of the work.

Below is described the allocation of responsibility for health, safety and environmental matters and an approach to the handling of these matters during the construction period.

Tunnelling work and the working environment are governed in particular by **Regulations relating to performance of work**, Chapter 27, Working with rock, but also by other legislation that sets requirements for other matters of importance for employee safety and the working environment. A list of relevant legislation is given in the appendix.

To achieve a good working environment below ground, it is especially important to:

- Develop general competence and knowledge by giving every owner, consultant, contractor, manager and worker training on the working environment and health hazards associated with the work site, equipment and tasks
- Carry out surveys of the working environment (mapping, measuring) and assessments, and ensure that relevant measures are planned and implemented
- Report undesirable incidents, monitor and evaluate the working environment and health situation in a systematic, regular and documented manner

The responsibility of the different players is described in the rules and regulations, but must also be agreed



*Ad hoc conference in a workshop. Photo LNS*



*Crew at face charging the cut. Photo LNS*

between the parties in each individual development project. Owners and government departments that call for competitive tendering should provide a clear description of the allocation of responsibility and tasks among the different parties to the project. Specific requirements should be set for the contractors, with clear references to how and where they should be priced. The consequences of non-fulfilment of requirements should also be made clear.

In a tunnel project, the quartz content, for example, affects the health hazard associated with dust in the tunnel atmosphere. The geotechnical surveys should include analyses of the quartz content of the rock, so that the risk can be assessed and measures be put in place in areas containing quartz-rich rock types. The owner and the contractor must agree between them how the responsibility for carrying out geological and working environment surveys should be allocated. Normally, it is the owner who carries out preliminary geological surveys so that necessary matters relating to health, safety and the working environment can be assessed. If such surveys are not carried out by the owner, each

individual contractor will be responsible for determining type and level of pollutants and for implementing measures in connection with the different types of work below ground. Who is to bear the costs of this work should then be made clear in the contracts. After the legislation was passed stipulating exposure limit values for the different kinds of exposure, the employer has been given a greater responsibility for documenting that pollutants are at an acceptable level.

The employer must also ensure that measures are implemented when the limit values are exceeded, and usually measurements must be made to be able to determine the exposure hazard. It is therefore expedient to clarify who is to bear the costs of such surveys, or how the responsibility is to be allocated.

### **ALLOCATION OF RESPONSIBILITY AND TASKS IN TUNNEL PROJECTS**

The overview below gives a recommended allocation of tasks based on the role and responsibility of the different players according to requirements in the rules and regulations governing the working environment.



Player / role	Responsibility and task(s)
Owner, orderer, principal	Address considerations of health, safety and the environment (HSE) at the construction site, describe/take into account risk factors, coordinate the work in the executing phase, and ensure performance of the players' obligations throughout the executing phase, draw up/update the owner's HSWE plan* for the individual project, set requirements for specific HSE measures, systematic HSE work and internal control at the contractor's (included in HSE plans**).
Project engineer	Risk-assess the HSWE situation at the building/construction site, describe necessary, specific measures
Coordinator	Coordinate in accordance with specific requirements (i.a. in the HSWE plan on behalf of the owner).
Main contractor/ Main enterprise	Follow HSWE plan. Special responsibility for coordination of the HSE work during execution by several companies at the same work site, by i.a. documenting competence, training and ID. Draw up an internal control system that works.
Sub-contractor	Follow HSWE plan, coordinate own (employer's) HSE plan with requirements in HSWE plan. Draw up an internal control system that works.
One-man company	Follow HSWE plan and other working environment legislation, assess the danger of own chemical impact (Regulations relating to performance of work apply). Allow coordination with main company's requirements.
Foreign company/ Employee	Become familiar with Norwegian working conditions, follow Norwegian regulations and follow employer's and owner's directions
Employer	Incorporate relevant parts of HSWE plan in own HSE system, draw up own HSE plan in relation to rock tunnelling operations and the relevant risk factors in work underground in the project, comply with regulations.
Company health service	Assist employer, employees, working environment committee and safety representative in creating healthy and safe working conditions.
Work supervisor/foreman	As supervisor with HSE responsibility, perform duties on behalf of employer
Employee	Follow instructed HSE routines that apply to employees
Safety representative	Perform his/her duty of seeing things are done according to laws and regulations

\*HSWE plan is the owner's plan for the individual project (HSWE stands for Health, Safety and Working Environment and is used to distinguish between the owner's plan for HSWE in the project and the plan for safeguarding the external environment (EE), and the employer's HSE plan for the specific work that is carried out)

\*\*HSE plan is the employer's plan for HSE in order to take care of the individual company's employees. Reference is also made to the Working Environment Act, Chapter 2, which lists the employer's and employees' duties, and Handbook R763 issued by the Norwegian Public Roads Administration, Chapter 3.1.2.

Table 1: Individual responsibility and tasks of different players in tunnel projects





**E10 Solbjørnneset-Hamnøy**

*E10 through Lofoten, undisturbed nature, dramatic, challenging. Between Flakstad and Moskenes in the outer part of Lofoten six sections are characterized as above average exposed to rock fall and snow avalanches. Last year (2014) NPRA opened 4.5 km road protected by tunnels or superstructures. The 1.5 km long Hamnøytunnel is part of the project. Photo NPRA, Tomas Rolland.*



## 06. TUNNEL EXCAVATION, RISKS AND PREVENTIVE ACTIONS

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This chapter looks at each of the main activities associated with tunnelling work, and describes challenges and measures for each one.

### I WORK IN FRONT OF THE TUNNEL FACE

Work in front of the face consists of processes implemented to carry out surveys of the rock ahead of the face, or to seal and/or reinforce the rock ahead of the face.

#### 1.1 Long-hole drilling from the face

Core drilling to examine the rock quality ahead of the face is carried out when there is a need for further clarification of rock quality or stress conditions. Core drilling is usually done using small diesel-powered drilling rigs, which makes ventilation necessary. Normally the ventilation requirement is smaller than in other tunnelling operations, and the system should be adapted so as to avoid unnecessary draught. Handling drill rods and drilled-out cores is heavy work. A rig area should be established close to the drilling rig to ensure good access routes and reduce the risk of unnecessary strain when handling rods.

During long-hole probe hole or grouting hole drilling with a tunnelling rig, rods must be added to and removed from the drill string. This work is heavy and requires those performing it to spend time in the drilling rig danger zone, close to boring machines that are in operation, where they are exposed to a high noise level from boring machines, spray from flushing and leakage water and oil mist from lubrication of shank adapters on the boring machines.

#### *Measures*

- Mechanical rod handling
- Hearing protectors with maximum attenuation
- Avoid staying close to boring machines in operation
- Use respiratory protective devices when in the vicinity of boring machines in operation
- Protective goggles
- Maintenance of boring machines and compressed air lubrication.

#### 1.2 Grouting

Pre-grouting is a normal sealing method used during tunnel excavation. Workers who carry out grouting below ground face a danger of exposure to grouting agents when handling them, and also during use, cleaning, maintenance or repair of equipment. The health hazard from exposure is greatest during the filling and mixing of cement and when pumping chemicals. Grouting cement, ready mixed grouting agent and recycled tunnel water are highly alkaline (pH 11-14). The chemicals used may be allergenic, posing a risk of developing asthma and allergy, especially when exposure is long term.

As grouting liquid is pumped at pressures of up to 100 bar, there is also a danger of spray from high-pressure grouting liquid.

#### *Measures against exposure:*

- Prevent exposure through safe handling of chemicals, good work routines, measures on site, such as, e.g., adapted ventilation/extraction
- Avoid eye and skin contact by using protective goggles, respiratory protective devices and gloves
- Delivery of cement in bulk reduces the risk of cement dust during filling
- Safe handling of grouting equipment requires training in use of the equipment
- Use the information in the safety data sheet for chemicals that are used, including cleaning agents

### 2 WORK AT THE TUNNEL FACE

Activities at the face include drilling blast and rock bolt holes, charging, blasting, loading, mechanical and machine scaling, bolting and spraying. Some of these work operations generate huge amounts of dust and the noise level is generally high. The work represents a large health and safety risk that calls for an assessment of the mineral composition of the rock types and risk situation, and the implementation of safety measures, good routines and continuous monitoring.





Figure 1: Filling of cement in big bags on a grouting rig

### 2.1. Drilling and charging

Factors that affect the working environment during the drilling of rock bolt and blast holes are primarily noise and possible oil mist from leakages from hydraulic systems or from shank adapter lubrication. Studies made by the Norwegian National Institute for Occupational Health (STAMI) in 2012 show that there can be substantial exposure to oil mist at the face from shank adapter oil on drilling rigs, if maintenance routines do not function satisfactorily.

The charge is normally loaded after drilling at the face has been completed and machines have been stopped. Today the use of emulsion explosives dominates in underground construction sites. The explosive is pumped into the blast holes via charging hoses on the drilling rig. Emulsion explosives are corrosive and it is vital that everyone involved is familiar with the safety data sheet.

A small proportion of the explosives used (often less than 1%) contains nitro-glycerine and nitroglycol. These substances can be absorbed through the skin during work with cartridged explosives, and cause headaches.

#### Measures

- Ventilation with adapted capacity
- Hearing protectors with high attenuation
- Avoid unnecessary presence close to boring machines in operation
- Eye protection must be used during charging of emulsion explosive

- Eyewash should be readily available in case of spray in the eyes
- Gloves must be used during charging work
- Maintenance of machines and equipment

### 2.2. Shaft excavation with raise climber

During inspections of the working environment, the highest levels of oil mist and dust have been measured in connection with shaft excavation using a raise climber (Alimak). Measurements taken during drilling showed as much as 15 mg/m<sup>3</sup> oil mist (intervention limit 1 mg/m<sup>3</sup>) and an extremely high dust content. This method is therefore considered to be unacceptable for use in shaft excavation, partly because it is not possible to give the operator sufficient protection against exposure through suitable protective equipment. In addition, the method is very physically demanding for the operator, and also represents a substantial safety risk. An overall assessment of the method indicates the use of other shaft excavation methods should be implemented wherever possible. Therefore, when selecting work methods and equipment, the employer (and owner) must consider the overall burden on their employees, and not simply assess individual environmental factors.

#### Measures

- Use a different excavation method for excavating shafts
- Maintenance of pneumatic equipment
- Respiratory protective equipment
- Dust damping

### 2.3. Blasting

During blasting, large amounts of gas and dust are produced. If the quartz content of the rock type is high, there is a greater risk because quartz dust is particularly aggressive when released by mechanical treatment, such as blasting and crushing.

Geological reports often describe rock type compositions in underground projects. The quartz content of the different rock types is known, but large variations can occur within each rock type and in addition there may be high quartz concentrations in intrusive rock that is difficult to map with any accuracy. A geological report should be used to present estimates of quartz content in the rock masses to be blasted. Possible measures for handling dust should be listed in a descriptive text.



Figure 2: Watering a muck pile

The introduction of emulsion explosives underground has considerably improved the working environment in tunnels, with concentrations of nitrous gases falling significantly.

The amount of gas and dust varies greatly depending on the blasting plan and the detonation of the explosive.

Effective watering of the blast pile for dust damping will reduce the amount of dust substantially, limiting the risk of chemical exposure correspondingly. To achieve effective dust damping through the addition of water, experience has shown that the amount of water added to the muck pile should correspond to at least 1% of the charged volume.

Efficient ventilation with a large volume of air up to the face will also help to reduce exposure. If emulsion explosives are replaced by other types of explosive, such as ANFO or nitroglycol-containing explosive, the harmful blast gases will increase in volume and represent a much greater negative factor for the working environment.

#### Measures

- Large flow ventilation and ventilation membrane extending to the face.
- Watering of the muck pile with large amount of water
- Optimisation of drilling, charging and detonation plan
- Avoid unnecessary presence in the blasting cloud
- Use respiratory protective equipment when in the blasting cloud
- Closed cabins on vehicles and machines that are in the cloud

### 2.4 Loading and transport

During loading of tunnel blast material a great deal of dust is released, and water damping of muck piles is an important measure to reduce the spread of dust. This must be done continuously and be incorporated into regular routines. Choice of the right machines, maintenance and good routines are also important factors in limiting exposure during loading. Transport vehicles that carry rock away from the face are exposed to blast gases and dust over prolonged periods of time. However, the driver's exposure when driving through the blasting cloud is dependent on the condition of the vehicle and transport routines. The driver must be given information about the factors that affect his working environment. Experience has shown that a lack of awareness of the risk has resulted in drivers being subjected to unnecessarily high levels of dust and gas exposure. The vehicles themselves are instrumental in swirling up dust, and so it is important that unnecessary presence of others in polluted zones be limited. Dust damping measures on the roadway should be implemented if necessary.

The introduction of low sulphur diesel and stringent requirements as regards engine technology have helped to reduce the hazards associated with diesel, but transport operations still contribute to diesel exhaust (gas and soot) pollution of the tunnel atmosphere.

Loading of tunnel blast material can be an extremely energy-demanding task, which puts great strain on machines and personnel. The loading machine should therefore be equipped with a good shock-absorbing driver's seat.

#### Measures

- Ventilation with sufficient capacity
- Watering of the muck pile to dampen dust
- Equipment with modern engine technology and high-quality fuel
- Electrically powered equipment
- Windows are kept closed and air intake is closed during transport through the cloud



Figure 3: Loading at the face without generating dust

- Control of gas level in the driver's cabin
- Service and maintenance routines, such as frequent cleaning and replacing of air filters
- Good roadway / even surface and efficient driving routines
- Shock-absorbing driver's seat

## 2.5. Scaling by machine and manually

Mechanical scaling using a pick-type scaler causes the generation of dust, high noise level and vibrations (impacts), and therefore the scaler should be equipped with flushing to dampen dust. The operator's work station should be ergonomically adapted, e.g., with an adjustable cabin, so as to minimise strain on the neck and shoulders. Mechanical scaling produces dust and entails a danger of rockfall and grit spray from crushed rock. The operator's cabin must be protected against noise, dust and falling rocks. Time spent in the danger zone should be limited to the absolute minimum, and always with the operator's permission.

### Measures

- Good lights on the scaling machine
- Closed and noise-proof cabin
- Tilttable cabin
- Hearing protectors, protective goggles and dust mask when spending time close to scaling machine

Manual scaling at height is usually carried out from a truck-mounted work platform, or from an approved personnel lift. Manual scaling should be carried out by two persons on the platform. Experience and knowledge of the properties of the rock are necessary to be able to perform the work safely, and there must be adequate lighting. Spray from scaling rods may occur and therefore protective goggles must be worn. Manual scaling is often done from lorry-mounted cages. During prolonged scaling it will be exhausting for the machine operator to keep

an eye on the personnel in the cage, and to take pressure off the machine operator in this situation, it is advisable to use internal communication in the hearing protectors.

If the rock conditions are so poor that manual scaling may cause rockfall onto personnel, the scaling must be stopped.

### Measures

- Good light
- Limited noise to be able to assess the sound signals from the rock
- Intercom during prolonged support of cage

## 2.6 Bolting

During bolting, workers may be exposed to a number of chemicals and cement mortar for bonding or grouting bolts.

Short-term measurements of particulate contaminants during mixing of cement for grouting bolts and pre-grouting have shown high values. The site of such mixing must therefore be especially well ventilated in order to reduce inhalation of dust. Mixing tanks should be positioned such that cement dust drifts away from personnel. Skin contact of irritant cement dust can be avoided by using suitable gloves and tools.

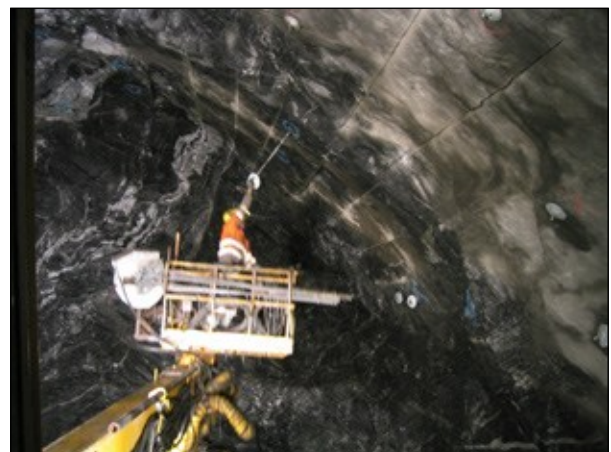


Figure 4: Bolting a roof

### Measures

- Extraction from a mixer or positioning such that dust drifts away from personnel
- Respiratory protective devices when mixing cement
- Protective goggles
- Gloves

## 2.7 Sprayed concrete

Sprayed concrete is used in tunnels for stabilisation at and behind the face, and for fire protection of PE foam in the installation work. During concrete spraying or shotcreting, depending on the equipment, materials and



routines used, the exposure to aerosols can be substantial and the noise level high. In addition, measurements have shown high aerosol values when spraying on oil to protect machines and equipment from concrete spills.

Shotcrete can be applied by both wet spraying and dry spraying. Wet spraying is the method used in all tunnels and caverns that can be accessed with a spraying rig, whilst dry spraying is used in shafts and wherever it is difficult to gain access with large equipment. During dry spraying, wet and dry constituents are mixed together at the spraying site, and therefore this method produces more dust.

In both wet and dry spraying an accelerator is added to the shotcrete in the nozzle, that is to say, during spraying. Compressed air is also added at the inlet to the nozzle to provide sufficient velocity to allow the concrete to be sprayed onto tunnel walls and roof, but has the added effect that the air becomes full of concrete dust and atomised accelerator. Protective goggles, dust mask and gloves should therefore be used during this work. Some spraying robots are equipped with an operator's cabin. This type of cabin will provide a better working environment for the operator, but may represent a safety problem if there is any rockfall from the tunnel roof. Many operators therefore prefer spraying robots without an operator's cabin.

Accelerators that are used today are basically of the alkali-free type with a pH in the range of 1.5-3, that is

to say, acidic. Until the latter half of the 1990s, alkaline accelerator based on sodium silicate (known as water glass) was universal. Water glass has a pH of about 11.5, and is therefore strongly alkaline. The health hazard for both types is that they are corrosive to the skin, eyes and mucous membranes. A splash in the eye could cause permanent damage, and therefore safety glasses or goggles and gloves should be worn during refill operations and other handling of accelerator.

PP microfibres are used as an additive to the concrete to improve fire resistance and are so fine (18 µm thick, 6 mm long) that engine filters become blocked after a few hours in the tunnel. Inhalation of atomised microfibres may be a health risk.

*Measures for a good working environment during concrete spraying:*

- Wet spraying
- Closed spray cabin (here it is necessary to be aware of other dangers such as the danger of rockfalls on the boom and a poorer view from the cabin)
- Use respiratory protective devices, face and skin protection when working with or close to shotcreting
- Routines for proper handling of chemicals
- Avoid unnecessary presence of crew in polluted atmosphere (during and immediately after spraying)
- Remote control of the rig during spraying



Figure 5: Spraying robot operated by remote control





*New Holmestrand railway station.  
Photo NRA, Hilde Lillejord*



## 07. DEVELOPMENT IN VENTILATION METHODS

LIMA, Jan - Hæhre Entreprenør AS

### ABSTRACT

Good ventilation, a result of a well-designed and well established ventilation system, is paramount for a satisfying work environment while excavating underground tunnels and openings. Threshold limit values give ceiling values for acceptable concentrations of various substances. This paper covers methods of ventilation and case stories.

### I BACKGROUND

#### 1.1 Health risks

Sufficient ventilation is crucial for the work environment with respect to health. Toxic gases and particulate pollution create health hazards if breathed in too high concentrations for too long time. Ventilation is also important for other factors; e.g. reduced sight due to dust increases safety risks.

#### 1.2 Threshold limit values

The threshold limit values, which represent limits for acceptable concentrations of gas, dust and fumes, are determined by the Directorate of Labour Inspection. The norms are set from medical, technical and economical evaluations. An overview is given in Table 1.

The limits are normally given as the highest acceptable average concentration over an 8 hour work shift. Higher concentrations are allowed as short time peak value (aggregate time with high concentration less than 15 minutes per shift), if compensated by lower concentrations during the rest of the shift. However, for some substances with risk of acute poisoning or irritating effects the maximum concentration (threshold limit value) is given.

This applies to NO<sub>2</sub> with limit 0.6ppm and aldehydes with limit 1ppm.

Basically, there are three ways of satisfying these limits:

- to reduce the pollutants to start with, e.g. by using explosives with less pollutants, watering the blasting round to suppress dust, using cleaner diesel fuels
- to reduce the exposure, i.e. ventilating the blasting fumes during meal breaks, using machinery (loaders, trucks) with protected cabins
- to provide sufficient ventilation to thin out the pollutants to acceptable concentrations.

This paper is concentrating on the latter. However, as a background, the development towards less polluting explosives is commented upon briefly below.

Substance	ppm	mg/m <sup>3</sup>
CO carbon monoxide	25	29
CO <sub>2</sub> carbon dioxide	5000	9000
SO <sub>2</sub> sulphur dioxide	0.8	2
NO <sub>2</sub> nitrogen dioxide	0.6	1.1
NO nitrogen oxide	25	30
NH <sub>3</sub> ammonium	15	11
Nitroglycerin	0.03	0.27
Formaldehydes	0.5	0.6
Dust:		
total dust (all dust < 10µm)		10
respirable dust (75% of all dust < 5µm)		5

Table 1: Norwegian threshold limit values for acceptable concentrations of selected gases and dust (2015)

### 1.3 Emulsions and slurries

Slurry explosives have been used for more than 30 year in above-ground mining and quarrying in Norway. It is characterised by high effects, good water resistance and good handling safety. Emulsion explosives underground were first used in 1994 for a test program in the Masfjord tunnel in Hordaland in western Norway. This continued in the Lærdal tunnel. In 1994-1995, the Public Roads Administration, Dyno Nobel and Department of Construction Engineering at NTNU performed a development project in the Hanekleiv tunnel in Vestfold, where emulsion explosives were used for the first time for regular tunneling, (Elvøy et al, 1996)

The results from the tests and the production comparisons between emulsion and ANFO show that:

- emulsion and ANFO explosives have comparable blasting effects
- by water inflow, and in down-sloped tunneling, emulsion explosives are advantageous due to its water resistance
- emulsion explosives gives a significantly improved work environment, in particular by reduced concentrations of NO<sub>2</sub> and CO and by reduced dust from the blasting round resulting in improved sight
- emulsion explosives also reduce the outlet of blasting fumes to the external environment, of particular importance for tunneling in built-up areas.

Since then, emulsion explosives are rapidly taking over the tunneling market in Norway. The Norwegian Public Roads Administration considers the use of emulsion explosives as preferable in long tunnels and for projects in cities. In the 7.2km Oslofjord subsea road tunnel, completed in 2000, the contract specified the use of emulsion explosives (Øvstedal, 2003).

## 2 TWO-WAY VENTILATION

### 2.1 Requirements and principles

During the 1990s two-way ventilation used to be required by the Ministry of Labour and Government Administration, Department of Working Environment and Safety for tunnels with cross section above 32 m<sup>2</sup> and at the same time being longer than 1km. This requirement was adapted to the use of ANFO. The purpose was to improve the work environment in the tunnel, by evacuating the blasting fumes rapidly by blowing them out through a duct, so that they do not pollute the tunnel air behind the work face. This is especially useful when it takes too long time to wait for the blasting fumes to be blown out all the way along the tunnel drive. Rapid evacuation allows work activities at or behind the face to start with less delay.

Two-way ventilation can be achieved by one or two ducts.

One duct is sufficient for tunnel drives with up to typically 5km to the work face, but has been tried for longer tunnels as well, e.g. for the 11.5km drive from the southern portal of the Lærdal tunnel. This solution utilizes a mobile platform with a mounted fan, which is used close to the work face, and blows out the blasting fumes in a short time through the same duct as used for the normal 'blow-in' ventilation. The advantages are fast removal of the blasting fumes, and lower costs than two-duct solutions. A disadvantage is high requirements to the tightness of the duct to avoid pollution of the tunnel air due to leakage. The blow-out air velocity must be high to avoid settlement of dust in the two-way duct, as the dust otherwise could be blown back into the face at a later time.

Two ducts, one for blowing in and one for blowing out, is a suitable solution for long tunnel drives (> 4-5km). The advantages are fast removal of the blasting fumes, continuous supply of fresh air from the surface, and the possibility of turning the air flow in the second ventilation tube to improve conditions both at the face and along the tunnel. Also for this solution, the tightness of the blow-out duct is important. The costs are significantly higher than for one duct solutions, typically 50%. It requires more space, which could be limited by the available cross section.

### 2.2 Case story Lærdal tunnel

The 24.5km Lærdal road tunnel was constructed 1995-2000. The contractors were NCC Eeg-Henriksen Anlegg AS from the Lærdal side and the Public Roads Administration, Sogn og Fjordane Construction Division from the Aurland side. The experience presented here refers to NCC Eeg-Henriksen's lot, which included an access tunnel down to the 1/4 point of the tunnel and two drives of 6 and 7 km respectively.

The explosive used were ANFO. The loading machines were Volvo L330C (60 tons with 6.5m<sup>3</sup> side-tipping bucket); i.e. modern machines emitting less gases in the exhaust than usual for older loaders (Nilsen, 1998). The main drainage ditch was blasted together with the face. Behind the face, permanent drainage, channel for electrical lines, as well as a high voltage line, were installed in parallel with the work at the face; normally at a distance of 600m-800m behind the face. At regular intervals the roadway was laid down, including asphalt (except the top layer). A large part of the permanent technical installations were installed while excavating of the drives took place. This reduced the overall construction time for the long drives, but put extra demands on the ventilation.



The ventilation was indeed a challenge; towards the end of the drives the air needed was approx. 8,000m<sup>3</sup> per minute. For each of the two tunnel drives two ducts of diameter 2.0m supplied air to the face pushed by two fans AL 17 of 230kW through Protan Ventiflex ducts (with effect steps of 30, 70 and 230kW). One duct was used for blowing towards the face, the other used also for blowing the blasting fumes out by a movable Gal 14, 110kW fan for each face. The operation of the fans and the regulators was controlled by a radio-system, initiated by push-button panels installed at different locations in the tunnel. In this way the tunnel crews could adapt the ventilation to the actual activities; drilling, blowing out the blasting fumes, loading, transport, rock support, installations etc. Through monitors at the site office, management could observe which activity was on.

The ventilation cycles typically ran:

- When the round was blasted, the outer fans were initiated and ran at full blow (step 3) in both ducts for 5 minutes.
- After 5 minutes, the two outer fans were geared down to step 2 and both directed to one duct only. The movable face fan started blowing out through the other duct. This period lasted until the blasting fumes were out.
- The outer fans then took over again, blowing towards the face through both ducts, while loading and transport were took place, or they were geared down while other less demanding activities took place.
- All these functions were remote controlled and could be operated by computers in the site office.
- Several safety functions were built into the system: e.g. prevention of fans blowing towards each other, locking function to use during duct installation and repair, emergency stop function, manual operation etc.

The air quality was measured in 24-hour periods for NO<sub>2</sub> and CO. This took place several times each week at different locations in the drives. Additionally, air pressure and air check for any leakage, to safeguard systematic maintenance and planned ventilation capacity. The results were satisfying with generally good air quality.

During some short periods of 5 to 15 minutes the gas concentration exceeded the threshold limit value. This happened during loading only. The large duct diameter saved energy. The access tunnel, however, had to be enlarged from a cross section of 56m<sup>2</sup> to 64m<sup>2</sup> to provide sufficient space for the ducts and the truck transport.

### 3 INTELLIGENT TUNNEL VENTILATION, ITV

#### 3.1 Development project

The development project "Intelligent Tunnel Ventilation" was based on an agreement of co-operation between (1) The Public Roads Administration's Central Directorate and their Hordaland Construction Division, (2) The ventilation equipment supplier Protan AS and (3) The Norwegian Industrial and Regional Development Fund (SND). Other companies involved were Telenor (telecommunication) that supplied the control system and Argo/Sichon and BBU (tunnel technology). The project target was to develop a total concept that would contribute to cost effective ventilation, to improvement of the work environment and finally to establish documentation of the achieved results (Lima et al. 1999).

The project included development of new duct materials, new duct jointing and new hook-up systems, as well as recording of air quality and automatic control of the ventilation fans. Emphasis was put on increased flexibility as to choice of equipment and adaptation of the ventilation to the different techniques of the drill & blast cycle, while improving the work environment and the documentation thereof.

The fan control and reduced duct friction would reduce power costs. More importance was put on the possibility to achieve an improved work environment. The project utilised as test arena the 4.2km long Sveio drive of the 7.8km long Bømlafjord subsea road tunnel on the southwest coast of Norway. The tunnel cross section is 80m<sup>2</sup> and the maximum grade is 8.5%. The lowest point is 260m below the sea level and the total climb from the lowest point to the Sveio portal is approx. 300m.

In order to reduce the toxic fumes, emulsion explosives were used, with an expectation of emissions of 1/25 of NO<sub>2</sub> and 2/3 of CO as compared to ANFO. An electric Brøyt 70 ton excavator was used for loading; the shotcreting jumbo was also electric. The main contributors to the pollution of the tunnel air was the 35 tons dump trucks (up to 13 units) hauling the muck up the long steep grade at low gear.

The ventilation was supplied by two AL 17, 250kW fans blowing through two 2.0m diameter ducts. Due to the spread pollution from the trucks, high capacity blowing ventilation was considered suitable: the capacity was 100m<sup>3</sup> per second.

The control system recorded measurements of gas (NO<sub>2</sub> and CO) content in the tunnel and air pressure and

velocity at the tunnel face and at the portal. The effect of the fans were controlled by a Programmable Logic Controller located outside the portal.

The recording units for gas were electro-chemical sensors placed in a container equipped with radio connected to a slave computer 150-600m from the face and 150m into the tunnel (in a cabinet). The recorded data were transferred (UHF low band) to the main PLC; a radio link boosted the transfer when the drive got longer than 2km. The main PLC was connected to a computer in the site office for logging and display of all measurements and events, as well as alarm picture, fans control parameters and trend diagrams. A number of manual radios were also provided, which allowed the crew to over-rule the automatics and control the fans manually.

After the initial development and testing of the prototype recording and control system, it was installed in the tunnel, which at that time had been driven 3km of the 4.2km drive. Because of this, only part of the potential for power cost savings were realised; ~ 35,000 USD per year against the full potential of ~ 85,000 USD per year.

The other experiences were positive:

- the handheld radios (manual controllers) worked well in the tunnel environment
- the electro-chemical sensors in the container (installed outside the container) and in the cabinet (in the tunnel) showed reasonable correlation to handheld sensors for CO, but with relatively large differences for the NO<sub>2</sub> measurements. The latter, however, being in the range of fractions of one ppm.

The results regarding air quality at the face showed that:

- the NO<sub>2</sub> concentration was hardly measurable
- CO from the blasting fumes was evacuated fast
- CO concentration during scaling from the muck pile was too high
- CO concentration inside the loader's cabin was too high
- Uncomfortable draft was experienced due to the high volumes of air
- Dust from mechanical scaling and shotcreting was not diluted sufficiently.

The results regarding the air quality throughout the tunnel indicated:

- Generally good air quality, but not suitable for other works until 1 hour after muck transport is completed
- NO<sub>2</sub> concentration was too high in the outer kilometer of tunnel drive due to the dumper trucks
- CO from the blasting fumes was high
- Measurements inside the dump truck cabins showed concentrations below the norms.

Measurements were also performed at face for NO, but no detectable values were recorded.

New duct material with significantly reduced expansion under high pressure was developed. The development of a new jointing system for the ducts was postponed for further development by Protan AS after the project.

The equipment for fan control was re-used in the Baneheia road tunnels in Kristiansand in southern Norway.

### 3.2 Bragernes tunnel

In the Bragernes tunnel near Oslo, a measuring station for dust, CO and NO<sub>2</sub> was installed. Similar results as in the Bømlafjord tunnel were observed:

- The CO concentration from the blasting fumes was high for a short while
- The NO<sub>2</sub> concentration increased over several hours during loading and muck transport.

The fan was kept running at full speed most of the time hence the power saving potential was not realised.

### 3.3 Main conclusions

The tests in 2 tunnels confirmed (Lima, 2001):

- The system functions robustly
- The control of fans with manual radios works well
- The documentation of the air quality with focus on measurements increases the consciousness about air quality and health
- It is possible to reduce the electric power consumption; the full potential may be realised as the attitude towards more "conscious" control of the fans will increase.

## 4 CONCLUDING REMARKS

Improvement is possible:

- Mobile (hand-carried) gas sensors should be connected to the data base, providing a more complete picture and documentation of the work environment at different locations in the tunnel
- A more extensive measurement scheme for duct pressure will provide a better monitoring of duct condition and need for maintenance
- More information is needed to encourage others to look beyond the initial high investment costs towards the long term benefits of better work environment and potential for reduced power costs
- The occasional use of "old machines" (loaders, dump trucks) may undermine the overall efforts and should be abandoned



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*Water problems in tunnel (Saurdal)*  
Photo: Statkraft



## 08. WORK BEHIND THE TUNNEL FACE

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When working behind a tunnel face, the workers are especially exposed to dust, gas and fumes as polluted air from the face flows backwards towards the tunnel mouth. The gas levels fall faster than the level of particulate matter, but repeated and new sources of pollutant generation, together with pollutant spread and the swirling up of settled dust, can contribute to constant pollution of the air. NO<sub>2</sub> from diesel vehicles accumulates together with other pollutants to the rear of the face. Long-term effects of this exposure over time are not known, but tunnel workers have been shown in general to be at risk of developing chronic obstructive pulmonary disease (COPD). Work behind the face is often carried out in poorly illuminated areas, with little air flow and the work operations may be physically heavy. Stores and workshops that are located inside a tunnel must have sufficient ventilation to prevent the infiltration of polluted air from the tunnel. In general, equipment and material will be muddy from transport and will emit a great deal of dust when handled.

### *Measures for a good working environment behind the face:*

- Watering of the muck pile
- Good ventilation for efficient venting of gases, also in storage areas
- Well lit storage areas
- Sharing of heavy work operations
- If possible, avoid movement in the tunnel whilst rock transport is underway
- Flushing during any drilling in rock
- Cleaning of machines and equipment
- Welding should as far as possible be done outside the tunnel, alternatively in a well ventilated area of the tunnel
- Avoid idling
- Protect stores from a build-up of mud

### **Welding fumes**

Welding is not an activity typical for tunnel excavation, but it may take place, especially in cases where minor damage to work equipment and other apparatus or installations is repaired. Welding can pollute in the form of gas, dust and fumes. Welding fumes are formed by condensation from a hot process and therefore consist essentially

of spherical submicron particles (particles of less than 1 µm), making the aerosol respirable. Special requirements are made when it comes to ventilation of areas that are used for welding. **See the Norwegian Labour Inspection Authority's brochure, Order Number 581, the Workplace Regulations, §7-1 to §7-3, and <http://www.arbeidstilsynet.no/artikkel.html?tid=79455>**

Operations below ground involving hot work such as flame cutting and welding can only be done after an assessment of the danger of fire and exposure to pollutants. Such work should be subjected to special measures for protection of the workers' health and safety, and the pollutants produced during welding should be removed according to requirements. This means that special measures must be put in place, and it should be borne in mind in particular that welding of chrome and nickel-containing acid-resistant steel produces carcinogenic aerosols.

### *Measures*

- Good ventilation of the area in which welding is carried out
- Polluted air must not flow through other work areas
- Own risk assessment during prolonged hot work
- Welding goggles or mask
- Respiratory protective equipment
- Fire prevention

### **Installation work**

Installation work comprises in this connection groundwork in the tunnel, installation work for water and frost proofing, concrete pouring of barriers/shoulders and asphalt work. Few analyses have been made of the working environment during installation work, and therefore only recommendations on measures to secure a good working environment can be given here, based on individual measurements and assessments related to them. A major challenge in connection with installation work in transport projects is that the construction period is short and there is a need to carry out many parallel activities. At the same time, it will often be difficult to control ventilation after breakthrough, since pressure conditions on the outside of the tunnel largely determine the direction of ventilation through the tunnel.



Figure 1: Concrete pouring of barriers

## TRENCH DIGGING AND ROAD CONSTRUCTION

The conditions and the equipment used during trench digging and road construction are decisive for the risk involved, and for how these operations affect other work in a tunnel. The work often consists of drilling and blasting for trenches and/or manholes. Blast gases and dust must be evacuated from the work areas before further work can begin. Short deadlines mean that installation work is organised in such a way that there are multiple and simultaneous working points. Gases and dust from one work site are then carried through the ventilation system to other crews. It is therefore of paramount importance to have good ventilation when there are many parallel activities. There may also be a need to section off work areas such that polluted air does not infiltrate into another work area. This sectioning can be done by building air barriers in the form of temporary walls. Local ventilation using mobile fans, together with sectioning of the tunnel, can give good results. Work in trenches may involve exposure to heavy gases, e.g., radon gas. In known radon gas areas, measurements should be made during the trench digging, if good air change in the trench is not achieved by ventilation.

Moreover, the laying of high-grade aggregates and materials used for tasks such as drainage, road con-

struction and frost proofing, has an impact in relation to dust generation and a potential danger of dust exposure. High-grade aggregates for road construction may have a high quartz content, and in tunnels with little water leakage, good ventilation may lead to a drying out of aggregates and dust generation during transport. The addition of water may be necessary to dampen dust generation. Early installation of high-capacity fans is recommended in road projects.

### Measures

- Facilitate early installation of fans in road tunnels
- Longer construction period to avoid many parallel work operations
- Local ventilation with mobile fans
- Sectioning of work areas using of air barriers
- Use of staggered work hours to prevent the most polluting activities from polluting other activities
- Dust binding of roadways
- Blasting of trenches should be done as much as possible at the face
- Distance between activities that run in parallel

### PE foam and concrete elements, fireproofing of PE foam

Different materials and elements are used for water and frost proofing of tunnels. Various machines and lifts are used for transport into the tunnel, internal transport and



installation of elements. This equipment is often diesel-powered and has industrial engines with old engine technology that has not been adapted for work in tunnels. Exhaust gas from installation work requires good ventilation. Here, too, parallel work operations will present a challenge as regards other crews being exposed to pollution from the installation work. PE foam is a commonly used material for water and frost proofing. It is installed in the tunnel roof using bolts, but must be covered with shotcrete to render the construction fire-proof. The installation of bolts, PE foam and reinforcement mesh represents a substantial task that must to a large extent be done with arms above the head, and it is important that ergonomic factors are taken into account for the installation workers.

The application of fire proofing in the form of shotcrete containing PP microfibres constitutes a significant source of dust and fibres. Fire-proofing work should therefore be done at times when there is no other activity in the tunnel. Plastic materials are used in membranes, pipes and cables (PVC), and in insulation materials (PE and PS foam). Installation of elements containing these materials, and also pre-cast concrete elements, represents an accident risk in general, and in particular in the case of fire. Reference is made to NFF's Technical Report No. 04, Plastic materials in tunnels and caverns. During normal installation work involving these materials there is little

risk of chemical exposure, but it must be ensured that the plastic materials are not exposed to heat in the form of heated material, lighting, equipment etc.

#### *Measures for a good working environment*

- Construction period that is adapted to the working environment challenges in the installation phase
- Early installation of ventilation fans
- Local ventilation with mobile fans
- Staggered working hours, such that the most polluting activities are carried out at separate times of the day
- Establishment of temporary walls for guiding ventilation, sectioning
- Monitoring of gases and dust and plans of action in the event of intervention values being exceeded

#### **Asphalt work**

Asphalt workers may be exposed to dust, oil mist, PAH (polycyclic aromatic hydrocarbons) and nitrogen dioxides. A study from the Norwegian National Institute of Occupation Health (STAMI) has shown increased incidence of work-related chronic obstructive pulmonary disease (COPD) among asphalt workers: <http://www.stami.no/okt-forekomst-av-yrkesrelaterte-kols-hos-asfaltarbeidere>. Several studies have reported increased mortality among asphalt workers due to COPD.



Figure 2: Laying asphalt

Exposure to asphalt fumes will be greater inside tunnels than outside, necessitating special measures and routines when asphaltting inside a tunnel.

An essential measure when laying asphalt is to use low-temperature or "warm-mix" asphalt. Studies have shown that asphalt produced at a temperature some 20 – 40 degrees lower than equivalent "hot mix" asphalt can give a reduction in asphalt fumes of more than 70 %. Another necessary measure in connection with asphalt in the tunnel atmosphere is suitable ventilation.

### **Rehabilitation of tunnels carrying traffic**

Occupational health studies during the rehabilitation of the Freifjord Tunnel in the western Norwegian county of Møre and Romsdal, whilst it carried traffic, were conducted by the Department of Occupational Medicine at St Olav's Hospital in Trondheim in 2009.

The study showed, among other things, high exposure to quartz from filler material during the removal (milling) of old asphalt. Measurements also showed that the workers were exposed to other gas and dust in different parts of the renovation work. In addition, the workers were exposed to the risk of accident, and several types of stresses at the same time, e.g., heavy work, long shifts, night work, noise, chemical pollution and short deadlines during their shifts. However, finished (especially short) tunnels will have better air flow than a tunnel under construction, but there are differences as to how well ventilated the tunnels are.

Tunnel renovation work may typically comprise (taking renovation of the Freifjord Tunnel as an example):

- Road traffic safety measures
- Cutting out of niches
- Rock stabilisation
- Installation of temporary lighting and communication
- Removal of sections of shoulder
- Pouring new concrete barriers (concreting work)
- Laying new conduits and aggregate behind the concrete barriers
- Removal of old fans
- Drilling holes and installing bolts for PVC membrane
- Installation of PVC membrane
- Concreting and installation of technical buildings
- Installation of new fans, signs, lights and electrical installation
- Milling asphalt and laying new asphalt

When renovating tunnels, the different types of operations must be risk-assessed with regard to the exposure to which the personnel carrying out the work are subjected. The study at St. Olav's Hospital involved taking measurements and assessing exposure for many of the work operations performed.

Quartz exposure when milling and laying new asphalt has proven to be particularly high, and must be monitored. The quartz originates from the filler material in the asphalt. Furthermore, dry drilling was carried out, which also shows high dust exposure values. Measures must therefore be implemented in this connection (do not carry out dry drilling, carry out dust damping, e.g., by manual handling of cement).

Measurements of diesel particles, oil mist, oil vapour and PAH have shown low values, and the same applies to NO<sub>2</sub> and CO (with the exception of a few peak exposures), but this will vary from place to place, depending on the conditions at the work site and the measures that are implemented.

As mentioned, during tunnel renovation the workers have other stresses in addition, which they do not have during tunnel excavation, and this perhaps indicates a greater need for assessment of the total stress to which these workers are subjected, and for more measures in relation to all the risk factors to which they are exposed.



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*Image from face tunnel Toven, Photo Hæhre Entreprenør, Tor Holm.*



## 09. HSE WORK IN PRACTICE

### – HOW TO CONTRIBUTE TO A LIVING SAFETY CULTURE

MARKUSSEN EEK, Hanne

#### I INTRODUCTION

The author of this paper has in her capacity as Head of HR and HSE activities made some interesting observations as to the change in attitudes to HSE at management level since she took up this position nine years ago.

At that time, the approach to HSE management, environmental measures and quality control was typically characterised by fine words, but even though all documents of importance included the text HSE – always first, HSE reporting was only ever given the last five minutes in management meetings. Today, however, the situation is quite different, with the first two hours of a management meeting dedicated to these matters.

#### 2 THE COMPANY – FRANZEFOSS MINERALS AS

The company was established in 1919 and started out with a small-scale limestone milling plant some 15 km west of Oslo. Today, still family-owned, the company operates mines and quarries at a number of locations in Norway with a focus on limestone and diorite, and is also involved in asphalt and concrete operations.

#### 3 HSE IN PRACTICE

##### What is important?

*Committed top management* – it is the group chief executive / managing director who must take the lead in addressing HSE values in a company, never a staff manager.

*Each individual middle manager* (production manager, pit manager, construction manager...) must set limits on a daily basis for what is acceptable and NOT acceptable in his/her area of responsibility in relation to safety.

It is important for all organisations to have a good tool box in the form of appropriate routines for preventive safety work. The most important and perhaps most common tools in this respect are:

- Safe job analysis
- Risk analysis

- System for reporting hazardous incidents
- System for reporting undesirable incidents
- A culture of collective learning and competence raising
- A culture of openness – where it is allowed to make a mistake, provided one owns up!
- A culture where everyone thinks safety – also for their colleagues

#### 4 HOW TO MAKE THIS KIND OF TOOL BOX

A good system is the least problem; there are countless master's degree engineers in Norway and the rest of the world who put their heart and soul into delivering the best HSE system. Whether they are successful is determined first and foremost by whether the system is implementable, i.e., is it manageable also for machine operators and other operators, or is it reserved for the pit manager, production manager and their management group?

The second obstacle, and the most serious, is whether there is a culture of willingness to implement within the company/organisation. There is a group of threats which collectively or separately obstruct the work of any HSE manager during the implementation of good HSE tools:

- 1st threat: empty words, a presentation of facts taken from accident statistics based on luck!
- 2nd threat: a culture in which injury-free days are focussed on so strongly that staff conceal injuries so as not to spoil the statistics.
- 3rd threat: managers who do not think it is their job to be "nannies". "Grownups must look after themselves". This means to say that there are managers who, as the company's representative, are not a visible supplier of terms and conditions of what is acceptable and not acceptable behaviour.
- 4th threat: experience or lack of experience is not taken into account during the planning of the job. The person(s) concerned have been given training in accordance with procedures, but do not have the experience their colleagues have.
- 5th threat: informal managers undermine the company's HSE training by ridiculing HSE routines established by the company.

- 6th threat: there is little open communication on the site/in the company. It is "safest" not to say anything, but to wait to see what "the manager" does/says. It is "coolest" to laugh if a colleague points out that rules are not complied with.

*There are many more threats. It is unbelievable how good we are at developing ways of sabotaging safety work when we are in a group of insecure individuals. Paradoxically though, these safety routines and HSE systems are made with a view to getting all these insecure saboteurs home safe and sound every day.*

## 5 WHAT IS SAFETY CULTURE ALL ABOUT?

Safety culture is in fact about all employees from the top down understanding that if those at home (wives, companions, children, parents, friends etc.) are to see them again – they themselves must make a contribution, each and every one of them.

- No one feels safe on a construction or industrial work site if they do not know that everyone around them is putting safety first.
- It is important that the job is planned by the crew through a safe job analysis where the correct protective equipment is assessed and communication agreed. If the job has been planned in accordance with safety there is also a strategy for the execution - and good quality assurance comes from this.
- It is important that nothing should be done in a hurry – "I thought I'd just ..." - has hurt many good employees and taken the life of even more.
- Safety rules may well hang on the wall, but this means nothing until all employees take ownership of them and make them their own.
- We do not let our children ride in a car without ensuring they are properly secured, we put winter/studded tyres on our car, we put on our seat belts, we ride our bikes wearing a helmet ... plus a number of other safety routines we have accepted because we want to protect ourselves and those we love – THE SAME must be true for a company's safety routines – IT'S ABOUT every single one of us coming home each day!

## 6 SO WHAT IS HSE WORK IN PRACTICE?

It is all about being a clear leader when it comes to the behaviour that everyone on the site or in the company should pursue, and any departure from this behaviour must have consequences. Examples may include:

- Broad involvement in safety work, collective learning of good safety analyses.
- Positive and strong focus on safety regardless of the project or job that is to be done. It makes an impression when the first question the managing director or production manager asks after a presentation is "How have you addressed safety during the work?" This question must be asked before he starts to inquire about the finances of the project.

Safety is about behaviour. Behaviour can be controlled by us as companies through the value concepts by which we define our company culture. But it is the responsibility of each individual to practice appropriate behaviour. Safety must be owned and wanted, no one can save the life of a colleague with words.



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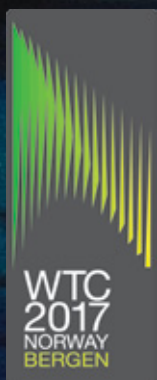
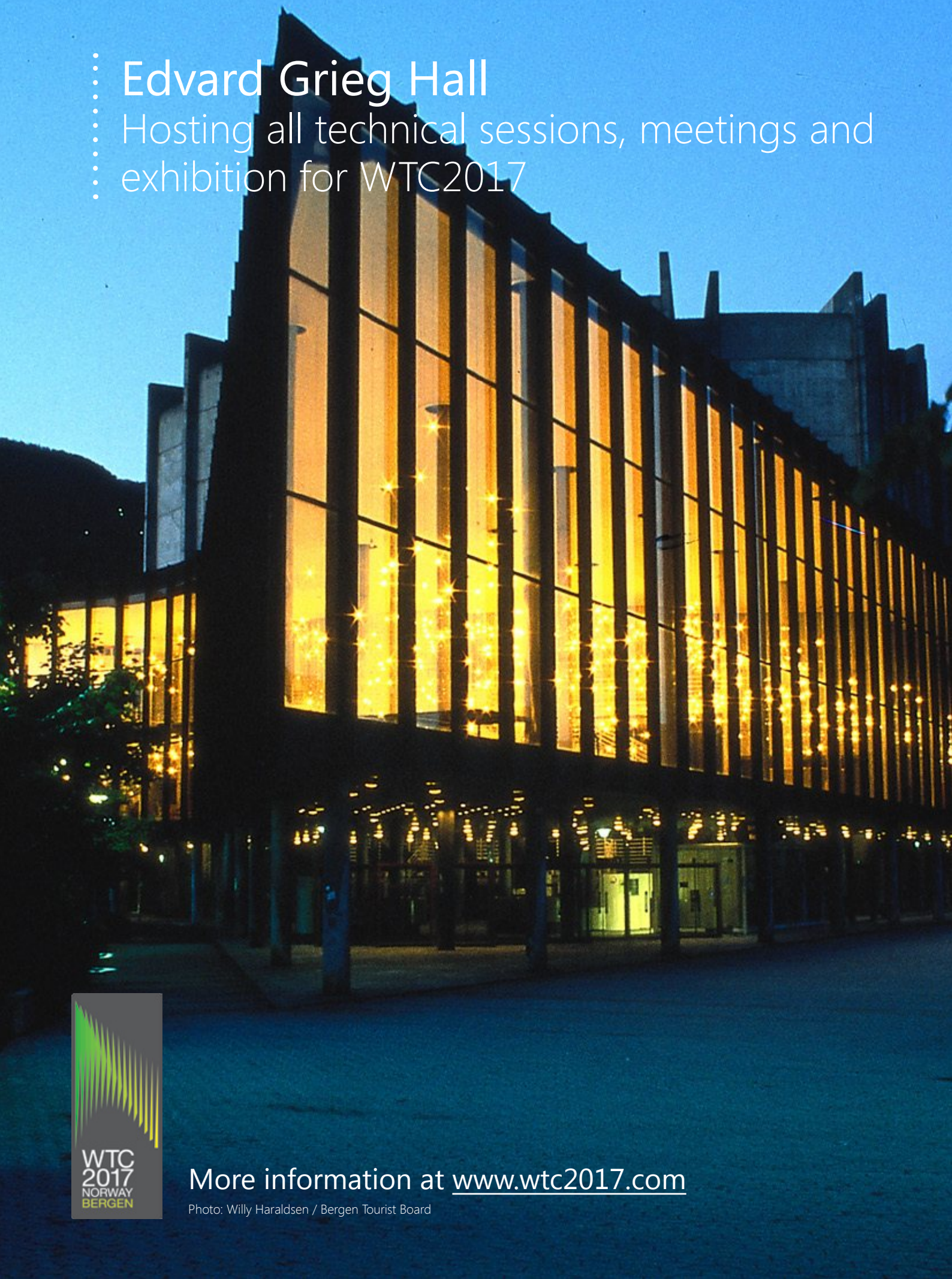
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Photo: Willy Haraldsen / Bergen Tourist Board



## 10. HOW DOES THE CONTRACTOR ENSURE MORE GOOD YEARS AT WORK FOR EVERYONE?

GJENNESTAD, Jørn Audun - Veidekke ASA

### 1 INTRODUCTION

The most important job for the contractor is to ensure that everyone working at the construction sites has a safe, as well as a physical and mental good working-environment. The target, zero injuries, requires continued efforts. Like numerous countries world wide, the Norwegian market area is controlled by laws and regulations on health, safety and working environment. These regulations are honed through a period of many years, always increasing demands, threshold limit values, in agreement with best practise, research and general increased attention from the society.

A main driving force for improving the safety work in practice comes from commitment among clients, designers, suppliers and contractors. In the end, the practical safety improvements at site come from the main contractors. These execute the work, and in most cases create and implement the good ideas, attitudes and improved technical solutions. Unfortunately, it is also among the contractors that we find the most cases of those who take dangerous short-cuts, which in turn may result in serious accidents, injuries and in the worst cases, deaths.

### 2 HSE VISION

Among the major Norwegian contractors there is general agreement that the safety of the employees shall always be given first priority. Work is being done to ensure that this is a mindset and culture that applies to everyone, from the CEO to the worker on site. The safety policy documents and the related specific criteria are developed in cooperation between the Board of Directors and the top management, later resolved and issued by the Board with subsequent distribution of adequate information.

As a part of the following up a report system is established. Achievements are frequently included as part of the Quarterly and Annual Reports. The target for contractor is zero serious accidents. A serious accident is defined as a fatal incident (death) or an injuries leading to permanent disability and/or reduced quality of life. Veidekke, one of the leading Nordic contractors, has additionally set the target to reduce ordinary injuries by

80 % (4 in 5 injuries). The target is ambitious, difficult to achieve and a challenge for everybody in the company.

### 3 HSE STRATEGY FOR VEIDEKKE

The company has decided that the distribution of necessary detailed information on HSE in general, the company targets and the importance of HSE activities shall be an ongoing activity. In order to lower risk levels significantly, the company shall:

1. Improve the understanding of risk assessment
2. Everyone working at and for the company must understand and be capable of handling the risks the work involves.
3. Render first class management
4. Safeguard that all employees, subcontractors and their employees are aware of the individual responsibility.
5. This includes "Mandatory HSE-training for everyone, including the Safety module 1"
6. Subcontractors and their employees shall be trained similarly, that includes "Project specific Safety module 2 for everyone" training to take place during the first week of a project.

The main priorities at site are:

1. Impose strict requirements and rules for all project workfaces as to tidiness and control of temporary installations.
2. Safeguard consistent HSE Risk assessment
3. To control the availability and use of correct and sufficient equipment.

Education and training is important to improve the understanding of risk. For major Norwegian contractors, it is a general requirement to all employees at site, whether main contractor subs or suppliers, that everyone performing work must have adequate and correct training. There are requirements to control of required certificates and permits, and several courses designed to increase competence to ensure that work is carried out as safely as possible.



Strategy for Safety, fig. 1.

The company has developed the so-called “Collaborative Planning” to be an important instrument for safety. All workers and a part of the project team shall be involved in the planning of the daily activities. The Collaborative Planning is conducted systematically to ensure the safe execution of work, while also resulting in efficient execution of the work. Good planning results in safety, the company credo says that “those undertaking the actual work have the best basis for planning its execution”.

Safe operations require every member in the project organisation taking responsibility for his/her level of


planning. Risk assessments are carried out at 6 levels, while allocation of the responsibility for execution has been determined and communicated. It is important that the workers take the responsibility for:

- Level 5 - Safe Job Analysis (SJA)
- Level 6 - Safety assessment is carried out at the start of a working day / shift
- Risk assessments takes always place prior to start of every new task.
- The implementation of the mandatory 2 minute risk analysis.

### Continual risk assessment

SAFE AND EFFICIENT WORK

What is the worst that can happen?  
What can possibly go wrong?  
What can I do to prevent it?



Only well prepared activities!

SAFETY

Have you considered these?

- ☐ Fall
- ☐ Falling objects
- ☐ Crushing
- ☐ Work equipment
- ☐ Protective equipment

HEALTH



Have you considered how you can avoid these?

- ☐ Unnecessary carrying
- ☐ Heavy and monotonous work
- ☐ Static work
- ☐ Poor work postures

Continual risk assessment

Task \_\_\_\_\_

Date \_\_\_\_\_ Actual time \_\_\_\_\_ Actual completed \_\_\_\_\_

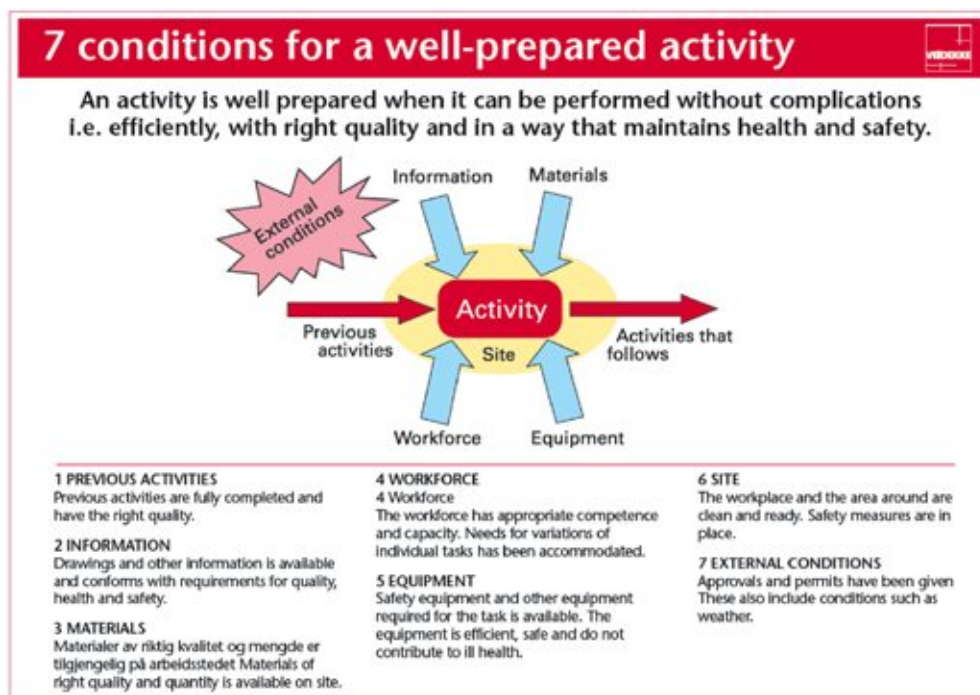
Date \_\_\_\_\_ Who \_\_\_\_\_

Did anything happen yesterday that will affect our work today?

Safety \_\_\_\_\_

Health \_\_\_\_\_





In all planning, and in particular to ensure safe execution of the work, it is important to remember the 7 conditions for a safe activity. These must be communicated, and it is important to report irregularities to avoid recurring incidents or hazardous conditions.

Where risk cannot be completely removed, it is necessary to reduce it. An important focus area is therefore to think of barriers to either reduce the likelihood of an incident occurring. Efficient barriers will also help to limit the consequences and extent of damage if incidents should occur.

#### 4 DISTINCT MANAGEMENT

In order to encourage the entire organization to think safety, clear and consistent management is extremely important. It cannot be optional, something managers can elect to drop. This means that we place great demands on our managers in that they must implement the contractors' safety strategy in a reliable and good manner. The aim is that everyone contributes, and that they feel a responsibility to do so. It also means that in the event of violations of statutes, regulations, our internal rules will lead to reactions as warnings or expulsions. Everyone with us, at all levels, not only has a right to contribute to a high state of safety, everyone has an obligation.

In order for work to be carried out safely at all times, it is also important that there is correct, necessary and adequate equipment present. Personal protective equipment should always be available. It is the responsibility of the management to ensure this. Then it is the responsibility of

each individual employee to use this and correctly maintain it. Among contractors and their suppliers technology and technical equipment exists and is constantly being developed that allows work to be carried out more safely. However, there must be requirements for training.

#### 5 HIGH STATE OF SAFETY - FOR AND FROM EVERYONE

Veidekke's strategy is not to distinguish between our own employees and those of our partners. It is just as important that our subcontractors, suppliers, customers and third parties arrive home safe and sound. This means that demands are placed on them when working on our projects. It also means that they may place demands on us. They take part in our safety training, our handling of irregularities and our collaborative planning. When Veidekke are reporting injuries and incidents internal, we don't distinguish between injuries among our own employees or among the employees of subcontractors.

The HSE-strategy is something we always have to emphasize as the most important for everyone at our construction sites. It is important that the customers, clients and designers also take their responsibility and ensure a good framework, conditions and assumptions in order for the work to be carried out safely. Through compliance with statutes and regulations, good cooperation throughout the industry and consistent safety thinking among all of our employees, the prerequisites for achieving our targets should exist. This will ensure more good years at work for everyone.





Workshop in tunnel  
Photo: LNS



# II. TUNNELLING WORK CULTURES, OBSERVATIONS FROM PROJECTS IN NORWAY

RAFDAL, Arne

Arne Rafdal, MSc. in mining, long time member of Norwegian Tunnelling Society (NFF), wide experience in the mining industry, coal in the Arctic, nepheline at Stjernøya and sulphur containing iron/zinc/lead/silver at Bleikvassli. Arne was later retained by the Directorate for Civil Protection/Energetic Materials Inspection and Dyno Nobel (Orica). In recent years Arne changed to sub-terrain construction, employed by Norwegian, German and Spanish contractors. NFF asked him for his observations on cultural impacts in underground construction.

## I INTRODUCTION

My responsibilities included operational management, partly with focus on Health, Safety and Environment (HSE). The observations below are personal, general and do not refer to one or more of present or past employers. My basis and approach to HSE are rooted in long-term employment in Norwegian companies and organisations.

Later I learned some lessons through my international employers.

## 2 LOOKING INTO THE MIRROR – WHAT WILL BE SEEN?

Looking at the Norwegian version, we like to believe that HSE is solidly connected to top management. We add that without such connection it is not possible to establish the required attitude concerning HSE at the actual work face.

- We have in general a picture of ourselves, telling us that HSE is well taken care of and that HSE matters continuously have our utmost attention. In some projects or in some stages of a project or at least in some sectors of a project this may be true. At the same time, we must admit that the openness related to such matters is limited. An example to support my observations is the fact that owners, media or third parties assume that HSE aspects are taken care of, and thus ask few questions
- An established unofficial practice is to limit what must be tabled

Domestic contractors are better informed on Norwegian laws, regulations, routines, “best practice”. Thus for contractors, just as for sportsmen, it is an advantage to play on one’s own turf:

- They benefit through established contacts.
- They have local work teams well aware of individual duties
- Simple management structure
- There are few communication problems, they speak the language and are familiar with local trade terms.
- Less hierarchy. Easy access/response between crew and management

The domestic contractors have a long tradition of using multidiscipline competent crews where all members are licensed to operate most machinery and equipment at face, including being certified shot firers. The advantages are inter alia:

- Few(er) individuals engaged at the workplace
- Good overview of the situation due to safety aspects.
- Easy to organize, enhanced safety
- Easy access to local boss

The reduced number of operators at tunnel face enhances overview, improves control of ongoing activities and eases detection of unwanted situations.

In my position we used to say “walk as you talk”. This is important and represents an attitude towards HSE and the principle “Everybody at site must adopt an active attitude in HSE matters”.

- If you are an employee, observing somebody involved in actions you understand to be unsafe or dangerous, your immediate obligation is to talk to the person(s) in question
- If you neglect your duty, it may be understood as approval of bad practice. The first agenda item in site meetings is often HSE. Easy for warming up, quickly concluded and nothing achieved. HSE must be an integral part of all items

Site management must advise the entire workforce on HSE matters

- If you were instructed to undertake work you feel is unsafe, your duty is to contact your boss and request his analysis, commonly called SJA (safe job analysis) prior to starting the actual sequence.
- Everybody should feel that safety for everybody is a priority matter.

Injuries happen, frequently due to "I was just going to do..." The message is "avoid smart modifications"

### 3 OUR COLLEAGUES ENTERING THE DOMESTIC MARKET FROM ABROAD

While employed by foreign contractors (foreign registration - NUF- active in the Norwegian market), I have learned that laws and regulations basically are the same within the EU/EEA, but the approach to the work at hand and the methods of organizing seem different from one country to another, here called work culture.

This is no surprise to me. Norwegian contractors occasionally entering international markets have frequently faced severe problems when meeting the actual work culture; the same seems to happen from time to time for contractors coming to Norway.

There are at least two methods of entering a new market.

- (i) Exploring the market situation through active participation in tendering.
- (ii) Exploring the work culture, including contract formats and the methods of organizing project implementation, and maybe establishing a local company including staff members familiar with actual work in Norway.

The first method may be faster with fewer initial investments, but is likely to involve additional risk factors.

The second method is the establishing of a local branch, competent management including competence within local work cultural, prior to the submittal of tenders and prior to entering a contract.

- Like Norwegian contractors, focus for "foreign contractors" is the construction work, contract parties and the progress. Substantial managerial work is allocated to meeting the contract specifications.
- Certification may be a problem. For crew members holding non-Norwegian certificates, control of validity/standard/conversion/acceptance is necessary.
- Communication with the governmental body concerned may be a challenge

Due to a different work culture and the organizing structure, discussions and decisions tend to include more people, and frequently also take more time. The use of several languages and different trade terms may work well; however, there is a risk of misunderstandings. The English language is used; the level of language command varies a lot.

For some projects, contract documents require Norwegian speakers (at least one) at face. In line with my experience, a better approach is to establish a quality introduction program, covering SHE aspects, safe job analyses and more.

If progress is behind the schedules, some contractors tend to increase the number of managers and crew. Not always the best approach. Increased number of people at face is in my opinion counter-productive and also increases risk factors.

- A vital item, again related to the work culture, crew members are used to taking orders from superiors, contrary to the Norwegian and Nordic system with increased discussions and participation based on competence. Slightly time consuming, requires patience, but efficient.

In my experience, foreign contractors are more systematic than their domestic colleagues in the reporting of unwanted incidents both to the owner and the governmental agencies like the Norwegian Directorate for Civil Protection (DSB)

We ought to give our acclaim, but also understand that this may cause an unbalanced view on safety between contractors.

Another aspect to mention is personal injuries and consequential absence from work.

- Norwegian contractors are aware of the consequences of higher «H-values», are clever and well organized in establishing temporary optional positions for injured individuals. This is good for all parties, and is a result of large owners checking «H-values» prior to acceptance of access to tendering
- Some of the «NUF-contractors» have introduced similar approach. (good)

I would also mention that an «NUF-contractor» recently constructed a 3.6 km long tunnel T-9.5 fully equipped that was handed over to the Roads Authority without injuries causing absence from work (zero days absence!)



#### 4 SOME SIMILARITIES, MUTUAL UNDERSTANDING

Different work cultures learn from each other – the competitive melting pot may also contribute to a positive development.

I would like to underscore that my observations are supported by a number of colleagues working for other foreign contractors or retained for joint ventures.

For all of us wherever we come from, whether owner, advisor or contractor, be reminded that we are all working in a sector exposed to severe criticism and negative angling of news from media. All of us will face difficult challenges. It is important to support openness and correct communication in HSE matters.

#### 5 IN CONCLUSION

- Some companies have experience from other continents, that may be good, but still we must remember to comply with Norwegian laws, regulations, standards, directives and more. To learn, listen and

adapt is useful common sense. Those entering the Norwegian market spend resources and time investigating the market, maybe the previously gained experience of others would be helpful.

- Mapping experience
- Several foreign companies will be successful; will be integrated in the professional environment and domestic associations. Looking forward to that.

Finally, a brief comment concerning company structure:

- Complicated structure > reduced rounds/advance per week
- Complicated structure > increased number of misunderstandings
- Simple structure > increased rounds/advance per week
- Simple structure > reduced number of misunderstandings



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## Underground Construction

**From Mapei UTT line: Reliable technology for underground construction**

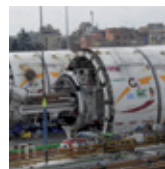
**Alkali-free set accelerators for shotcrete.**

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***E10 Solbjørnneset-Hamnøy***

*Also from E10 in the outer Lofoten area. (compare page 40). The same climatic challenges, this section however, protected by reinforced concrete. Photo NPRA, Peter Fure.*



## 12. EMERGENCY PREPAREDNESS

VIKANE, Kjetil

### 1 INTRODUCTION

The construction industry is regarded as a high accident rate work area. The fatal accident rate, however, has been reduced by 75% during the last 40 years. That may not be an excuse or acceptance for injuries nor lost time at a work place today.

Emergency Preparedness means to be prepared for handling serious incidents. By training, information, organizing, implementation of accident preventives, the number of serious incidents shall be further reduced and the project shall be better prepared for handling a worst case scenario.

Comprehensive risk analysis is the basis for HSE plans and gives the framework for an Emergency preparedness plan. Identification of Risk and possible Accident Scenarios give the input to an Emergency preparedness plan. Below are discussed various important elements for preparedness planning in tunneling.

### 2 EMERGENCY PREPAREDNESS PLANS

The Emergency Preparedness plans should include the following elements:

- Emergency Organization, including a definition when it shall be established
- Possible Accident Scenarios
- Action plans
- Notification plan
- Emergency equipment list
- Assembly point and escape routes
- Training plan
- Emergency report procedure including debrief instructions

It is important to go through the plans with all managers and to practice different situations at least once a year. Signs shall mark the assembly points, escape routes and important emergency equipment. The work force must be included both in the training and the general information system. The plans, maps, emergency and notification instructions must be available at key points, installations and all facilities.

### 3 EMERGENCY ORGANIZATION

An Emergency Preparedness plan should include a description of the involved organizations; the Emergency organization locally at Site; the contacts and relationship between Client and Contractors Emergency organizations. It is important to describe which role each party shall execute in an emergency situation. In some cases, the Client has an existing emergency organization, when possible the existing plans should be expanded to include the tunnel works. In most cases, the project is situated in areas where neither Client nor Contractor has established an emergency organization. In Figure 1 a typical basis Emergency organization shown.

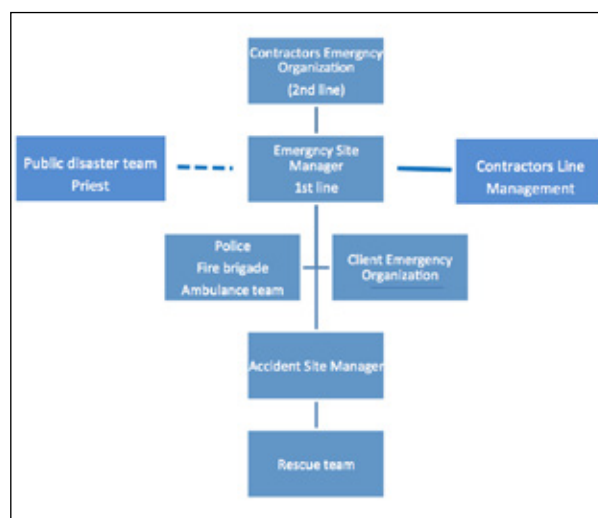


Figure 1: Example of an Emergency Organization.

In a situation where the Police or Fire Brigade are involved, they most likely take the lead at Site. The Project Management will assist and continue its work in agreement with the Preparedness Plans, assisting, writing log and reporting to Client and Company.

It is important to have well prepared facilities for the Emergency Site Manager and crew. An office equipped with telecom, internet/intranet, radio connection, log-book, emergency preparedness plan, notification plan, lists of contact info for staff and crew. The entire set

up must reflect size, where, complexity etc. If possible, the manager should have access to assistance. In some countries, also in Norway it is required by regulations to continuously tag workplace of everybody at site, also if they have accessed a tunnel. In some cases, the tunnel or cavern structure is complex. Common practice is to install a computer aided tagging system using zoning as necessary.

The Emergency Preparedness plans should also identify an assembly point where all people on site assemble if a situation occur. At this place, all registered people on site will be accounted for. It is important to show whom in the organization who will have this role.

If the accident have a fatal or serious outcome, it might be advantageous to make arrangements with local emergency authorities, other teams and the church.

#### 4 IDENTIFYING POSSIBLE ACCIDENT SCENARIOS AND ACTION PLANS

All Possible Accident Scenarios shall be identified. Risk analysis based on tasks to be executed in the project is a good approach for identification of Possible Accident Scenarios.

These are the most common Accident Scenarios in tunneling projects:

- Fire in tunnel
- Huge water leakage or flooding of tunnel
- Personal injuries caused by falling rock, machinery, blasts, fall from above ground, etc
- Landslides and avalanches
- Collapse of or inside the tunnel



Figure 12.2: Training is very important.

After this identification process, Action Plans for each scenario shall be prepared. The Action Plans shall describe the Accident Scenario, Notification procedure, actions to be taken and list equipment and resources available. Map references should be included. Selected landing place(s) shall be marked to be able to give quick and correct notification to H helicopter transport; if possible a Helicopter landing place should be marked and notified in advance to the Air Ambulance site.

#### 5 EMERGENCY EQUIPMENT

Based on the Action plans necessary Emergency Equipment will be identified. In addition, it would be preferable to list all Emergency equipment in a separate attachment in the Emergency Preparedness Plan and add alternative equipment available on Site and alternative equipment. The list should also include equipment available through the local municipality, police, fire brigade, neighbors etc. The list shall describe the location of all equipment.

These are the most common emergency equipment in a tunnel project:

- Firefighting equipment
- First Aid equipment and First Aid containers
- Rescue containers with oxygen, should be maximum 500 meter from face.
- Self-Savers (light active coal filter masks) for every person underground and on the different machines
- Machinery: wheel loaders, excavators, water tank trucks, fans
- Water and water pipe connection
- Life vests
- Radio and other communication equipment



Figure 12.3: Rescue container with oxygen shall be placed maximum 500 m from face.





Figure 4: Picture of a self-saver; each worker in tunnel shall have this available

## 6 TRAINING

Training is perhaps the most important things to do to avoid a disaster or the consequences of a serious situation. Studies after serious accidents shows that people who practice an emergency is more likely to survive. Testing of equipment and how it works is also critical. Fire in the tunnel is one of the worst scenarios.

Frequently one escape route only and fire can be behind face. It might get impossible for a rescue team to access the tunnel due to smoke, lack of communication equipment, extreme heat, or risk for the tunnel to collapse. In Norway the workers train how to use their self-savers, how to use the rescue containers and how to execute first aid.





***Charging the next round***

*According to the new safety regulations charging while drilling is prohibited (all work ahead of the boom hinges while drilling is prohibited.) Photo LNS.*



## 13. ENVIRONMENTAL MANAGEMENT, MONITORING AND MITIGATION DURING CONSTRUCTION

TVEITEN, Vidar - Vidar Tveiten AS  
GREPSTAD, Gisle K. - Multiconsult AS

### 1 INTRODUCTION

The E, “Environment”, in HSE comprises two topics; (1) the working environment and (2) the neighbourhood and natural environment surrounding the construction site / project area. Hence in Norway we now use the term “Safety, Health, Working Environment and External Environment” abbreviated in Norwegian “SHA og YM”. This is to distinguish that we deal with two different topics demanding different skills and measures. We will concentrate on the External Environment only in this article.

### 2 GENERAL

The construction area is located in densely populated urban areas, close to residential areas, schools and kindergartens or recreational and natural areas. Hence the construction activities need to be regulated. The Project’s Environmental Impact Assessment EIA identifies the environmental challenges and constraints. Provisions regarding the construction activities are often stated in the zoning plan. Hence it is important to scrutinize the zoning plan proposal and discuss with the planning authorities before the plan is adopted if the proposed provisions are difficult / impossible to implement.

In the detailed design phase environmental themes are usually stated in the Environmental programme and during the construction phase in the Environmental Follow-up system. In Norway these are often based on the NS 3466 standard; Environmental programme and Follow-up system in the construction (NS 3466). Different organisations use different names but the objective is the same. The environmental programme identifies the project’s environmental targets, while the follow-up system presents how environmental issues are handled during the construction phase.

It is important that the environmental activities and demands specified in the above mentioned documents are included in the contract documents. The descriptions must be specific, targeted and feasible to implement. In unit price contract it is important that the environmental activities and mitigation measures are given price bear-

ing items because it is a saying that «If you can measure it, you can manage it». In EPC contracts the Clients specifications and the Contractors descriptions of how to solve the environmental challenges and how to document it is of outmost importance. Unfortunately major environmental activities are often included as lump sums even in unit prize contract.

The Contractor prepares an Environmental Plan describing in detail how he plans to fulfil the environmental requirements before the work commence. He must also prepare an Environmental Risk Analyses for all construction phases in order to identify potentially undesirable incidents and take measures to reduce the impact of such incidents. An Environmental Plan and Risk Analysis is not mandatory but common practice in some sectors. An Emergency Plan is usually prepared prior to any works being carried out. The emergency plan describes all necessary and intended measures that may affect the environmental matters and specifies possible mitigation measures.

Some of the environmental themes are discussed below.

### 3 NOISE AND VIBRATIONS

Noise is often the most negative environmental impact of construction activities at least in urban areas. Road and railway construction takes years. Both the Developer and the Contractor often want to work around the clock to reduce construction time and cost. This is seldom compatible when it comes to noise from construction sites and noise is often the main negative impact for the neighbourhood of construction sites.

In Norway the noise limit values originate from the Land planning guidelines for noise and management (“T-1442/2012) and the national standard (NS 8175). . The T-1442 is just a guideline not a regulation, but some places, like Oslo, have local mandatory regulations. The Norwegian Tunnelling Association technical publication 15 (Teknisk rapport 15) describes in detail how noise should be handled.

Noise predictions are normally presented in the zoning plan, including noise contour maps for airborne and structural-borne noise. These maps are based on terrain models and anticipated noise levels based on earlier measurements.

Restrictions if any on working hours, blasting, drilling, sheet piling etc. are based on these noise predictions and the guidelines in T-1442/2012 or local regulations

An application to the appropriate authorities is submitted if the noise predictions indicate that the noise limits will be exceeded. The application is submitted as early as possible to give the authorities ample time to process the application. The application is usually prepared by the Contractor and submitted by the Client. The authorities may give a dispensation. The dispensation is often attached with some kind of mandatory mitigation measures. Isolating the façades or temporarily moving people are possible measures.

Control measurements of the actual emitted noise and vibrations should take place throughout the construction period with instruments located at the most exposed neighbours. The results are normally transmitted to a server and made available to relevant project personnel and other stakeholders.

It is now common practice in Norway to send SMS to neighbours prior to each blasting so the vibrations and sound is expected.

#### **4 CONSTRUCTION TRAFFIC**

Construction traffic is a nuisance to the neighbourhood. Increased traffic of heavy duty vehicles creates fear and uncertainty for pedestrians especially children. Mandatory routes for heavy duty vehicles are often included in the zoning plan provisions.

Construction traffic generates noise and dust. A never ending challenge during construction is to keep the roads clean to prevent dirt and dust. Even with washing bays cleaning of roads is needed daily at times.

Maintenance of roads together with routes and transport restrictions is specified in the contract to reduce the negative impact on neighbours. It is important that public walkways and cycling paths are kept open and alternative walkways and paths constructed if the ordinary ones are closed.

Transport passing schools are often restricted during the beginning and the end of the school day. Routes, transport restrictions and consideration of pedestrians and cyclists are important topics in the Contractor's training/information of drivers and Subcontractors.

#### **5 WASTE AND SPOIL MANAGEMENT**

Prior to start of Work, a waste management plan is prepared establishing procedures and a system for waste handling. Normally the contract specifies that at least 80% of all waste shall be sorted for recycling. Each working site must allocate enough space sorting of waste. All waste must be sorted according to categories and classification and delivered to public waste disposal sites. Upon delivery, each type of waste (as defined by its waste code) shall be accompanied by a declaration form. Different waste types shall not be mixed during handling, treatment, sorting or transportation.

Nowadays professional waste handling companies takes care of the documentation and delivery of waste and fine the contractor for un-sorted or wrongly sorted waste.

With spoils we mean both soils and rock debris usually categorised as:

- Inert spoils
- Chemically contaminated spoils
- Biologically contaminated spoils
- Top soil and arable soils

All spoils must be sorted according to the categories and classifications. Documentation must be produced showing that spoil has been sorted by category of the Norwegian Environmental Agency's quality class and transported to sites having authorisations to deposit or process the spoils in question. Minimising mixing or cross-contamination of categories or classes of spoils is essential during excavation. In areas with an unknown degree of contamination necessary supplementary environmental investigations is carried out. A clean up action plan is mandatory for removal of chemically contaminated soils. Biologically contaminated spoils must be handled according to the biodiversity act (Naturmangfoldloven).

It is essential that handling, transport and delivery of the different categories are included in the contract documents. Documentation of spoil handling, transportation and delivery at all times is needed.

#### **6 WASTE WATER MANAGEMENT**

Wastewater from construction sites consists of various types of wastewater. Wastewater from the construction welfare facilities and accommodation, offices, washing bays, workshops and canteens are usually connected to the municipal sewage system according to municipal rules, and regulations. Wastewater from tunnelling operations and other construction activities are usually treated in on-site treatment plants before discharged into a river, a stream, the sea or the municipal sewage system depending on location and permissions.





Figure 1 A double camber semi permeable sedimentation pond

It is the Provincial Governor who issues permits for wastewater discharge from construction sites into rivers or the sea. Usually there are restrictions regarding amount of suspended solids, pH, total hydrocarbon and other chemical parameters. The concentration limits are based on site specific impact assessments and stated in the permission.

Surface run off from rig areas, rock fills etc. are infiltrated in the ground if possible or emitted to a river, stream or the sea after treatment. The level of treatment depends on the vulnerability of the recipient.

Water treatment of surface run off from construction work is challenging due to difficulty of collecting the water and the variation in the amount of water to be treated. Silt curtains and semi-permeable sedimentation ponds have shown to be effective treatment solutions.

Quite advanced treatment plants have been the standard on tunnelling projects in Norway in recent years. Our experience is that strict discharge limits are achieved as long as the contractor has skilled and dedicated opera-

tors on site. Anomalies often occur during grouting or similar activities, weekends and holidays. The tunnel water treatment plants/facilities must be in place before to construction activities begin.

The plant should be monitored on a continual basis to ensure that the specified treatment requirements are fulfilled. Turbidity, pH and water discharge is normally measured continuously on tunnelling projects. The monitoring equipment usually has an automatic online warning system responding when levels exceed the discharge limits. Samples for chemical analysis are often taken weekly as a pre-determined proportion of the flow rate from the treatment plants.

## **7 ENVIRONMENTAL PRODUCT DECLARATION AND ENVIRONMENTAL ACCOUNT**

Environmental Product Declaration (EPD) and substitution to more environmental friendly products has been emphasised in recent years. The major Contractors are ISO 14000 certified, and hence have focus on these issues. But in a tight market the cheaper product is often

chosen for the environmentally friendly one if not specified explicitly in the contract.

Environmental Accounting is not yet common practice for major construction projects in Norway. Some guidelines are given in the Norwegian Tunnelling Association technical publication 16 (Teknisk rapport 16). The challenge is to establish an accounting system that includes the main items. The goal is environmentally and resource effective projects not more paper work neither for the Client nor the Contractor.

## 8 SITE INSPECTIONS

Environmental on-site inspection is an essential part of the environmental management and monitoring. Site inspections are carried out at predefined intervals (weekly, bi-weekly or monthly) Representatives from the Contractor and the Client participate. It is important that the representatives have the authority needed to carry out remedial measures. The inspection comprise following up of noise measurements, water quality monitoring, waste handling, handling and storage of chemicals, adherence to working hours, complaints from neighbours, etc. The environmental management and monitoring team also perform ad hoc inspections.

## 9 NEIGHBOURHOOD CONTACT

Nobody appreciates living next to a construction site. The neighbourhood experiences noise, construction traffic, dust, annoying light etc. This may create anger and/or fear. Information reduces such fear. Close cooperation with the roads authorities, schools and neighbourhood is essential. Information meetings, flyers and SMS warnings are useful tools in this respect. Be frank do not underestimate the negative impact of the construction activity in the communication with the neighbours. It is impressive what neighbours accept as long as they are informed about what is going on and why.

The safety at construction sites in Norway improved when common practise from the off shore oil industry was introduced. Environmental awareness has increased tremendously in recent years. The Central, Provincial and Local Government, the public, private and public developers and Contractors have all more knowledge about eco systems and environmental challenges and solutions than a decade ago. We hope that this awareness will improve the environmental management further to reduce the negative environmental impacts during the construction phase for the benefit of us all.

## REFERENCES:

NS 3466, «Miljøprogram og miljøoppfølgingsplan for ytre miljø for bygg-, anlegg – og eiendomsnæringen»

T-1442/2012, «Retningslinje for behandling av støy i arealplanlegging»

NS 8175, Acoustic conditions in buildings - Sound classification of various types of buildings, 2012

Teknisk Rapport 15 «Støy fra bygge- og anleggsvirksomhet» The Norwegian Tunnelling Association

Naturmangfoldloven «Lov om forvaltning av naturens mangfold», Norsk Lovdata

Teknisk Rapport 9 «Behandling og utslipp av driftsvann fra tunnelanlegg» The Norwegian Tunnelling Association

Teknisk Rapport 16 «Ambefalte retningslinjer for utarbeidelse av miljøbudsjett og miljøregnskap for tunneler» The Norwegian Tunnelling Association



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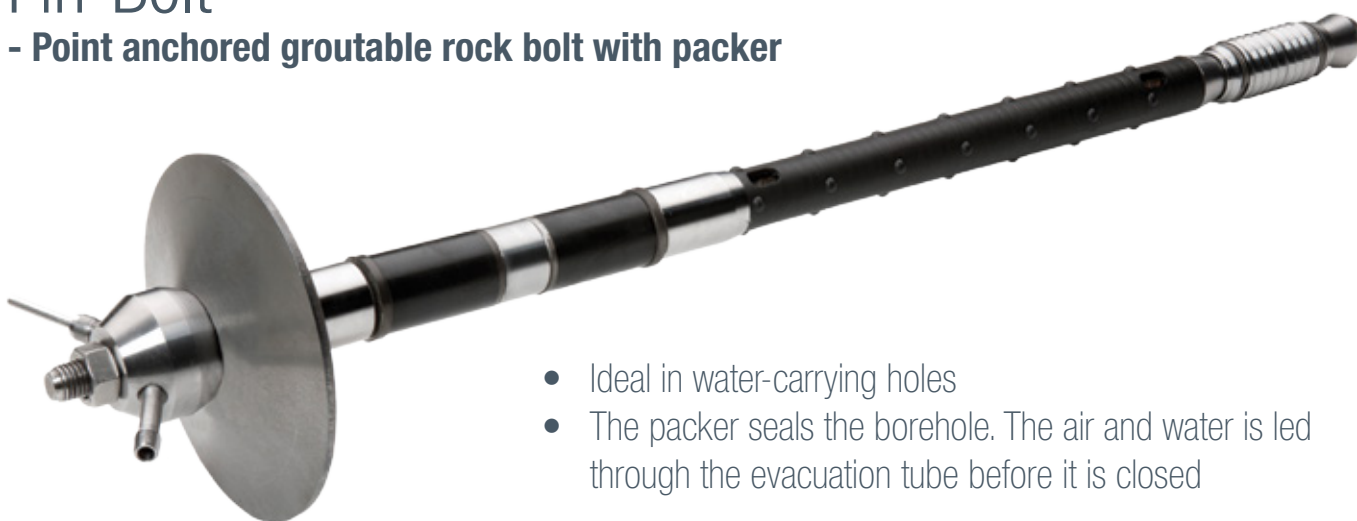
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- Quickly installed, easily grouted

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Vik Ørsta also operates in the areas of lighting columns, traffic safety and marinas. CombiCoat® is our contribution to extending the lifetime of steel that is exposed to extreme conditions. CombiCoat® is a combination of two different surface treatments; hot dip galvanization and powder coating.





*Personal protection is to be seen*  
*Photo: NRA Hilde Lillejord*



## 14. VEIDNES TERMINAL - AN EXAMPLE ON HOW CO-OPERATION DURING PLANNING AND DESIGN CAN IMPROVE H&S DURING CONSTRUCTION

BERNITZ, Pia  
SOLBERG, Wenche  
ØDEGAARD, Henki

HEIMLI, Per  
STORMYR, Elisabeth



*Veidnes and the Sarnes Fjord at Magerøya, looking north east*

*Photo: Multiconsult*

In a very northerly and arctic part of Norway, Veidnes at Magerøya, Statoil has been assessing the feasibility of an on shore terminal for oil storage and export. Rock caverns for oil and gas storage have a long tradition in Norway due to the general hard rock quality. At Veidnes, however, the rock quality is varying, partly poor and has been a main challenge in the planning process, regarding construction methods, stability and HSE. With Statoil's aim for "Zero Harm" in relation to HSE in their projects the challenges became a starting point for an educational and productive collaboration between the client, consultants and contractors. The process and outcome is presented in this article.

### I INTRODUCTION

In 2014, 1 of 3 fatal occupational accidents in Norway occurred in the building and construction industry where the fatal accident rate has been increasing the last 5 years. Due to the high accident risk in the construction industry, a HSE charter was signed by authorities, clients, designers, contractors and employees organisations in June 2014. The main obligation for the designers is always to perform risk assessments with respect to the execution phase when selecting architectural and technical solutions and to always describe the HSE related services and deliveries in a project.

In Norway, the Construction Client Regulations, CCR, concerning safety health and working environment at construction sites, defines the Client's, Designer's and Contractor's responsibilities in a building and construction project.

These regulations require designers (architects and consultants/engineers) to perform risk assessments with regards to occupational health and safety at the construction site during the engineering phase. The designers shall consider risks and hazards involved in the project to eliminate or reduce hazards and risks in the construction phase. This requires an understanding of the construction work and types of health issues that are involved. The consideration of these matters must be an integral part of the design decision process. Despite having had these regulations for several years, the quality of the designer's risk evaluations is not always satisfying. We believe that detailed risk assessments during planning and engineering with regards to H & S in the construction phase will contribute to a safer work site.

In complex projects, the risk assessments in co-operation between the client, consultants and experienced contractors during the design development is important to ensure a safe execution of the project. The Norwegian

organisational culture is based on Norwegian work values. In general the work environment structures are flat with little hierarchical regimes. This openness provides opportunities for cooperation regardless of position or role, and is highly valued. At the Veidnes Terminal, this culture encouraged the cooperation between the client, the consultants and the contractors that led to changes in construction methods and design.

## 2 A COMPLEX PROJECT

The Johan Castberg oil field is located in the Barents Sea, about 240 km north of Hammerfest. Two concepts has been evaluated for the oil export; a floating off shore unit and an onshore terminal. At present the project is put on hold as the concept method is yet to be decided.

Multiconsult AS and Kværner ASA, were engaged by Statoil in 2012 to evaluate suitable locations for the onshore terminal, followed by a concept study for the layout and design of the terminal. To assist Statoil and partners in the election of an on shore or off shore concept, Multiconsult AS, Aibel and Norconsult AS were engaged in an extended concept study to further evaluate and detail the on shore concept.

Veidnes was chosen for the on shore terminal for its availability from the Barents Sea and the protected sailing and birthing conditions. Veidnes is located at Magerøya in the most northerly part of Norway. It is a bare and beautiful headland with rock outcrops and low

growing vegetation. Today the area is mainly used for reindeer grazing, holiday houses, camping and hiking.

The arctic climate in the area is challenging due to its strong winds and snow drift during the winter season. Snow drift can block roads and buildings and cause avalanches. However, the most challenging condition at Veidnes is the poor rock quality. The terminal would require large rock caverns for temporary crude oil storage. Two rock caverns should each hold 191.000 m<sup>3</sup> oil and include 5% volume for gas.

With these conditions and presumptions the project went into a constructive and collaborative design process. This article focuses on the design development of the rock caverns and challenges in regards to construction and H&S.

## 3 COLLABORATIVE DESIGN PROCESS

The concept study should ensure a proposed site preparation concept and design solution that was in accordance with Statoil's "Zero Harm" goal for the project, and within the planned construction schedule. Constructability studies were performed in several phases of the project and constructability reviews were held to reveal HSE risks. Only the H&S issues are considered in this article.

The challenges with the poor rock quality became more and more evident through the concept study.



Northern shoreline at Veidnes, looking west towards the Veidnes Bridge.

Photo: Multiconsult



Multiconsult researched literature to find reference projects with similar conditions. In agreement with Statoil, contact was made with the client and consultants for a tunnel at Veidnes that is constructed in similar rock conditions, and with a contractor with special experience in tunnel construction in difficult rock and climate

conditions. In addition, new consultants were engaged for the detailing phase for the terminal design and layout. Through interdisciplinary workshops and reviews, the extended project group worked systematically aiming to eliminate H&S risks. Focus areas were evaluated and presented with recommendations such as in the table below:

FOCUS AREA	RECOMMENDATIONS
Caverns and tunnels, excavation and rock support. Very fractured rock Main issues related to: <ul style="list-style-type: none"> <li>• Global stability</li> <li>• Local stability</li> </ul>	<p>Experience from construction of nearby road tunnel in the same rock mass was obtained through meeting with contractor/workers, in order to develop optimized excavation and rock support procedures to ensure an acceptable H&amp;S risk and to verify feasibility of schedule.</p> <p>Special excavation and rock support procedures (bolting and sprayed concrete) must be developed, to account for the rock quality and the required excavation / transport logistics.</p> <p>Supplementary diamond core drillings and examination of boreholes by OTV.</p> <p>Verify in situ stress conditions during access tunnel excavation, and re-evaluate detailed design of rock support measures after explorations by contractor from tunnel/cavern face.</p> <p>Real time observations of rock deformations should be carried out throughout the entire excavation period; develop a monitoring program and response procedures related to the monitoring results.</p> <p>Allow sufficient time for additional rock support work.</p> <p>Evaluate need for special H&amp;S procedures.</p>
Caverns and tunnels, mass transport	<p>Separate tunneling and mass transport – construct dedicated transport tunnel at the lower end of the caverns rather than going through the caverns.</p> <p>Intersections in the access tunnel system should be horizontal and as wide as possible to give good view, if possible roundabouts.</p> <p>Contractor to construct his own meeting places in the access tunnel if required.</p>
Future caverns	Evaluate how construction of the future caverns may affect the stability and operation of the existing caverns during the expansion work.
Timely completion / schedule	Schedule/installation time is prime uncertainty. Allow sufficient time for additional rock support work.
Constructability	<p>Conduct Constructability HAZID for layout /site prep/cavern changes.</p> <p>Risk evaluation of cavern construction.</p>
Traffic safety, mass transport	<p>Ensure no end tipping at deposit sites or into barges.</p> <p>Driving patterns, avoid reversing of trucks.</p>
Emergency preparedness	Include for greater than normal emergency response capacity to handle incidents related to rock-fall/blasting, equipment/traffic, men falling into water, hypothermia, chemical discharges to ground and sea, etc.

#### 4 GEOLOGICAL CONDITIONS

The local rock type at Veidnes has alternating layers of sandstone, meta-greywacke, slate and shale. The entire rock sequence has developed a bedding-parallel cleavage and fissuration, and folds occur on varying scales. The rock quality is generally poor to very poor and major stability problems have been encountered nearby when tunnelling through the same rock mass. A typical rock outcrop is shown in the photo below.



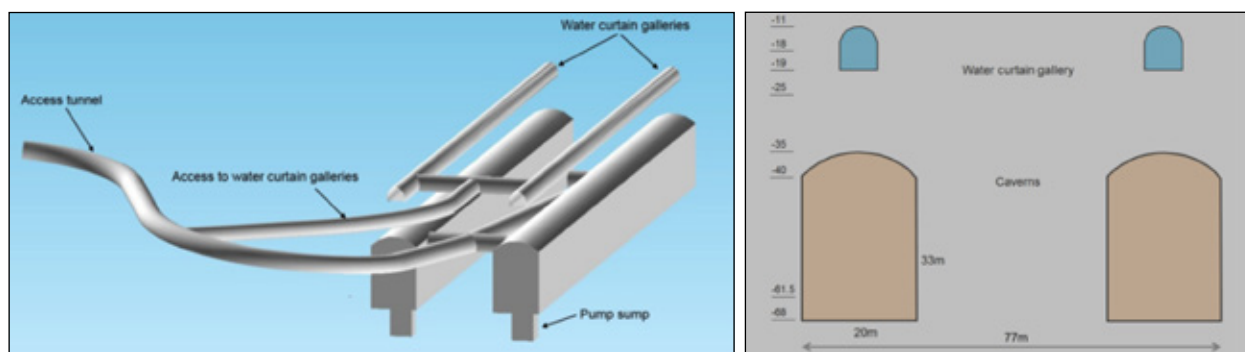
*Characteristic layered rock outcrop at Veidnes  
Photo: Multiconsult*

#### 5 CAVERN DESIGN DEVELOPMENT

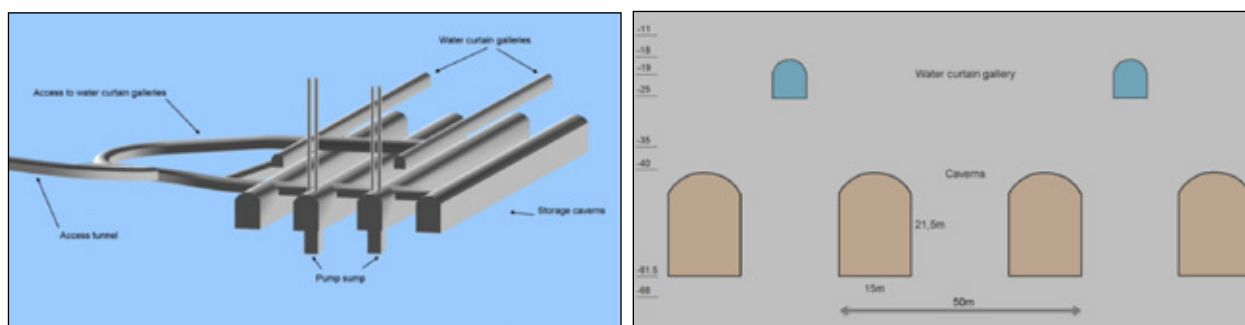
The initial cavern design at Veidnes was a conventional layout for unlined crude oil caverns with a water-filled access tunnel and a concrete plug where the tunnel enters the cavern. At the bottom of the caverns there are pump pits for oil and water, and the pits are connected to the surface by vertical pump shafts. It is also common to arrange a water curtain system in the rock mass above the caverns in order to maintain sufficient water pressure around the caverns. Holes for the water curtain are drilled from a water curtain gallery.

The layout was then subject to a constructability review with the client, the consultants and the contractor. Several H&S related challenges and risks regarding the design were uncovered. The main risks were related to space limitations for future caverns and stability issues due to the large cross sections. The design was altered to two pairs of caverns with smaller cross section.

The cavern height was reduced from 33 meters to 21.5 meters, and the width from 20 meters to 15 meters. In addition the inclined access tunnel was moved to the side of the cavern system. These measures allowed an improved construction method, reduced rock support and enhanced safety during construction.

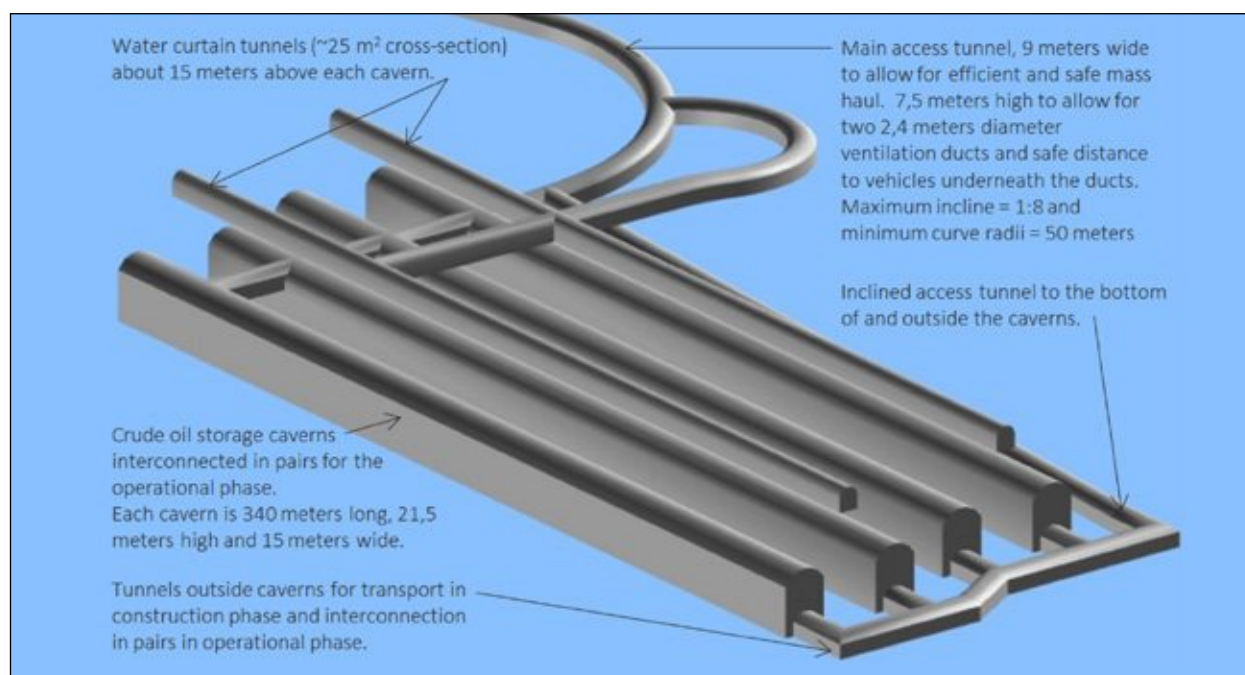


*Conventional layout and cross sections with two straight caverns, 3D model by Multiconsult*



*Revised layout and cross sections with two pairs of caverns, 3D model by Multiconsult*





Final cavern layout. Pump sumps, concrete plugs and shafts not shown, 3D model by Multiconsult

The revised layout was again evaluated in a workshop with the client, consultants and the contractor. One of the results regarding H&S was that the lower interconnecting access tunnel were moved outside the far end of the caverns to avoid traffic conflicts during simultaneous excavation of the caverns.

## 6 H&S CONCERNS IN THE CAVERN CONSTRUCTION PHASE

The collaborative workshops and reviews also resulted in improved H&S solutions for the cavern and tunnel construction phase. The main issues are presented below.

### Excavation

A main concern with regard to tunnels and caverns is instability of the crown. The instability can be caused by excessive downfall of rock, either from structurally controlled large wedges, or by progressive unravelling of heavily joined rock mass. The rock fall causes risk for serious injuries or loss of lives if detailed site specific procedures are not followed. Work specifications must highlight H&S performance as the primary success criterion.

The proposed rock excavation method at Veidnes was a drill and blast technique using modern, computer controlled drilling jumbos. The jumbos are highly automated, reducing the need for manual labour at the working face, and hence reducing risks for occupational accidents.

### Shafts

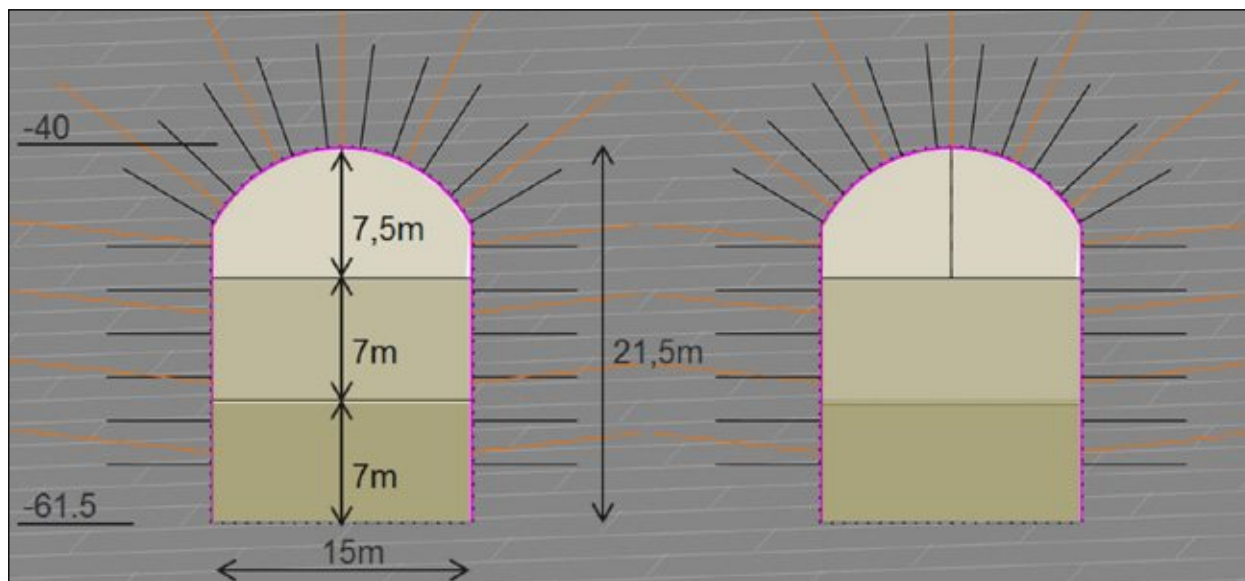
The vertical shafts should be raise bored from the surface using a steered pilot hole drilled from the surface downwards to the cavern crown. When the pilot has pierced the cavern crown the hole is reamed to the required diameter. The reaming shall be performed prior to excavation of the first bench level in the cavern. This will ensure easy access for the reamer bit installation, and avoid greater fall height for equipment or personnel. In addition, early installation of the shafts is a prerequisite for sufficient ventilation for the work environment in the caverns.

With the serious H&S risks in shaft work it is of high importance that the contractor evaluates the construction plans and works out safety procedures.

### Rock support

Systematic rock bolting combined with fibre reinforced, fast curing sprayed concrete was proposed as key factors for the rock support of all underground excavation works at Veidnes. Important experience from a road tunnel at Veidnes showed that stabilising the blasted rock surface with sprayed concrete efficiently stopped further unravelling of the rock mass. There were also strong indications that the sprayed concrete itself was sufficient support to ensure temporary stability of the crown until bolting could be executed.

Radial rock bolting with combination bolts was chosen for the rock support as the bolt type ensures immediate support



*Schematic overview of the main rock support and excavation levels for one pair of the caverns. Radial rock bolts (black), anchors (orange) and sprayed concrete (purple)*

and tensioning by the mechanical anchorage. All installed rock support was to be regularly inspected to detect any negative development such as de-bonding or jointing of sprayed concrete, or failure of rock bolts and anchors.

Continuous and qualified monitoring of stability and deformations and evaluations of the rock support method should be performed throughout the construction period by presence of skilled and experienced engineering geologists. This will reduce the risks and enhance personnel safety.

## 7 CONCLUSION

The conditions at Veidnes, the complex project and the rock quality in particular required specific detailing of the consequences and feasibility. The challenges instigated the extended interdisciplinary collaboration between the client, the consultants and the contractor. This type of collaboration is possible in the flat working environment structure in Norway. The general interdisciplinary discussions revealed problems and solutions regarding the cavern cross section and layout. The discussions also generated important input from the contractors on methods, equipment and schedule that is essential in the evaluation of constructability during engineering.

The outcome of the collaboration was applied and resulted in a revised layout as well as improved construction methods that in turn reduced the H&S risks which would improve the working conditions in the caverns.

Not all projects have the same challenging and complex conditions, but an interdisciplinary collaboration is useful



*The proposed terminal seen towards south east with the construction jetty to the right and the product jetty to the left. Visualisation by Multiconsult.*

for most projects and the experience is usually transferable to other projects. When the result in addition can be applied to avoid or reduce the number of unwanted incidents it should be a general principle to follow.

## PROJECT PARTICIPANTS AND ROLES:

Statoil ASA – Client and project owner

– Involved in all phases

Multiconsult AS – Civil consultant

– Involved in all phases

Kværner AS – Process engineering consultant

– Location study and first phases of concept study

Aibel AS – Process engineering consultant

– Extended concept study phases

Norconsult AS – Civil consultant

– Extended concept study phases

LNS AS – Concept study phases



# — Rock Engineering —

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*Vettekollen underground water reservoir in Oslo*

*Installation of mechanical equipment for the operation of the reservoir. Photo Byggeindustrien Ådne Holmleid.*



## 15. HSE-CHARTER TOWARDS ZERO INJURIES AND DEATHS IN THE BUILDING AND CONSTRUCTION INDUSTRY

AASE, Johan Larsen  
JASPAL, Tina

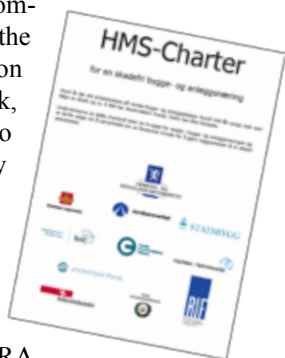
LIEN, Jan Erik  
SAND, Terje

18th of June 2014 the actors of the Norwegian building and construction industry signed the charter towards zero injuries.

The charter was signed by the government, clients<sup>1</sup>, representatives for the project consulting companies, representatives for building and construction companies and representatives for the workers. By signing the HSE-Charter all actors are committed to carry out selected tasks to improve the occupational health and safety in the industry.

Every year several persons working on construction sites in Norway dies at work, approximately 100 persons ends up with injuries that will mark them for life and approximately 8000 persons are not able to work for one or more days because of a work related accidents at the building and construction site.

The HSE-Charter is the commitment that shall make the building and construction site a safer place to work, in order for each worker to be able to go home every day without any work-related injury. The charter is the first step towards a zero vision regarding work-related injuries and deaths. NPRA, NNRA, Statsbygg and Forsvarsbygg, who all have signed the HSE-Charter, are the representatives for the client, with NPRA and NNRA representing the public client for construction and Statsbygg and Forsvarsbygg the public client for building.



The clients' commitment to this charter are:

- To be an ideal client in the field of HSE and make sure that all of their projects do have a safety and health plan that deal with the specific risks that must be dealt with at the construction work.

- Make sure that learning from incidents and accidents at construction sites are distributed to all the projects of the client, including the actors represented in the charter.

The charter is managed by a board consisting of a representative from each of the signing parts of the charter. The board shall make sure that the commitment set out in the charter is fulfilled by each partner of the charter. The board shall also establish a plan that includes the tasks each signed partner of the charter has committed to. The plan shall be evaluated and revised once a year. After two year, the work carried out according to the plan shall be evaluated.

The Norwegian Labour Inspection Authority representing the government in the board, will act as the secretariat for the board.

### THE ACCIDENT STATISTICS AND MEASURES TO PREVENT ACCIDENTS AT THE CONSTRUCTION SITE WITHIN THE CLIENT DEPARTMENT OF NPRA.

*By Jan Erik Lien, Norwegian Public Roads Administration (NPRA)*

#### Accident statistics

The last five years the number of work-related accidents related to the client department of NPRA has been increasing significant. Especially the work-related accident with serious outcome and death have increased in this period. Which means that more of the building and construction related deaths have happened at the construction sites of NPRA. The number of person who have died in work-related accidents within the area of the Norwegian Labour Inspection Authority have had the same variation as earlier years of 2010-2014. The graph below shows the development in number of killed between 2003 and 2014 related to the construction business of NPRA in red, building and construction industry in blue and area of the Norwegian Labour Inspection Authority jurisdiction in yellow (total). In 2003 NPRA

<sup>1</sup>As defined in COUNCIL DIRECTIVE 92/57/EEC

was established as a client organisation, when the production department was established as an own company.



Analyses done regarding the most severe accident in 2012 and 2013, shows that the sub-contractor is the one who is involved in most of the severe accidents. The analyse also shows that when server accidents happens, in most cases the “safe work” risk analysis covering the work that shall be done, is not carried out. The reason for this is that during the planning of the work, the risk was regarded as low. In lot of the accidents covered by the analysis, the work was ordinary carried out daily, like transport, backing up heavy-duty vehicles, use of diggers and other construction machines.

The death related to 2013 and 2014 were all related to use of construction machines, building of bridges and work in tunnels.

In September 2014 a sever accident including explosives happened. At this accident lead to death of three persons. The cause of the accident is still too early to conclude on, since it for the moment is under investigation of the Norwegian Labour Inspection Authority, but it seems to be agreement among the experts that the explosion was detonated during the preparation.

The thoughts of the experts are in line with the findings of the damage done during the explosion.

This was the first accident in 2014 at one of the construction sites of NPRA, were one of the workers who passed away was foreign. Before this accident, only Norwegian citizens had lost their lives at the construction sites of NPRA. The foreigner who passed away was citizen of Lithuania.

### Measures to prevent accidents

At NPRA a lot of measures has taken place to prevent accidents, especially in 2011. Some of the measures relates to the work the client, NPRA, are doing at construction site to follow up the safety, while other measures relates towards

how the work at the construction site is organized. These measures are both expected to have a short time effect and a long time effect, and some of the measures will have influence on the safety culture at both construction business as a whole and at each company carrying out the work.

Some of the measures put into action are listed below:

- HSE to be part of the cooperation process between the client and the contractors, including sub-contractors.
- Use of management inspections and 1:1 inspections.
- Established procedure to stop dangerous work.
- Established procedure to follow up critical incidents and accidents.
- Strengthen the routines of control when new sub-contractors are introduced to the construction site after the project has started.
- Meeting to follow up accidents that have led to deaths.
- Requirement to limit the number of sub-contractors to two under the main contractor.
- Enforced the competence of HSE/OHS within the organisation of the client.
- In a systematically way, make sure that learning and experience are made available throughout the organisation.
- Established routines for control of reception
- The id-card construction is required from day 1
- Strengthen the requirement for use of personal safety equipment (including clothing)
- Increased focus on risk analyses/evaluation.
- Increased focus on safety culture, the attitude to be safe at work and the behaviour the worker.
- Terminate contract when HSE requirements are not followed
- Excluded from future contractual work if HSE requirements are ignored repeatedly.

An evaluation of the effect of the measures put into action during 2011, 2012 and 2013 has been done. The conclusion was that the actors was positive to the measures put into action, but that it was too early to conclude if the effect of them was as expected.

The result of the KPI values regarding frequency of accident (H-value) and frequency of incidents (N-value) showed a positive trend for 2014, with a reduction of frequency accident and an increase of frequency of incidents<sup>2</sup>.

The focus on safety of building and construction sites has never been as high as it is today, and it will be interesting to follow the development on this field in the future.

In addition to the measures that NPRA has put into action, many of the other actors of the building and construction industry are doing the same. All working



systematic and dedicated towards a safe working environment within the building and construction industry.

## WORK AGAINST SOCIAL DUMPING

*By Tina Jaspal, The Norwegian National Rail Administration (NNRA) and Terje Sand, Norwegian Public Roads Administration (NPRA)*

### Public builders and government working against social dumping

Ministry of labour and social affairs have recently brought forward a strategy to strengthen the effort of work against social dumping and the wider risk area working crime. Control agencies, like Norwegian Tax administration (Skatteetaten), Norwegian Labour Inspection Authority (Arbeidstilsynet), Police (Politiet) and Norwegian Labour and Welfare Administration (NAV) will work together on controls and preventing actions. Norwegian Public roads Administration (NPRA) and Norwegian National Rail Administration (NNRA) evaluate these official actions as vital for our work against social dumping and preventing less seriousness.

### Regulations and supervisor duty

NPRA and NNRA have a duty to supervise labour conditions based on the regulation of labour conditions in public contracts. As a public builder we have included supervisory duty as a demand in our contracts valid for all participants at any project.

### Cooperation Public Builders

Top management have been clear that we will have no tolerance on social dumping. The mandate was quite clear; shape up processes and tools so we can fight this problem and continue to build seriousness. Agency for Public Management and eGovernment (DIFI) have organized this work together with the largest public builders in order to get best practice that could support our work. DIFI have their mandate from Ministry of labour.

### Risk evaluation and management

Through a series of work meetings lead by DIFI all public builders have managed to create a common ground and establish the greatest common divisors. One of the main symbols of this work is a mutual decision to make use of a comprehensive risk evaluation and implement this internally in all organizations, to address each projects need to carry out a supervisory control. The risk evaluation is based on principles and analysis that point towards finding potential subcontractors that are at risk or may be conducting social dumping in their work force.

A toolkit is under development for projects and contract holders. In this toolkit, checklists and templates on how to conduct a control of pay and working conditions, especially of foreign workers, is described from A-Z. In extension of the toolkit each organization will hold courses, seminars and simulate cases based on finding traces of social dumping or violation of work and salary regulations. The key premises to succeed further in implementing a new risk evaluation and follow through, is management commitment.

### How to organize – a vital action

Two vital actions is needed to succeed in this matter. Anchor the importance and need for resources with top management, as well as implementing tools, training and competence all the way out in our organization. We have monitored a successful process by establishing regional task forces who are responsible for training, organizing experience and local controls as well as the local and regional cooperation with public control agencies.

### Tools within preventing and controlling deviations

We have put a strict focus on developing actions and tools which have an preventing impact. It will create seriousness and save costs if we would be able to prevent cooperation with client who practices social dumping.



Fig 1. Processes, work against social dumping

Our tools within control environment during implementation of contract, includes check of vital documents as well as check of ID-cards and standard labour conditions. Control regime will be expanded with audits based on investigation methods when needed.

Experience database – evaluation of future cooperation  
All actions we organize to prevent social dumping at our projects will give us both positive and negative experiences. These experiences will be saved in at database in order to use this in future qualifications processes.

<sup>2</sup>The increase of incidents are positive because this shows an awareness among the workers to report incidents, and especially those who only have a potential for things to happened. The reported incidents are also the base for preventive safety work.





*A section of the tunnel face supported by sprayed concrete prior to drilling for next round. Photo LNS*



## 16. SYSTEMATIC OCCUPATIONAL HEALTH MANAGEMENT

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### 1 MAPPING FACTORS INFLUENCING THE WORKING ENVIRONMENT

Mapping the working environment is essential in order to safeguard health and the environment. Measurements alone do not provide the basis for an absolutely complete assessment of all factors related to the quality of the working environment; nor do they give a clear picture of the potential risk as the working environment is extremely complex and complicated. However, measurements are an aid in identifying, assessing and taking preventive measures, and also help to monitor working environment factors that are detrimental to health. They allow the mapping of type and level of the pollutants encountered during tunnelling work.

The mapping and measurement methods used today are described in **the Norwegian Labour Inspection Authority's brochure "Mapping and assessment of exposure to chemical and biological contaminants in the working atmosphere" (Order No. 450)**. This brochure describes the main principles for mapping, measuring and assessing risk associated with chemical and biological exposures in the working environment, and is based on a number of international standards.

Measurements must be made by personnel with occupational health expertise who are to be found, inter alia, in the occupational health service. This is because sampling is part of the mapping work that represents the greatest uncertainty (risk of incorrect measurements, results and interpretations), and therefore must be quality assured. See Appendix 1 for an overview of the measuring methods that are normally used. It should be possible to use the results of measurements as a basis for assessments and planning of new projects.

Risk assessments should be documented, and the documentation should show that the factors described in the table have been assessed and should also indicate the results of the assessments.

### 2 RISK ASSESSMENT

Requirements for risk assessment of chemical, biological and physical working environment factors are laid down in working environment legislation, more

specifically in **The Norwegian Labour Inspection Authority's Regulations relating to the performance of work**, Chapter 3 (chemical factors), Chapter 14 (noise and vibrations) and Chapters 15 and 16 (different forms of radiation).

Risk is determined by assessment of consequences of an exposure, and the probability of the consequence occurring. A combination of degree of severity of consequences and the likelihood of the different consequences determines the risk.

An aspect common to chemicals and pollutants, and physical factors such as noise, vibrations and radiation, is that it is their effects must be mapped and considered, i.e., the consequences of exposure to these factors must be assessed.

In tunnel projects all players are responsible for (and have a safety representative to contribute to) implementation of mapping, risk assessment and measures:

**a) Project owner's HSWE plan should be based on mapping and assessment of all risk factors that may arise during tunnelling work:**

The owner, or construction client, should risk assess the following in particular, based on the requirement for measures in the **Construction Client Regulations** §8(3)(c), and points 13 - 16):

- Work that entails a risk of harmful exposure to dust, gas, noise or vibrations
- Work that exposes people to chemical or biological substances that may impact on health, safety and the working environment, or which involves a statutory requirement for health surveillance
- Work with ionising radiation that requires the designation of controlled or monitored zones
- Work that involves a fire and explosion hazard.

Conditions at the place of work should also be assessed, e.g., order and hygiene and the need for measures in relation thereto.

The risk factors that are identified during planning and project design should also be incorporated in the competition documents (cf. the Construction Client Regulations § 5(2)(b) and § 6 regarding risk factors). This means that all risk factors that have to be followed up by contractors in each project should be mapped.

According to the Regulations (§ 8(2)), the owner should also make sure that the HSWE plan is continuously updated if there are changes that are of significance for health, safety and the working environment. This means that working environment conditions (both as regards health and safety) should be assessed constantly with regard to hazards and risk, and should be described specifically in the plan.

The owner must, for example, conduct the necessary surveys of geological conditions that are relevant for the exposure and risk factors (cf. inter alia, Regulations relating to the performance of work, §27-1, concerning preliminary surveys in connection with underground construction operations). On the basis of these surveys, an assessment can be made of, e.g., the risk of exposure to quartz, which must be described in the HSWE plan and the documentation on which it is based.

A HSWE plan should always be based on a mapping and risk assessment of the conditions in the individual project. The risk assessment should be specific to the actual conditions at the development site, and it must be shown that local conditions have been assessed, e.g., the geology. All requirements as to measurements in the plan should be founded on real hazards and risk factors that are known in advance, and on those that arise in the course of ongoing operations and follow-up. This requires the owner to be in constant dialogue with the contractor.

#### **b) The employer should conduct a continuous risk assessment of his employees' working environment**

There is a general requirement that every employer (contractor) should conduct risk assessment based on a mapping of what their employees are subjected to during their work (see the Regulations relating to organisation, management and cooperation § 7-1).

The employer must also take into account the owner's risk assessment and the description (requirements) in the HSWE plan of measures that should be implemented, and must routinely provide information of conditions that change during operations and impact on the risk. In addition, the contractor must carry out independent surveys and assessments of risk based on his practices, equipment, routines and actual work methods.

Below follows a description of the conditions that must especially be considered in a risk assessment of chemical and physical working environment factors.

### **3 ASSESSMENT OF THE EFFECT OF DIFFERENT CHEMICAL AND PHYSICAL WORKING ENVIRONMENT FACTORS**

#### **3.1 Chemicals and pollutants**

The effect of the chemicals is determined by their inherent chemical (and possibly physical) properties. Information about these properties is found in safety data sheets and other literature about substances and products that are used or emitted in polluting processes. To be able to assess the effect of chemicals, the data sheets in the substance index must be used as a source in risk assessments.

The occupational health service should also contribute additional information and must often assist in the risk assessments because specialist knowledge is required to consider the information on the data sheets, and to assess possible effects of exposure to several substances at the same time.

The tables in this handbook describe different effects of the different types of pollutants. See, for example, Tables 3 and 4 regarding the risks posed by chemical factors, and the different sections concerning the individual pollutants, gases and vapours, dust and fumes.

#### **3.2 Noise, vibration and physical factors**

The impacts of noise and vibrations are determined through investigations of possible effects on the employees' exposure to these factors. The dangers of exposure to and effects of noise and vibrations are described in sections 3.2.2 and 3.2.3.

The regulations require that the following effects be investigated:

- The effect/consequence of the exposure to the individual factor
- The effect on the health and safety of employees who are particularly exposed to risk
- Each effect on the employees' health and safety that is due to interplay between noise and chemical substances and between noise and vibrations during the work
- The effect of the noise on the possibility of hearing warning signals or other sounds that must be heard to reduce the risk of accidents
- Vibrations - indirect effects on the employees' health and safety that are due to interactions between vibrations and the work site or the equipment



### 3.3 Effects of radiation

Different types of radiation have different effects, and the consequences of these are largely known, although there may be insufficient information about the connection between exposure and health effects. Chapter 3.2.4 describes the harm caused by radiation (see in particular the dangers of radon).

Different factors affect the probability of the occurrence of the consequences of the chemical and physical working environment factors and their effect. Awareness of these factors is more important than the general knowledge of what effects (consequences) the different exposures may have.

### 3.4 Effects of climatic conditions

An assessment must be made in each project of whether there may be adverse consequences arising from particular climatic conditions. See the description in Chapter 3.2.1. The requirements that should be made in respect of climatic conditions (acceptance criteria) must be described in the owner's HSW plan and the employer's HSE plan. Normally, **the Norwegian Labour Inspection Authority's Guidelines on climate at the workplace (Order No. 444)** apply.

### 3.5 Assessment of the probability of different effects of exposure

It is very important to assess what aspects of employee health and safety have the largest influence on the risk of injuries, sickness and health problems (effects/consequences). It is, e.g., well known that the human factor, i.e., what employees do (how they plan and carry out their work, handle and use the equipment, follow routines) has particularly substantial impact on the risk.

Below follows a list of matters it is important to assess in relation to individual environmental factors, on the basis of both the requirements in the regulations and the occupational health knowledge about risk assessments.

The factors indicated are those that affect the probability of the occurrence of the different consequences of chemical and physical stresses during underground construction operations. These are general factors that also feature in working life otherwise.

The key point, however, is that these assessments must be made on the basis of a mapping of all processes, situations and operations in underground work in tunnels where these working environment factors may represent a potential hazard for different employees and groups.

### 3.6 Types of exposures

It is essential to identify the types of pollutants (substances, physical factors) that will be present in the working environment. The employer should map and document the occurrence of chemicals, including dust containing asbestos fibres, and assess all risks for employee health and safety associated with these substances. In many cases, it will be necessary to take measurements to find out what substances are in the air.

However, a first basic geological survey must be conducted by the owner in order to be able to plan operations, evaluate safety and assess the risk of the exposure to harmful minerals such as quartz dust and, less commonly, asbestos.

The Regulation relating to the performance of work, § 27-1 concerning preliminary surveys (mapping), requires that geological, rock engineering and other factors be investigated before work is commenced, and to the extent necessary for the work to be done safely.

On the basis of the result of these surveys, it may (if possible) be assessed whether the mineral dust involves a potential risk of exposure to noxious particles. However, the limited scope of these surveys will mean that not every area will be mapped during excavation, resulting in an inadequate mapping of the correlation between geological survey results and the dust composition found in the air through working environment measurements (even though some surveys of this kind have been made).

### 3.7 Level of the exposures

A common feature of the chemical and physical exposures is that their level can normally be determined through measurements. **The Regulations relating to the performance of work**, § 27-18, require that the amount and concentration of noxious substances in the air should be assessed during underground operations.

Chemicals and pollutants are determined through measurements, by establishing either the level of the pollutants at the workplace, or the level of personal exposure based on how much the employees are exposed to and for how long. Normally, it is the employee's personal exposure that is to be determined.

If the pollutant level is not known, it can be established whether measurements have been made by others in similar situations, which might give some indication of the level. Such assessments must, however, be made by competent occupational health personnel who are familiar with the different factors of significance for exposure.

Moreover, it is not possible to smell or see all pollutants found in rock caverns, and thereby obtain a basis on which to assess the level of the pollutants. In any case, it is however better to implement measures immediately and solve an exposure problem than waste resources on measurements. As an example, rock caverns that have been without ventilation over a long time should always be treated as oxygen-free.

Noise is measured both to determine the noise from the source and the noise dose to which the individual employee is exposed, thereby determining level (and type) of exposure. The vibration load level is also determined in a similar way.

Moreover, the manufacturer's information about the noise and vibration level of the equipment may also be taken into account when assessing the exposure level. The use of the equipment must then also be assessed at the same time (see the separate point below on methods of use etc.)

Furthermore, it must be established whether the noise level will impede the employees' ability to perceive sound signals, thereby increasing the risk of accidents at the work site. Noise can thus, both directly and indirectly, result in adverse effects on employee health and working environment. The possibility of concentrating when carrying out hazardous work at high noise levels in the tunnel must also be risk assessed.

The level of radiation, e.g., radon can be determined through separate short-term and long-term measurements.

Appendix 1 contains a description of how measurements of the chemical and physical factors are made and how levels (amounts) are determined.

### 3.8 Duration and frequency of the exposures

For all chemical and physical factors, in addition to type and level of the exposure, it must be determined in particular how long the effects last at a time (on each shift), and how often they occur (how often on the shift, how often each week etc.).

This is of great significance for the probability of effects from the exposures. That means to say that the longer the exposure lasts, and the more frequently it occurs, the greater the risk of damage to health is in the short and long term. And the greater the exposure, and the worse the effect of the substance, the greater the risk is.

Through an assessment of type, level, frequency and duration of the exposures, the dose, and hence the risk,

to which the employees are actually exposed may be determined, as well as the extent of the risk.

The length of the shifts worked is of consequence for exposure and risk. During long shifts, the risk of injury to health increases if the exposure level is not reduced. Long shifts should therefore be avoided because today there are no criteria for assessing risk as a result of exposure for more than eight hours, which is what forms the basis for the intervention levels. This applies both to chemicals and to the physical factors. The risk for injury to health will increase with increased exposure time if the exposure level is not reduced. Currently there are no set criteria for assessing chemical exposure during long shifts, and if this is not risk assessed and results in measures, injury to health might occur. Also, due to the substantial uncertainty in measurements, the risk will be greater than estimated if steps are not taken to keep the level of chemicals well below the intervention and limit values for the individual substances (under ¼ of the limits).

## 4 CONDITIONS AT THE WORKPLACE WHERE THE POLLUTANTS ARE FOUND, AND WHERE THE EXPOSURE OCCURS

Relevant conditions that are assessed for chemical and physical factors are:

Chemical exposure: what arrangements are made at the workplace to prevent this? Does the ventilation work? Have other necessary measures to prepare the workplace been implemented? Have sufficient measures (e.g. extraction, cleaning) been implemented to prevent spread of pollutants?

Noise in the rock cavern: what are the noise conditions? Has the workplace been prepared so that technical devices can be set up and used to prevent unnecessary noise? Is there any unnecessary driving/operation of equipment? Is suitable equipment used? Are measures in place that reduce the spread of sound through the air, for example, by using screens, internals or sound absorbers. This is perhaps not so relevant in rock caverns, but shows what types of assessment must be made at a workplace with noise sources.

Vibrations: how are the driving conditions in the tunnel and the configuration of the roads with respect to reducing vibrations? What is the condition of the machinery and equipment used? Has suitable equipment been chosen? How are speed and driving conditions regulated?

Factors of significance for risk must be assessed at each workplace, for each work operation during tun-



nel excavation and during any renovation of tunnels. The employers' and employees' own knowledge of risk factors associated with the work comes in addition. It is important to use own knowledge and experience in HSE activities in tunnelling work, inter alia, about how the exposures occur.

## **5 HOW THE WORK IS DONE, HOW THE EQUIPMENT IS ADJUSTED/ POSITIONED AND USED**

This is especially important in risk assessment of the chemical working environment. The method of use of chemicals must be mapped to assess, inter alia, whether there is any improper handling of chemicals, unnecessary exhaust gas emissions from combustion engines, welding without the use of extraction etc.

Execution of work in relation to the source applies to both chemical pollutants and noise; the shorter the distance to the pollutant/noise source, the more the exposure increases.

How is, e.g., work behind the face carried out? How are the workers affected by the chemicals and the physical factors? In what situations are particular people and groups exposed? This must be checked through, e.g., safety check rounds.

Is unnecessary noise produced because of the way the work is done or the way the equipment is used? These are examples of what should be assessed with regard to noise in underground work. However, noise can rarely be avoided, which makes the routines for use of hearing protection even more important. This is the main means for reducing noise exposure for the individual employee, but nevertheless, measures at the workplace and control of how the work is done must not be forgotten.

The same applies to vibrations – how is driving done at the workplace, how is the equipment used (is overloading prevented)?

All work operations that cause exposure to the individual chemical and physical factors are risk assessed separately and collectively to gain an overview over the total risk to which the employees are exposed.

### **5.1 The work processes and equipment used (quality, design, suitability)**

The equipment that is used, and its suitability are of great importance for chemical exposure.

The condition of the vehicles and equipment fitted with combustion engines is of consequence for the type

and extent of pollutants emitted from the equipment. Examination and assessment of maintenance routines can be important in condition checking of equipment. All players are responsible for assessing their own equipment and its effects on the total working environment below ground, and not only in relation to the risk for own employees.

Noise from different types of equipment varies, and it must therefore be assessed whether the equipment used is appropriate. Vibrations are affected, inter alia, by the condition of the equipment, so the quality of the equipment with regard to vibrations must be assessed.

These are examples of important factors that must be taken into account in the risk assessments, and in relation to which measures must be considered.

### **5.2 Other risk factors and conditions that must be assessed**

Many factors impact on the risks in tunnelling work and other hazardous operations.

It is relevant to ask the following questions in this connection:

- How do established routines work? Are they followed up by all employers and the owner?
- Are HSWE/HSE plans followed? Is this followed up by owner/employer?
- Are the measures decided on to reduce the risk implemented? And do they in fact reduce the risk?
- Are cases of non-conformance reported, recorded and dealt with routinely? (Are health problems, injuries/illnesses from exposures registered, and is the knowledge/experience used in the risk assessments?)
- Is the work organised in a suitable and proper manner?
- Are there reasonable working time arrangements and work progress and tempo requirements?
- Responsible participation from all parties? (Duties)
- Are particularly vulnerable employees taken into consideration? (Tolerance limits can vary)

These are organisational factors of importance for how the work is carried out, which in turn may have an impact on the effect of the working environment factors. They are also factors that must be looked at when risk is to be assessed, to clarify whether the real risk has been assessed and all important factors elucidated.

By carrying out risk assessments in accordance with the points above, in collaboration with the employees, the following is achieved:

Probability factors	Example
Type of effect	Chemical and physical factors Degree of hazardousness/toxicity
Exposure level	Amount
Duration and frequency	Duration and frequency
Conditions at the workplace	Can measures give an acceptable level?
How the work is done	Ergonomics and shielding Work practice and routines
Other risk factors	Organisational and personal factors
<b>Consequences</b>	
Death Reproductive/ genetic damage Cancer Lung disease (COPD, fibrosis) Asthma and allergy Skin disease Hearing damage Vibration injuries Radiation damage Other possible effects	

Table 1: Probability factors and consequences

- The most important factors affecting risk of exposure to chemical and physical factors will be assessed
- All parties at the workplace are made to feel responsible/involved
- The requirements laid down in the Norwegian Labour Inspection Authority's regulations will be met

In summary, the following surveys are central to a risk assessment in addition to the knowledge of the hazards of the individual chemical and physical factors:

The table shows factors that affect the risk (probability) of health problems, injuries and illnesses (consequences).

The risk assessment can be presented in separate descriptions and by using a form or table. Forms can provide a good overview if there is a great deal of information and data. However, in simplified forms reference must be made to any surveys, investigations and measurements made, as well as to acceptance criteria on which the assessments are based.

What is important is that all the factors described above are assessed. If this is not done, the actual risk will not be established. Without having control

of what in situ conditions are like and how the work takes place (is done), the risk (level) cannot be indicated. There will then be a higher risk for injuries and illness among employees than is indicated by the employer's risk assessment. This in turn can give grounds for the Norwegian Labour Inspection Authority to issue special requirements for measures.

All work operations that constitute a risk of exposure and injury to health or illness in the short or long term must be risk assessed. In tunnelling work this applies, inter alia, to drilling, grouting, handling cement, concrete spraying, loading and transport. In addition, different types of work behind the face, hot work and work in polluted zones must be assessed, and, if necessary, measures implemented as described in Chapter 4.

To the right is a schematic overview of examples of types of information that could be given in the risk assessments.

Information and data from the occupational health service must also be used in the assessment, as well as the effect of already implemented measures (not personal).



<i>Workplace/ Work site/ Work operation</i>	<i>Assessed probability factors, conditions of significance</i>	<i>Consequence of the exposure (potential effect)</i>	<i>Measures and control measures (effect)</i>	<i>Risk after measures (L,M,S*)</i>
Description of process, location, different types of underground operation	Risk factors described in Table 6, Other factors of significance in tunnelling work	Health problems, accidents, injuries, illness in the short and long term (without implemented measures)	Physical organisational, personal measures	Any prerequisite condition for assessed risk should also be given

\*L=low, M=medium, S=substantial)

*An overview of this kind contains an initiatives (action) plan for HSE (HSWE/HSE plan).*

## 6 MEASURES

Chapters 3 and 4 list different types of measures that are relevant for some chemical and physical factors in different connections (situations, work processes and when using different types of equipment). The measures must be implemented on the basis of surveys, which are a prerequisite for carrying out the risk assessments. The result of surveys and measurements is decisive in determining what measures are necessary. The measures must also be assessed on the basis of how they will work in practice.

In general, e.g., the use of protective equipment to avoid exposure to gases is considered to be a measure that must not replace other organisational and/or physical measures. The reason for this is that it is too easy for each individual employee to be slipshod in his use of the protective equipment. Half masks used by people with a beard will, e.g., not protect against pollutants. It is therefore necessary both to implement measures and to check that they work (inter alia, by internal control). Consequently, it is important to give priority to measures that do not require huge resources for this kind of continuous follow-up and control, e.g. good and efficient ventilation which makes regular (and costly, time-consuming) measurements unnecessary.

The owner is responsible for ensuring measures are implemented in the light of the risk assessment on which the HSWE plan is based.

**Regulations relating to the performance of work,** § 27-9 contains, for example, requirements for measures against air pollution. It is a requirement that the employer should ensure that satisfactory measures are taken where a health or safety risk may occur as a result of substances being emitted into the air. In relation to the physical factors, measures are also required in the (6) most central working environment regulations.

**Regulations relating to the performance of work,** § 27-18 concerning hazardous substances in underground operations requires that measures be implemented to prevent/reduce exposure. In some cases one measure will be to conduct continuous monitoring of the pollution level. When such measures (which become operative automatically) are put in place, the measured values must be registered, stored and used in follow-up work. Such routines are normally described in the HSE plan.

### 6.1 Measures in general

**Regulations relating to the performance of work,** § 27-18, requires measures in relation to hazardous substances in underground operations. Measurements must be taken to assess the amount and concentration of the noxious and potential explosive substances in the air.

According to § 27 – 9, the measures should remove or collect pollutants at source, or dilute the pollution to a level that does not entail a risk for the employees.

**The Workplace Regulations,** § 7-1, also requires such removal of pollutants.

For the other working environment factors, it is also required that measures be implemented if the measured levels exceed the established intervention and limits values for the individual substances and environmental factors (noise, vibration, radiation). See Regulation 704 for a list of exposure limits.

### 6.2 Measures in relation to ventilation:

§ 7- 1 of the **Workplace Regulations** requires that all workplaces (work premises), or other areas to which employees have access and where the work or processes can cause air pollution, should have mechanical ventilation and process-adapted extraction so that the concentration of chemicals in the work atmosphere is kept at a completely reasonable level with respect to health and explosion hazard.

According to § 27 – 9 of the **Regulations relating to the performance of work**, ventilation systems should be designed and function in such a way that areas in which people must work or spend time have satisfactory air quality. The ventilation parameters should be measured and registered regularly. An example of measuring equipment and documents for control of ventilation conditions that can be used is found in Appendix 4.

In places where work is carried out where it is not possible to establish satisfactory permanent ventilation installations, special measures should be implemented to secure employee health and safety, for example, temporary ventilation.

It is also important that employees be given the necessary training on measures to avoid exposure to air pollution (how they must work to avoid it, how equipment must be handled, and how they themselves must avoid spreading pollutants to others, or expose others unnecessarily to the pollutants produced in their work).

Further, there must be routines for continuous maintenance of ventilation installations and membrane. Maintenance must especially comprise removal of fouling and contaminants in the installations that may entail a hazard.

## 7 DEALING WITH NON-CONFORMANCE

All enterprises must have routines for spotting, registering, investigating and correcting (following up) undesired incidents and working environment conditions, or requirements in the rules and regulations which have not been/will not be met in an adequate manner. This must be seen as a means for HSE enhancement, as preventive measures to avoid repetition, or to ensure that the conditions will be put right.

Examples of non-conformance can be proven injuries to health from the exposures identified through health check-ups. This is also an example of why results of health check-ups are important when the risk factors at a workplace are to be assessed.

### Health check-ups and follow-up

Health check-ups focussing on lung function, airway symptoms and hearing should be carried out every two to three years.

For more information on pollutants in tunnel excavation and a possible need for health monitoring, reference is made to **NFF's Technical Report No. 13: Air quality during tunnel excavation, health exposure and possible measures** (November 2012).

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## ABOUT THRESHOLD LIMIT VALUES AND MEASURING METHODS

NFF, Publication no 24  
Appendix I.

The Regulation "Work Environment" gives threshold limit values for various environmental impacts on human beings. Collected data must be compared with the given values. It is important to obtain true values.

The given values should be obtained; nevertheless that is no guarantee against health injuries at work. Employers are free to introduce lower (safer) threshold values as bases for analyses of new/improved work environment procedures. The table below describes the measurement of various chemical and physical work environment factors and contamination/pollution.

Sampling of chemical pollution in the work environment shall be executed by technicians in the health section of the actual contractor, the analyses undertaken by certified laboratories. Exemptions are made for controls using direct reading devices. Test intervals depends on the ongoing activities

It is of utmost importance that test programs are implemented by well qualified staff, competent within test strategy, methods, quality of the tests, irregularities that may influence on the tests.

Data from measurement of pollution are usually values as mean concentration over the 8hour work day and compared to given threshold limit values. Variations during the actual day is not registered. For some components there are threshold limit values also for shorttime exposure.

If the test data are higher than given limits, one must implement actions in order to reducing the pollution to acceptable level. Some types of gas/dust measurements are complicated.



Figure 1: Dräger PAC 7000 measuring device for gas CO

Factor	Measuring methods
Gas	For measuring of gas commonly used are electrochemical sensors and indicators for direct reading. Equipment/units for automatic control are available
Dust/aerosol generally	Dust and/or aerosol are measured by means of air filters and pumps. Quantities and mix are analysed. Content of quartz on the test filters shall be sent for special analyses in laboratories. Fibres on the filter are counted by special microscopes. (light or electron) Dust measure takes place by direct reading devices (particle count). To decide on quantity of dust by particle size there are several methods, e.g. use of cyclone to decide on the irrespirable quartz fraction.
Welding smoke	Particle test of welding smoke shall take place as for dust in general. Sometimes one will check content of chrome, nickel, iron, manganese analytic.
Solvents	The quantity of solvents is measured by passive metres using coal as absorbent or active testing by pumps sucking air through coal. For some solvents direct reading devices are available.
Oil-fog / mist	Difficult testing. Oil particles tend to evaporate from the filter during sampling and afterwards. Measuring of oil fog must take place once a year as long as test results are well below threshold limits. There are several sampling methods. For oil fog filter and coal adsorption; for oil fog and oil fumes a combination of oil filter and coal using pump. While testing oil fogs one should also collect oil samples.
Climatic	Vapour and temperature normally not controlled. For extreme situations risk factors should be considered.
Noise	Noise measurements take place as needed. Measuring devices may also control frequency by use of filters. Dosimeters for control of noise level over a period of time. Sampling to take place in various parts of the underground area included at the very point of the source, thus establishing a mean value. (equivalent value) also to draw frequency graph. (NS 4815)
Vibrations	Vibrations measurements (entire body) shall take place under normal work operations and various stages of the work. E.g. for a truck operator during loading, driving, at dump and return trip empty. Measurements shall take place at the seat or, in case, at the place of the operator. Tests on arms/hands in agreement with the national standard. (NS-EN-ISO-5349-2 (2001)).
Radiation in general	Measurements and mapping according "Guide concerning radon emission at work place" issued by The National Labour Inspection. Further information available from Norwegian Radiation Protection Authority ( <a href="http://www.nrpa.no/en/">http://www.nrpa.no/en/</a> )
Radon/ Radon daughters	Several methods for control of radiation level are available <ul style="list-style-type: none"> <li>- <u>Film exposed to radiation</u></li> <li>- <u>Active carbon method (carbon box method)</u></li> <li>- <u>Scintillation detector method</u></li> </ul> Radon level should be controlled at least once every year.
Light measurements	Measurements, as needed, using luxmeters and illumination meters.

Chemical and physical work environment factors and measurements

## DEFINITIONS AND/OR EXPLANATION OF TERMS

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Appendix II.

### **Access monitoring.**

Any system designed to monitor individuals entering or leaving the actual area/project/tunnel etc.

### **Accident Rate (H).**

The number of accidents causing absence from work per one million working hours. H is in the English language called Lost Time Injury (LTI).

### **Acryl-amide (C<sub>3</sub>H<sub>5</sub>NO)**

Crystalline solid or liquid also used as additive for grout mix. Acryl-amid is poisonous until the polymerisation is complete.

### **Active heat protection**

A system established to reduce heat increase of a defined item during an emergency situation. Commonly used is water.

### **Actual risk.**

Risk estimated through analytical approach.

### **Administration software.**

The computer program handling input from the sensors at the checkpoints.

### **Administrative norms for pollution in the working atmosphere**

Documents established by Government authority giving accepted limits for exposure to certain harmful gases, dust, chemicals etc. In the English language a frequently used expression is 'Threshold Limit Value' (TLV). Also used is 'Occupational Exposure Limit' (OEL). Most 'tunnelling' countries have established domestic limits.

### **ADR**

International regulations for transport of dangerous goods on road. (Accord Europeen relatif au transport international des marchandises Dangereuses par Route ). See also RID.

### **Air pollutants**

Gases, dusts etc that lower the air quality.

### **Alpha-quartz**

Deep-seated quartz (beta-quartz = high-seated). Alpha-quartz is the quartz variety met in underground excavations. Alpha-quartz is stable by room-temperature and is the quartz-modification that must be analysed concerning work conditions underground. The content of quartz is the dominating factor in 'Administrative Norms' concerning dust. High content of quartz leads to low accepted TLV, whereas low quartz content leads to higher accepted TLV. Example: TLV for respirable dust without quartz is 5 mg per m<sup>3</sup> for 8 hours exposure. If the respirable dust, however, contains 100 % quartz (pure quartz) the TLV is 0,1 mg per m<sup>3</sup> for 8 hours exposure (a reduction by 1/50!).

### **Alpha radiation**

Radiation of Helium+ particles. Easily stopped by clothes etc. Harmless outside the body.

### **Ammonium NH<sub>3</sub>**

See toxic gases.



**ANFO**

Acronym for Ammoniumnitrate fuel oil. Prilled ammonium nitrate mixed with approximately 6 % diesel oil.

**Automatic Charging of Emulsion Explosives**

Remote controlled charging of the drilled blast holes by means of mechanical equipment.

**Behind face**

A term used in tunnelling and mining. Activities taking place somewhere between tunnel face and tunnel entrance, not hampering the progress of excavation. Also see Rear Section.

**Blow-exhaust-combination ventilation**

The direction of ventilation air is adapted to the actual work sequences using the same duct(s): fresh air inbound and polluted air outbound.

**Carbon monoxide (CO)**

See toxic gases.

**CE marking**

The CE marking declares that a product complies with the Essential Requirements of the applicable EU directives (Attestation of conformity). Certain products require EU marking if sold in the EU market. That include machinery, electrical equipment, protective equipment, equipment for use in potential explosive environment and more.

**Chronic obstructive pulmonary disease**

Chronic lung disease.

**COPD**

See: chronic obstructive pulmonary disease.

**Client**

Owner of a project.

**Construction Client Regulations**

Regulations concerning the responsibilities of the client (owner) of a project in regard to safety, health and environmental issues.

**D&B tunnelling**

Excavation of a tunnel by means of the drill and blast method.

**‘Danger zone’**

The area between the tunnel face and the hinges of the booms carrying the drifters (drilling machines) in front of a drilling jumbo is defined as ‘danger zone’.

**Diesel quality**

Quality of the oil, in this respect with special emphasis on sulphur content.

**Double-tube technique**

Ventilation by means of a double tube system for fresh and polluted air respectively

**Emulsion explosives**

A water resistant explosive material that contains oxidisers dissolved in water as droplets surrounded by oil. Sensitivity depends on voids, e.g. nitrogen bubbles.

**Escape routes**

Optional exits for the personnel in case of a dangerous situation (e.g. a fire).

**Experienced risk**

Actual risk as observed during excavation.

**FEV1**

Forced expiratory volume in one second. Measured by spirometry.

**Formaldehydes**

Alcohol deprived from its hydrogen atoms. Extremely reactive.

**Geological hazards**

Risks related to the ground conditions, in the context of this publication mainly due to physical aspects of the rock mass during excavation underground.

**Health & Safety work**

The totality of efforts aimed at improving health and safety aspects.

**Health effects**

Negative impact on health due to the working environment.

**HSE**

Health, Safety and work Environment.

**Hydrogen sulphide (H<sub>2</sub>S)**

See toxic gases. Poisonous and colourless gas, smells like rotten eggs. (The smell fades over time).

**Intelligent Tunnel Ventilation**

Intelligent Tunnel Ventilation is a concept that contributes to cost effective ventilation and improved work environment. Computers read sensors and operate the fans etc in agreement with a pre-programmed procedure.

**Internal Control System**

In addition to third party inspection of health and safety precautions, the executing party has an independent responsibility for his own implementation of a proper system to safeguard that all formal requirements as to safety, health and work environment are met.

**Ionising radiation**

See radiation. **Low-sulphur diesel**

Diesel oil with a maximum sulphur content of 50 PPM (available in qualities down to 10 ppm).

**Methane**

Methane (CH<sub>4</sub>) is colourless, odourless and inflammable. May cause fires and explosions. Gas frequently encountered in coal mining. Methane is lighter than air, therefore content is normally higher in the roof area.

**Monitoring stations**

In the context of access control systems: Equipment positioned in the actual control area reading electronic 'tags' and communicate with the administrative software.

**Natural gases**

An aeriform fluid applied to the gaseous state of a substance best known in that state (at normal temperatures). One example is methane (CH<sub>4</sub>). In this publication, used about gases emanating from the rock, rock mass or ground water.

**Nitrogen dioxide (NO<sub>2</sub>)**

See toxic gases.

**Nitroglycerin**

[C<sub>3</sub>H<sub>5</sub>(O. NO<sub>2</sub>)<sub>3</sub>] Ingredient in explosives like dynamite. Also used in medicine.

**N-methylol-acrylamide**

Main component (acrylamide being a chemical intermediate) in NMA grouts

**Non-flammable materials**

Materials not supporting flame

**Occupational Exposure Limits (OEL)**

Also called 'Administrative norms for pollution in the working atmosphere'.

**Occupational health and safety (OHS)**

Health and safety related to the work situation.

**Particulate filters**

Filters used in engines, designed to reduce emission of harmful particles in the exhaust.

**Pleural mesotheliomas**

Cancer in the lining of the lungs, frequently caused by exposure to asbestos.

**Psychological loads**

Stress factors of psychological character.

**Physical loads**

Stress factors due to heavy work and adverse working climate.

**Radiation**

Emission of particles from unstable atoms. Alpha, beta, gamma or neutrons (the latter generally produced in nuclear reactors). Alpha particles (helium nuclei, two protons and two neutrons) are heavy and slow and can be stopped by human skin. Harmless as long as source is outside the human body. Beta particles (electrons) are very fast and more penetrating. Gamma rays are weightless electromagnetic radiation travelling at the speed of light and much more penetrating. Neutrons are strongly penetrating. The consequence of radiation may be damage to ability of a human cell to reproduce itself. DNA molecules may become ionised directly or may be changed indirectly with harmful effects leading to inheritable genetic defects or the development of cancer. Ionised radiation is defined as radiation with sufficient energy to ionise the molecule.

**Radon**

A heavy, 8 times heavier than air, colourless inert radioactive gas (noble gas) available in radium (derived from uranium) containing ground.

**Radon-daughters**

Heavy respirable particles that can settle in the lungs and may cause cancer from alpha radiation (Radon-222, Polonium-218, Lead-214, Bismuth-214, Polonium-214).

**Reading capacity**

The reading capacity of access monitoring observation means, i.e. the capacity to register a group passing seated in a vehicle.

**Rear section**

The section of the tunnel between the face and the portal. The term is used in connection with work activities not taking place at the tunnel face.



**Reduced lung function**

Reduced capacity of the lungs due to illness, insufficient ventilation, silicosis etc.

**Respirable dust**

Defined as 75% of all dust with particle size  $< 5\mu\text{m}$ . The portion of the particle load that enters the alveolar region of the lungs.

**Respiratory diseases**

Lung diseases, frequently reduced lung capacity.

**RID**

International regulations for transport of dangerous goods on rail. See also ADR.

**Risk**

Expression for the danger that unwanted events (hazards) represent for people, environment or material values. Risk is characterised by probability and the consequences of such unwanted events.

**Risk Analyses**

A method to analyse the potential possibility of damage to people or any construction in the surroundings of a blast site. Previous accidents, experience, systematic review of the actual situation is the basis for the analysis.

**Safety Container**

A container built to certain safety standards with the aim to serve as a temporary safe-heaven for personnel in an emergency situation.

**Safety Element Method (SEM)**

A tool for HSE improvements (in five steps).

**Silicosis**

Disease caused by breathing in quartz dust ( $\text{SiO}_2$ ).

**Single-tube technique**

Ventilation of a tunnel or underground opening by means a single tube. For fans supplying fresh air to the face only, soft fabric is commonly used as tube material. To utilise suction solid tubes are necessary.

**SINTEF**

An independent research organisation working in co-operation with NTNU (see above) and the Oslo University. Tunnelling technology is covered by the Rock and Mineral Engineering section

**Size Sensitised Explosives (SSE)**

Emulsion sensitised at site by the use of gas, thus transformed to explosives.

**Slurry explosives**

Term for explosives consisting of high viscosity salt (nitrate) water solution and a sensitiser.

**Smoke plug**

The gases developed by a blast. In a tunnel this volume is ventilated through the tunnel, moving like a 'plug' Also called Blasting Plug or Blasting Cloud.

**Spalling**

Breaking off of plate-like rock pieces from a free rock surface due to high tangential stresses, causing tensile strain failure, sometime with violent ejection of the fragments.

**Spirometers**

Lung function meters.

**Spirometry**

The measuring of the lung function.

**STAMI**

National Institute of Occupational Health. (Norway)

**Tags**

Tags in the context of access control means an active chip with a unique identification number.

**TBM.**

Tunnel Boring Method, also frequently used for Tunnel Boring Machines.

**Thoron**

A gaseous radioactive element formed from thorium (Th) and isotopic with radon and actinon.

**Thoron-daughters**

A term related to radiation.

**Threshold limit values (TLV)**

Limits for acceptable exposure values for various pollutants.

**Total dust**

The total content of dust in the air (particles < 300 micron). Respirable particles are those particles that can be inhaled into the nose and the mouth during breathing (particles < 100 micron).

**Toxic gases**

For underground work, fire effluents are most important. That include emissions from engines burning oil and gas/smoke from fires. Common gases are: Carbon monoxide (CO), Carbon dioxide (CO<sub>2</sub>), Hydrogensulphide (H<sub>2</sub>S), Nitrogen oxides (NO<sub>x</sub>) and Ammonia (NH<sub>3</sub>). The physical effect on human being depends concentration of the gas, period of exposure and the ventilation. CO and CO<sub>2</sub> are termed narcotic gases, the others are classified as irritants. CO is the most important as far as fatalities are concerned. Exposure to CO reduces the ability to transport oxygen to vital parts of the body. In high concentration death may occur within 1 to 3 minutes. CO<sub>2</sub> is not particularly toxic at levels normally observed, in high concentration (100 000 ppm and above) threshold of unconsciousness reached within 30 to less than one minute. NO<sub>x</sub> is a strong irritant that may cause immediate death. NH<sub>3</sub> has a strong smell, unbearable odour, irritating eyes and nose.

**Two-way ventilation methods**

See Blow-exhaust ventilation and Double-tube technique.

**Whole body vibration**

Vibration of the entire body due to the operation of certain pieces of machinery.

**Work Related Illnesses (WRI)**

Illness due to the consequences of the work environment.

# THE PHRASING IN ENGLISH OF NORWEGIAN MINISTRIES, DEPARTMENTS, LAWS, REGULATIONS RELEVANT FOR HSE MATTERS

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Appendix III.

Several Norwegian acts and regulations are translated to other languages, frequently to the English language. Below is referred to some of these. You may check and download from internet <http://www.uio.no> Proceed to Library, Library for law, find acts and regulations respectively. (<http://www.ub.uio.no/ujur/ulov/english.html>)

## 1. Ministry of Climate and Environment

*-The Pollution Control Act (Forurensningsloven av 13.3.81 nr. 6)*

## 2. Ministry of Justice and Public Security

***Department of Civil Protection Prevention and Analysis, Norwegian Directorate for Civil Protection [dsb]***

*- Act relating to the prevention of fire, explosion and accidents involving hazardous substances and the fire service (Fire and Explosion Prevention Act) (Lov om vern mot brann, eksplosjon og ulykker med farlig stoff og om brannvesenets redningsoppgaver av 14.6.02 nr. 20)*

*- Regulations relating to the handling of dangerous goods. (Regulations on Explosives) (Forskrift om håndtering av farlig gods, også kalt Eksplosivforskriften av 26.6.02 nr.922)*

## 3. Ministry of Labour and Social Affairs

***The Working Environment and Safety Department***

*- Regulations relating to systematic health, environmental and safety activities within enterprises (Internal Control Regulations) (Forskrift om systematisk helse-, miljø- og sikkerhetsarbeid i virksomheter av 6. 12.96, også kalt Internkontrollforskriften)*

*- Act relating to worker protection and working environment (The working environment act), (Arbeidsmiljøloven (AML) av 4.2.77 nr.4)*

*Regulations concerning Safety, Health and Working Environment on Construction Sites - 'Construction Client Regulations' also called Owners Regulations (Forskrift om sikkerhet, helse og arbeidsmiljø på bygge- eller anleggsplasser også kalt Byggherreforskriften)*

*Regulations on execution of work, the use of work equipment and associated technical requirements] (Forskrift om utførelse av arbeid, bruk av arbeidsutstyr og tilhørende tekniske krav)*

*Regulations concerning Machinery (Forskrift om smaskiner)*

***The Norwegian Data Protection Authority.*** An independent administrative body under the Ministry with the responsibility of following up the stipulations in the relevant act and regulations i.e.

Personal Data Act of 14.4.2000, no.31

Personal Data Regulations (17 p.) of 15.12.2000

## 4. Ministry of Transport and Communications

***the Directorate of Public Roads***

*- Road traffic act (Vegtrafikkloven av 18.6.65 § 43)*



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Appendix IV.

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## PICTURES

Pictures and illustrations are provided by the authors where no further information is given.

## NORWEGIAN TUNNELLING SOCIETY NFF INTERNATIONAL SUPPORT GROUP

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Appendix V.

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Appendix VI.

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