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Health and Safety in Shotcreting

ITA Working Group on Shotcrete Use in Tunnelling
Prepared by Koichi Ono on behalf of the Japan Tunneling Association (JTA)

Abstract—*This report summarizes the responses to a questionnaire, distributed to ITA member countries, on health and safety in shotcreting. The report deals with the following aspects of this topic: use of shotcrete; influence of dust on the human body; regulation and guidelines regarding dust concentration; efforts to reduce dust production; efforts to reduce dust emission and improve personal protection; and demands for Research and Development of shotcrete. An appendix presents the various countries' specific responses to the questionnaire.*

Foreword

The ITA Working Group on Shotcrete Use in tunnelling was established in Toronto 1989. Its first task was to compile an overview of the status of shotcreting technology in different countries, published by the Swedish Rock Engineering Research Foundation and distributed to the ITA member countries (Franzén 1991). Next, existing guidelines for shotcreting were compiled (Malmberg 1993a). Both of these reports have also been published in summarized form in Tunnelling and Underground Space Technology *(Franzén 1992, Malmberg 1993b). A few years ago, the Working Group decided to make a survey of health and safety aspects of shotcreting, a theme of major interest, especially with respect to dust emissions during spraying with different techniques. This task has been fulfilled by Dr. Koichi Ono, Japan, primarily based on an enquiry sent to the member countries. The result reported herein represents another valuable overview of different traditions, requirements, and regulations in 14 countries. Let me forward our sincere thanks to Dr. Koichi Ono, Vice-Animateur of the Working Group, for his efforts in preparing this document, which will now be distributed within the ITA community.*

— Tomas Franzén, Animateur,
ITA Working Group on Shotcrete Use in Tunnelling
Stockholm, March 1996

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Introduction

This report is a summary of the aspect of workers' health and safety in shotcreting, based on a questionnaire submitted to the ITA member nations in 1993 and 1994. Replies were obtained from 14 countries: Austria, Canada, France, Germany, Hungary, Italy, Japan, Morocco, Norway, Portugal, Sweden, Switzerland, U.K., and the U.S.A. The importance of reducing dust emission in tunnel construction is recognized in each country, and there are increasing demands to improve shotcreting technology.

The report comprises the following sections:

1. Use of shotcrete.
2. Influence of dust on the human body.
3. Regulation regarding dust concentration.
4. Efforts to reduce dust production.
5. Efforts to reduce dust emission and improve personal protection.
6. Demands for research and development in health and safety issues related to shotcrete.

Appendix: Selected responses to the questionnaire[1].

1. Use of Shotcrete (questionnaire items 2, 2.1)

Annual use of shotcrete for rock support is reported in Table 1. Table 2 shows the proportion of wet and dry mix used. Use of the wet mix is increasing because it produces less dust; however, it was noted that the wet mix may produce more harmful dust than the dry mix.

2. Influence of Dust on the Human Body (questionnaire items 4.6, 4.7)

Skin disease, eye disease, pneumoconiosis, and other negative health effects were reported in many countries. In some countries, there have been lawsuits for these

[1] The full appendix containing all responses to the questionnaire are provided in the report published by the Japan Tunnelling Association.

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Pergamon

Table 1. Annual use of shotcrete by country.

Nation	Annual Use of Shotcrete for Rock Support (in m^3)	
Austria	?	in 1992
Canada	50,000	in 1993
France	70,000	in 1992
Germany	500,000	in 1993
Hangary	60,000	in 1992
Japan	2,000,000	in 1991
Morocco	20,000	
Norway	80,000	in 1993
Portugal	3,000	in 1989
Sweden	50,000	in one year
Switzerland	100,000–150,000	in 1993
U.K.	1,500	
U.S.A.	500,000	in 1994

Table 2. Wet and dry mix proportions used, by country.

Country	Wet (%)	Dry (%)
Austria	5	95
Canada	5	95
France	60	40
Germany	15	85
Hungary	10	90
Italy	90	10
Japan	80	20
Morocco	10	90
Norway	99	1
Portugal	20	80
Sweden	80	20
Switzerland	65	35
U.K.	10	90
U.S.A.	60	40

diseases.

In North America, the right of workers to refuse unsafe work is guaranteed by OSHA regulation.

3. Regulation Regarding Dust Concentration (questionnaire items 1.1, 1.2)

In general, each country has regulations, guidelines, or standards regarding dust concentration. In many countries, these regulations, guidelines, and standards are applied to dust control in tunnel construction.

Tables 3a and 3b show threshold limits for mineral dust prescribed in the regulations or guidelines.

Dust concentration is being measured using low-volume air samplers, high-volume air samplers, piezometric balance dust meters, digital dust meters, etc., in each country. Dust measuring methods are shown by country in Table 4. The dust measuring time interval varies by country, from every day to about once a year.

4. Efforts to Reduce Dust Production (questionnaire items 2.2–3.6)

Efforts to reduce dust production in shotcreting have focused on improving both shotcrete itself and shotcreting equipment. In many countries, wet mix is considered to produce less dust compared to dry mix. On the other hand, wet mix may generate a more hazardous mist that contains droplets of highly caustic additives.

There is a difference of opinion with respect to the effect of dust control additives. The higher cost (between 5% and 20%) of these additives has had a negative effect on their use, even in countries where the beneficial effects of such additives have been confirmed.

Table 5 shows the percentages of the nozzle method of operation in shotcreting, by country.

There is remarkable variation by country in the adoption of mechanical or manual nozzle operation. A difference of opinion was noted regarding the effect of mechanical nozzle operation in reducing dust production, although this operation is known to increase safety. The operator's skill is also an important factor in reducing dust production.

Improvements in shotcrete guns, such as in the shape of the nozzle, reduction in air pressure, method of mixing the additives, use of centrifugal force, etc., are noted in Section 6 of this report.

Dust control becomes more important in excavation of longer tunnels, where an ordinary ventilation system is less effective.

5. Efforts to Reduce Dust Emission and Improve Personal Protection (questionnaire items 3.7–4.5)

Ordinary ventilation systems are almost always used in most countries.

Effects of water curtains or air curtains have been recognized in some countries, although only in Canada are they normally used.

The effects of dust scrubbers are recognized in many countries. However, they are not normally used in many countries, except in Canada and Japan, partly because they produce noise and create an obstacle for the excavation work.

Several R & D concepts are being tried to reduce dust emission. In Italy, a manipulator with two nozzles closed in a case is being tested, and in Japan, the use of static electricity is being tested.

Regarding personal protection equipment against dust

Table 3a. Regulations: threshold limits for mineral dust.

Country	Quartz		Portland Cement				
	Particle Size μ	Content mg/m	Particle Size μ	Portland Cement mg/m³	Total Dust Content mg/m³	Total Dust Content	Comment
Canada	< 10	< 20		< 10			Respirable – ACGIH curve 8 hrs/day, 40 hrs/week
Germany	< 5 Quartz > 3.75 (weight - %)	< 0.15				6 Quartz < 1 (weight - %)	
Norway	< 0.1	< 0.6				5 respirable 0.1	
Sweden	< 5	< 0.1	< 5	< 5	< 10		
Switzerland	< 5	< 0.15	< 5	< 6		irrelevant	
Portugal	6% 6% to 25% > 25%	< 5 < 2 < 1					
U.K.	< 5	< 3*	Total inhalable dust 10* Respirable dust 5%				
U.S.A.	< 5**	< 0.1					Respirable dust 1.0 for 8% alphaquartz

* Long-term 8-hr. Time Weighted Average. Relies on application of HASAW Act and COSHH (Reg. 10) HSE Guide Note EH 40 Limits.
** For tunnels, see formula in text and Note (1) in Section 5.6.

Table 3b. Guidelines: threshold limits for mineral dust.

Country	Quartz		Portland Cement				
	Particle Size μ	Content mg/m	Particle Size μ	Portland Cement mg/m³	Total Dust Content mg/m³	Total Dust Content	Comment
Austria		< 4.0		< 10		15	
Canada						10 for < 1% SiO_2 0 Asbestos ACGIH, TLVS	
Italy	< 0.7 + 5.0	< 0.3				10.0	
U.S.A.				< 10		10.0	OSHA Permissible Exposure Limit = 10 mg/m³/(2 + % alpha quartz)

Table 4. Dust measuring methods.

Dust Measuring Method	Country
Low-volume air sampler	Austria, Japan, Italy, Norway, U.K., U.S.A.
High-volume air sampler	Germany, Norway, Switzerland (5)
Piezometric balance dust meter	Austria, Japan
Digital dust meter	Japan, Norway Switzerland: Tyndallometer for rough assessment
Other methods	Portugal : Filtration method Sweden : Measure of exposure to compare with hygienical limits in AFS 1993 (9). Measure of exposure elucidates the worker's exposure, i.e., how much air pollution the worker is inhaling. The measuring is done in the breathing zone with filter and mobile measuring instruments.
Not normally measured	Canada, Morocco

emission, special working suits, helmets, masks, gloves, and glasses are almost always used in many countries. Goggles with full-face shields are being tried in some countries.

Extensive operator training and periodic medical checkups are being conducted in some countries.

6. Demands for R & D Related to Health and Safety in Shotcrete Use

(questionnaire items 5.1–5.6)

In shotcreting, there are still many areas that will require additional R & D to improve human health and safety in shotcreting. Enactment of or changes to regulations or guidelines are demanded in many countries to solve dust emission problems.

There are strong demands to improve the shotcrete mixture, particularly in the development of dust reducers and less harmful accelerators.

In addition, there is a definite trend to replace hand-held manual nozzle operation by manipulators.

Personal safety equipment also should be improved. In 1994, the Japanese Supreme Court ordered a mining corporation to pay ¥3 million to ¥12 million to each ailing worker. This is a warning that lawsuits for pneumoconiosis based on dust emission in tunnel construction may increase. Establishment of pneumoconiosis checkup methods and regulations are also demanded.

Other demands for improvement in shotcreting concern

- reduction of rebound and dust;
- development of high production techniques;
- improvements in the early age strength;
- achievement of high strength and high durability; and
- improvements in the prevention of ground water infiltration and establishment of quality control standards.

Appendix 1 expands on this summary by providing specific answers given by respondents to questions on the survey.

Table 5. Use of nozzle method of operation in shotcreting.

Country	% Mechanical Nozzle Operation by Manipulator	% Manual Nozzle Operation
Austria	10%	90%
Canada	15%	85%
Germany	10%	90%
Hungary		100%
Italy	80%	20%
Japan	90%*	10%
Morocco		100%
Norway	98%	2%
Sweden	80%	20%
Switzerland	wet 95% dry 10%	wet 5% dry 90%
U.K.	10%	90%
U.S.A.	30%	70%

*Generally adopted when the excavated area is larger than 50 m .

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Appendix: Selected Reponses to Questionnaire*

1 Dust concentration

1.1 Types of regulations related to dust emission

☐ law

Canada : Occupational Health & Safety Act - OHSA
Workplace Hazardous Materials Information System - WHMIS

Germany : TRGS 900
Unfallverhutungsvorschmfteu (i.e."dust")
SR "Bauarbeiteu unter Tage"
Leitfadeu fur Tunnelbauer

Italy : DPR 320-Cap VI no 53÷65

Japan : Ordinance on Industrial Safety and Health; Ministry of Laber, 1947

Norway

Portugal : Decree-Law no. 162/90 of May 22nd
General Regulation of Safety and Health in Mines and Quarries Works

Sweden : Legislation of working environment 1978

Switzerland : Federal law on accident insurance and decrees

U.K. : Health & Safety at Work Act 1974
Control of Substances Hazardous to Health Regs. 1988

U.S.A. : OSHA 1926.55 Dust Level
OSHA 1926.103 Respiratory Protection

☐ guideline

*Austria : Maximale Arbeitsplatz-Konzentration gesundheitssch**licher Arbeitsstoffe, 1990*

Canada : WHMIS - Material Safety Data Sheet - MSDS

Japan : Technical guideline for Measurement of Dust concentration in underground construction; Ministry of Laber, 1986

Morocco

Norway : Administrative norm

Sweden : Supported by law; The announcement of the Industrial Welfare Board, AFS 1993; 9, Hygienical limits AFS 1992; 16, Quartz, AFS 1988; 3, Measures against air pollutions, AFS 1986; 17, Rockwork

Switzerland : on subterranean works and on tunnel ventilation

U.K. : H.S.E. Guidance Notes EH40 - Occupational Exposure Levels

U.S.A. : Code of Federal Regulations (CFR), Title 30, Part 57, Subpart D.57.5001

Item 1.1 continued on following page

* Responses to all items covered in the questionnaire are included in the full report, available from the Japan Tunnelling Association (address given on first page of this report).

Item 1.1 (contd.)

☐ standard

Morocco : EUROPEAN

Portugal : NP-1796
prNP-2266-Safety and Health in Work-sampling of air dust and gases

U.K. : BS 6164 : 1990 Safety in Tunnelling in the Construction Industry

U.S.A. : American Conference of Governmental Industrial Hygienists (ACGIH) publishes Threshold Limit Values (TLV)

☐ others

Canada : (Legal regulations)
OHSA - Regulation Respecting Silica
OHSA - Regulation Respecting Control of Exposure to Biological or Chemical Agents (Portland cement)

Portugal : Safety and Health Regulations in Underground and Surface Works -Commission of Inspection of the Hydroelectric Schemes - 1965

U.K. : H.S.E Guidance Note EH44 Dust : General Principals of Protection - Classification, packing, labeling of Dangerous Substances Regulations

1.3 Dust measuring method being used :

☐ not normally measured

Canada

Morocco

☐ low-volume air sampler

Austria

Japan

Italy

Norway

U.K.

U.S.A.

☐ high-volume air sampler

Germany : i.e. vc25

Norway

Switzerland : vc 25

☐ piezometric balance dust meter

Austria

Japan

Item 1.3 continued on following page

Item 1.3 (contd.)

☐ digital dust meter

Japan

Norway

Switzerland : Tyndallometer for rough assessment

☐ others

Portugal : filtration method

Sweden : Measure of exposure to compare with hygienical limits in AFS 1993; 9. Measure of exposure are to elucidate the worker's exposure, i.e. how much air pollution the worker is inhaling. The measuring is done in the breathing zone with filter and mobile measuring instruments.

1.4 Dust measuring time interval

☐ once a day

U.S.A.

☐ once a week

Italy

U.S.A. : If tests indicate levels well below minimum.

☐ once a month

Austria

☐ twice a month

Japan

☐ others :

Austria : no specific regulation

Canada : full shift (8hrs) sampling

Germany : time interval according to the danger of exceeding the threshold-limit for mineral dust

Japan : Interval between measurements is not prescribed in any law at this time. The Office of Labor Standards Superintendence determines on the interval, otherwise it is up to the contractor to decide.

Norway : Not regularly measured

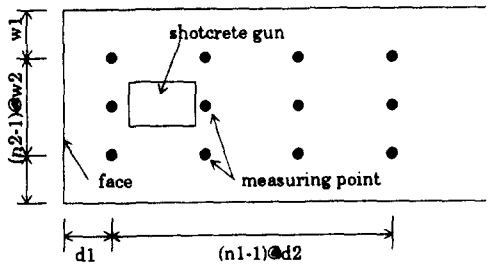
Portugal : Not defined

Sweden : Once a year. If respirable quartz content > 0.1mg/m^3 a new measuring must be done within six months.

Switzerland : as required by method (wet/dry) and conditions

U.K. : as and when required

1.5 Typical disposition of measuring devices



d1 m (distance from the face)

n1 points (number of measuring points along the tunnel)

d2 m (pitch between longitudinal measuring points)

w1 m (distance from side wall)

n2 points (number of measuring points across the tunnel)

w2 m (pitch between cross measuring points)

h1 m (height of measuring points)

Nation	*d1* *m*	*n1* *points*	*d2* *m*	*w1* *m*	*n2* *points*	*w2* *m*	*h1* *m*
Austria	*5~10*	*3*		*~1*	*2~3*		*~1*
Canada	*Personal sampling on Nozzleman or Pot operator*						
Germany	*As close as possible to the exposed persons head.*						
Italy	*4*	*1*		*100*	*1/100*	*4*	*2*
Japan	*5*	*3 <*	*10*	*1*	*2*		*0.5 to 1.5*
Norway	*0~10*		*40~50* *(Behind the ventilation outlet)*				
Switzerland	*cannot been answered that way position as close as possible to the exposed persons head*						*1.70*
Sweden	*The measure point is within the worker's breathing zone in the working area. In Sweden Stationary measure points aren't related to regulation about hygienical limits. Stationary measure points are related to localization of dust sources.*						
U.S.A.	*(when used) Personal air sampling devices are worn by* *1) Nozzleman 2) Shotcrete machine operator* *3) Laborers and cleanup crew*						

2.5 Average increase in concrete cost due to additives addition

Italy : 10%

Japan : 10~20%

Switzerland : 5%

U.K. : N/A %

2.6 Effect of dust control additives on reducing dust production

☐ very effective

Japan

☐ effective

Germany

Italy : to 4mg/m³

Item 2.6 continued on following page

Item 2.6 (contd.)

☐ not so effective

- *Austria*
- *Sweden*
- *Switzerland*
- *U.S.A.*

☐ unclear

- *Canada : not commonly used*
- *U.K.*

☐ others

- *Japan : 0.1% addition allows reduction to 1/2 , 0.15% to 1/3*
- *Morocco : not used*
- *Switzerland : affects shotcrete quality*
  low effect on respirable fraction

2.7 Effect of adjusting aggregate's grading to reduce dust

☐ effective

Austria

☐ not so effective

Morocco

☐ unclear

- *Canada : not commonly used*
- *Germany*
- *Japan*
- *Norway*
- *Sweden*
- *Switzerland*
- *U.K.*
- *U.S.A.*

2.8 Favorable grading of aggregate

- *Austria : Microsilica*
- *Morocco : not used*
- *U.S.A. : In accordance with ACI 506 recommendations*

2.9 Other countermeasures and R&D being tried to reduce dust production related to shotcrete mixture

Canada : None known

Germany : reduce smallest particles in the mixture improving mixing of the additives using special cements without accelerators (additives)

Italy : improving the mixing of the additives to the mix by increasing the length of the nozzle or the number of holes of compressed air or changing the pumping pressure

Japan : R&D of dust control additives
improvement of accelerators

Sweden : No R&D being tried now. However, the question is of great importance and will shortly be subject to further research.

Switzerland : promotion of wet spraying method
optimation of thin stream conveyance in wet spraying

U.K. : Wet shotcrete, Wet accelerators

U.S.A. : Wet Shotcrete, Liquid Accelerators
Commercial development of admixtures by suppliers

3 Dust remove countermeasures

3.1 Design capacity of forced ventilation

Nation	*for person* m^3 */person/minute*	*for machine with diesel engines*
Austria	*2.0*	*4.0m^3/kw/min*
Canada	*TLVS + 18% O2*	*100cf/min/BHP*
Germany	*2*	*4m^3/kw/min*
Italy	*3*	*4m^3/hp/min*
Japan	*3.0*	*Shovel series 2.2 m^3/ps/min* *other machines 0.8m^3/ps/minute*
Sweden	*varying*	*varying*
Switzerland	*1.5*	*4m^3/kw/min*
U.K.	*6*	
U.S.A.	*5.7*	*2.8m^3/horsepower/minute*

3.8 Effect of water curtain or air curtain

☐ effective

Canada : depends on dimensions of heading

Germany

Switzerland

☐ not so effective

Portugal

Item 3.8 continued on following page

Item 3.8 (contd.)

☐ unclear

- *Austria*
- *Japan*
- *Sweden*
- *U.K.*
- *U.S.A.*

3.9 Use of dust scrubber

☐ normally not used

- *Austria*
- *Germany*
- *Hungary*
- *Italy*
- *Norway*
- *Sweden*
- *U.S.A.*

☐ occasionally used

- *Switzerland : mainly on TBM's*
- *U.K.*

☐ sometimes used

Japan : 1986 : 47% → 1990 : 38% → 1991 : 37%

☐ almost always used

Canada : with roadheaders / continuous miners

3.10 Effect of dust scrubber

☐ effective

- *Canada*
- *Japan*
- *Germany*
- *Switzerland*
- *U.K.*

☐ not so effective

☐ unclear

- *Austria*
- *Sweden*
- *U.S.A.*

Item 3.10 continued on following page

Item 3.10 (contd.)

☐ others

Japan : If installed near the excavation face, besides the noise nuisance, it interferes the excavation works.

Morocco : not existing

3.11 Others countermeasures and R&D being tried to remove dust emission

Canada : changes in mining method - long hole blasting
- hydraulic drills
- cleaner diesel engines
polyurethane ground control applications - possible problems with isocyanates

Germany : Water curtain of high pressure (~ 700 bar)
Air curtain by combining blow-in and suction-ventilation

Italy : CIFA MILAN is testing a manipulator whose 2 nozzles are closed in a case, and the dust is always contained in a closed space.

Japan : The method of making use of static electricity is not much in use at present. However, the system can become popular if an automatic turn-off system that senses the transit of people is added.

Sweden : No R&D being tried now.

4 Personnel protection against dust and actual physical harm caused by shotcrete dust

4.1 Use of special working clothes

☐ normally not used

Austria

Norway

☐ occasionally used

Germany : Air stream helmet (Racal)

Italy

☐ sometimes used

Japan

Portugal

Switzerland

U.S.A.

☐ almost always used

Canada : coveralls, mask with personal air purifying respirator

France

Hungary

Morocco

Sweden

U.K.

Item 4.1 continued on following page

Item 4.1 (contd.)

☐ others

Switzerland : not a dominant problem

4.2 Use of mask

☐ normally not used

Austria

☐ occasionally used

☐ sometimes used

Sweden

☐ almost always used

Canada
France
Germany
Hungary
Italy
Japan
Morocco
Norway
Portugal
Switzerland
U.K.
U.S.A.

4.3 Use of glasses

☐ normally not used

Portugal

☐ occasionally used

☐ sometimes used

Austria
Germany
Norway
Sweden
Switzerland

Item 4.3 continued on following page

Item 4.3 continued

☐ almost always used

- *Canada : trend to use of goggles / full face shield*
- *France*
- *Hungary*
- *Italy*
- *Japan*
- *Morocco*
- *U.K.*
- *U.S.A.*

☐ others

Switzerland : screen goggles

4.4 Use of spraying robots

☐ normally not used

- *Hungary*
- *Morocco*
- *Switzerland*

☐ occasionally used

Canada : few remote spray booms

☐ sometimes used

- *Austria*
- *France*
- *Germany*
- *U.K.*
- *U.S.A.*

☐ almost always used

- *Japan*
- *Norway*
- *Portugal*
- *Sweden*

☐ others

- *Italy : CIFA-MILAN supplies a software for its new manipulators*
- *Switzerland : (robots, not manipulators)according to our knowledge not used in Europe*

4.5 Other countermeasures and R&D being tried to protect physical harm caused by dust

Canada : None

Germany : Medical checkup before and during work
Personal safety equipment (helmet, suits, gloves etc.)
No quartz in accelerators
Minimizing smallest parts in mixture

Japan : An extensive training program with the fieldteams.
A pneumoconiosis medical checkup is made before, during, in an yearly basis, and soon after completion of works to each personnel. People prone to long diseases are not permitted in the tunnel.

Morocco : not existing

Norway : Gloves,helmet it, combination of helmet and air stream mask

Sweden : No countermeasures or R&D

Switzerland : R+D of non-affecting setting accelerators(i.e. alkali-free) to reduce physical harm.

U.K. : Improved - low aggressive additives
Training

U.S.A. : Wet mixes
Less harmful accelerators
Some mines use Racal Airstream Helmets

5 Required action and R&D to solve dust emission problem in your country

5.1 Regulation related to dust emission

☐ almost complete now

Canada

Germany

Switzerland

☐ additional correction is needed

Italy

Japan

U.K.

☐ it is necessary to enact a law or regulations

Hungary

Morocco

☐ law or regulation are not effective to reduce dust emission in tunnel

Austria

Hungary

Item 5.1 continued on following page

Item 5.1 (contd.)

☐ other point or opinion

Canada : implementation not very easy

Norway : Environmental health criteria is given as a norm based on technical, economical and medical values. They are not given 100% protection from damages, and should be evaluated and improved.

Sweden : More R&D is needed in order to enact a law or regulations.

U.S.A. : Need to increase awareness of shotcrete crews to potential problems caused by dust.

5.2 Shotcrete mixture

☐ more R&D are needed

Austria
Canada : in area of dust control
France
Germany
Hungary
Japan
Morocco
Sweden
Switzerland
U.K.
U.S.A.

☐ not fully comprehended yet, but more R&D is not wanted

Italy

5.3 Shotcrete machinery and system

☐ almost completely developed

Canada
Italy
Morocco

☐ more R&D are needed

Austria
France
Japan
Sweden
U.K.

Item 5.3 continued on following page

Item 5.3 (contd.)

☐ not fully developed yet, but present technology is good enough

Germany
Hungary
Norway
Switzerland

☐ other point or opinion

Canada : Needs continued updating as shotcrete mixture R & D develops
U.S.A. : Need to improve training in proper application of shotcrete, especially for small jobs.

5.4 Ventilation method

☐ more R&D are needed

Austria
Hungary
Japan
Morocco
U.K.

☐ not fully developed yet, but present technology is satisfactory

Canada
Germany
Italy
Norway
Sweden
Switzerland
U. S. A.

☐ other point or opinion

Canada : Relies heavily on quality control of ventilation system
Japan : An innovative "fuzzy" ventilation system is under development, which is capable of analyzing concentrations of NOx and dust, as well as temperature.
Switzerland : Goal is dust suppression at source!

5.5 Personnel protection

☐ almost completely studied

Canada

☐ more R&D are needed

Austria

France

Hungary

Japan

Morocco

Sweden

U.K.

U.S.A.

☐ not fully developed yet, but present state is satisfactory

Germany

Italy

Switzerland

☐ other point or opinion

Canada : Good methods available - but not always used

France : to make it more user's friendly

Norway : Difficult to get the workers to use all the equipment for personal protection.

5.6 Other points or opinion generally related to shotcreting

France :

Wet shotcrete is less dusty, but might generated a mist containing droplets of highly caustic additives(accelerators) which are hazardous. Is it really safer?

Germany :

In respect of humanizing working situation by shotcrete application the wet method will take place more and more as well as handhold nozzles will be replaced more and more by manipulators. More R+D measures are needed for shotcrete

- *machinery*
- *application methods*
- *mixtures (wet+dry)*
- *additives like accelerators*
- *dust reducers*
- *personal safety equipment*
- *ventilation and air pollution control*
- *pneumoconiosis checkup methods.*

Italy :

In the next year the Italian construction companies are going to change the usual way of working as at the end of this year,1994, a law will oblige us to respect the ISO 9000(Anality Assurance).It means that the machinery, the materials and manpower will be qualified in order to get the required results and even the regulations on health and safety will be part of the "mix design".

Item 5.6 continued on following page

Item 5.6 (contd.)

Japan : Major concerns related to shotcrete, at present, in Japan are

	Concern	Target or means	Present Status
1	Rebound reduction	To reduce costs	It is being carefully studied more than previously.
2	Dust reduction	To improve the air quality in the tunnel	
3	Development of high production techniques	To enable construction of large scale, longer length tunnel	In some site, a production level of nearly 20 m^3/h was reached.
4	Improvement in the early age strength of concrete	To improve productivity; to thinnen shotcrete layer	A shotcrete with a design strength of 500kgf/cm^2 started to be developed.
5	Improvement in the strength and durability qualities	To enable realization of the single shell layer concept	For the time being, a reduction in the layer thickness is envisaged, but, in the long run, the aim is to improve the durability to try on the single-shell concept.
6	Countermeasures against groundwater infiltration	Via new construction methods, and improved mix design	
7	Lack of homogeneity in the quality	To establish quality control standards	

In March of 1994, the Supreme Court returned a case of compensation for pneumoconiosis, where a mining corporation was ordered to pay from ¥3 millions to ¥12 millions to each ailing worker.

Morocco :

1) Shot crete in our country is based on regulations adopted in europe.

2) Shot crete is generally used to repair existing tunnels and dams slope stabilizing.

Sweden :

If ventilation can be controlled so air pollutions are transported away from the working place. Work with shotcreting when no other working groups are working in the area. Shotcreting in tunnel is often planned like this.

U.S.A. :

Need to improve quality of all aspects of shotcrete placement. Need training of shotcrete crews and increased awareness of potential for dust problems by everyone, including shotcrete crews, inspectors, construction managers, engineers, and owners.

** : Note (1) for Item 1.2*

The OSHA Permissible Exposure Limit (PEL) for respirable dust containing cyrstalline silica (alpha quartz) is :

$$PEL\ (mg/m^3) = 10\ mg/m^3 / (2 + \%\ alpha\ quartz)$$

The term "respirable" refers to the size fraction of dust that deposits in the lungs. The respirable dust level is determined with a collection device that has a 37-mm dia. filter preceded by a 10-mm nylon cyclone. A "personal sampling" pump draws air through the cyclone that removes larger sized non-respirable particulate. The smaller respirable sized particulate passing through the cyclone is collected on the filter for weighing and quartz analysis. From the above equation, dust that has 8% alpha quartz has a PEL of 1 mg/m^3.