Health and Safety in Tunnel Construction

TRAINING MATERIAL PREPARED BY

Donald Lamont C.Eng FICE
Health and Safety Executive, UK
Animateur ITA WG5
Introduction

Sources of guidance

- CEN Standards
- ITA publications
- National legislation and standards
- Industry guidance
Introduction

ITA publication “Safe Working in Tunnelling”
Introduction

The hazards of tunnelling are exacerbated by

- Uncertainty and variability of ground
- Confined space of tunnel environment
- Inadequate safety culture
- Lack of commitment by all parties
- Failure to learn from mistakes
- Work in compressed air

Health and Safety in Tunnel Construction
Occupational health
Chapter 1

Occupational health

- To ensure fitness for work
  - e.g. Eye sight requirements for plant operators

- To address ill health due to work
  - e.g. Hand arm vibration syndrome from use of vibrating pneumatic tools
Ill health in tunnelling

- General occupational ill health
  - No published data in UK
  - Very little published data worldwide

- Decompression illness
  - UK data published
  - Some data published for other countries also
Chapter 1

Occupational health hazards
- Cementitious materials – dermatitis
- Epoxy materials – dermatitis and respiratory problems
- Noise – hearing loss

Health and Safety in Tunnel Construction
Chapter 1

Occupational health hazards

- Heat strain
- Vibration
- Manual handling
Chapter 1

Occupational health hazards
- Dust
- Soil conditioners
Chapter 1

Occupational health hazards

- Work in compressed air
  - Decompression illness is a hazard
  - Risk of DCI reduced by use of oxygen

*Health and Safety in Tunnel Construction*
Chapter 2

Welfare
Chapter 2

Welfare

- Basic toilet facilities
- Washing facilities
- Drinking water
- Messing facilities
- First aid
Safety
Chapter 3

Role of Client

- Sets environment for procurement
  - Can dictate health and safety strategy
  - Designers take on Client’s values

- Provides resources for health and safety in terms of finance and time
  - Can require contractors to do likewise
Chapter 3

Role of Designer

- Design influences on health and safety include:-
  - Avoidance of contaminated land
  - Setting of tunnel diameter
  - Facilitating use of TBMs
  - Specification of fire fighting, atmospheric monitoring, communications systems

Health and Safety in Tunnel Construction
Other procurement issues

• Partnering
  – Should have benefits for health and safety
• Joint ventures
  – Use expertise of all parties
• Good project management
  – Includes health and safety management
• Role of insurance companies

Health and Safety in Tunnel Construction
Ground risk

- Risk to Client
  - Financial loss
- Risk to work force
  - Death or injury
- Risk to public
  - Death or injury
- High consequence low frequency event
Chapter 3

Ground risk

- Primary lining of fundamental importance to safety of tunnel
- Sequence of excavation as designed must be maintained
- Adherence to specification for materials and workmanship essential
- Learn from mistakes of others

*Health and Safety in Tunnel Construction*
Chapter 3

Ground risk

- Site investigation must be adequate if risk to be minimised
- Design must address excavation and primary support requirements
- Designer and Contractor should liaise
  - Stability of permanent works
  - Stability of primary lining
  - Tunnel stability at all stages of construction
Chapter 3

Excavation & Lining methods

- Soft ground
  - TBM
  - NATM or SCL
  - Hand techniques

- Use of TBM
  - Limits settlement
  - Speeds excavation
  - Enhances safety underground
  - May increase risk to 3rd parties

Health and Safety in Tunnel Construction
Chapter 3

Excavation & Lining methods

- Hard rock
  - Unshielded TBM
  - Drill & Blast

Health and Safety in Tunnel Construction
Chapter 3

Observational Methods

- Require extensive engineering input
- Most probable and most unlikely cases
- Incremental steps
- Triggers and alarms
- Contingency plans
- Emergency plans
Chapter 3

Machinery Safety Standards

- EN 815 – Unshielded TBMs
- EN 12336 – Shield machines
- EN 12111 – Roadheaders
- EN 12110 - Airlocks
Chapter 3

Tunnel machinery hazards

- Segment build area
  - Heavy loads
  - Poor visibility
Chapter 3

Tunnel machinery hazards
- Fire
- Electricity
- Control points and systems

Health and Safety in Tunnel Construction
Chapter 3

Tunnel machinery hazards

- Access to cutterhead
- Handling of heavy components
- Rotation/stability
- Walkways and access openings
- Visibility

Health and Safety in Tunnel Construction
Chapter 3

Excavation & Lining methods
- Control points and systems
- Hydraulic systems
- Fire
- Operator protection
- Potentially explosive atmospheres

Health and Safety in Tunnel Construction
Chapter 3

Explosive atmospheres
- Explosion protection of mechanical and electrical plant when in potentially explosive atmospheres
- ATEX Directives

Health and Safety in Tunnel Construction
Chapter 3

Tunnel transport systems

- Bored tunnels
  - Railway systems
    - Fuelling
    - Exhaust emissions

- Other tunnels
  - Wheeled or tracked vehicles
    - Exhaust emissions
Chapter 3

Tunnel transport systems

1. Visibility poor
2. Driver visibility poor
3. Separation of vehicles and pedestrians
4. Reduce vehicle movements
   - Slurry systems
   - Conveyors
Chapter 3

Tunnel atmosphere hazards

- Oxygen deficiency and enrichment
- Toxic gases – CO, NO, NO\(_2\), H\(_2\)S, NH\(_3\), SO\(_2\)
- Carcinogens – Toluene, benzene, xylene
- Asphyxiant gases - CO\(_2\)
- Potentially explosive gases - CH\(_4\), VOCs
- Radon
- Dust - silica
- Heat
Ventilation
  - Removes contaminants
  - Brings in fresh air
  - Cools tunnel
  - Controls smoke

- Must be correctly positioned
- Must be maintained

*Health and Safety in Tunnel Construction*
Chapter 3

Explosives

- Drilling hazards
  - Dust
  - Noise
  - Vibration

- Premature detonation
- Toxic fume
- Blast shelter
Chapter 3

Fire, flood, rescue and escape

- Fire + smoke = major hazard to workforce
- Fire can damage lining
  - This threatens the existence of the tunnel – a valuable asset
Chapter 3

1. Fire, flood, rescue and escape
   - Extensive flammable material underground
2. Need for fire mitigation policy
   - Low flammability hydraulic fluid
3. On-board fire suppression systems

Health and Safety in Tunnel Construction
Chapter 3

1. Fire, flood, rescue and escape
   - Good housekeeping is essential
   - Detection and alarm systems required
   - System for accounting for personnel

*Health and Safety in Tunnel Construction*
Chapter 3

Fire, flood, rescue and escape

- Rescue team if necessary
- Oxygen self rescuers for everyone underground
Fire, flood, rescue and escape

- Clear walkway for escape
- Rescue train in long tunnels
- Rescue container in tunnel
Chapter 3

Work in compressed air

- For ground stability below water table
- Essential to safe operation of certain TBM types
- Use of TBMs reduces numbers of exposures

Health and Safety in Tunnel Construction
Work in compressed air

- Enhanced fire risk
  - Increased mass concentration of oxygen in compressed air
  - increased volumetric concentration if leakage/discharge of oxygen to tunnel atmosphere
Chapter 3

Work in compressed air
- Safe working pressure
- Controls and instrumentation
- Dimensions
- Fire protection
- Oxygen breathing

Health and Safety in Tunnel Construction
Conclusions and references

This presentation has focussed on three important aspects of good tunnelling practice
- Occupational health
- Welfare
- Safety

In the time available it has only been possible to present an overview but more information and references can be found in my paper.
Thank you for your attention