Guidance on the safe use of temporary ventilation ducting in tunnels

ITA WG5 – Health & Safety in Works

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During construction and refurbishment work in tunnels, adequate ventilation must be provided to reduce risks to health from atmospheric contaminants or lack of oxygen. Ventilation can also be used as a means of cooling the tunnel environment. It is important that the components of the ventilation system should not themselves present additional risks to those building the tunnels.

This guidance gives recommendations for the materials to be used in such ducts and their installation and maintenance.

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1 >> VENTILATION SYSTEMS

Two main configurations of ventilation system are used underground

1.1 FORCED VENTILATION SYSTEM

Fresh air is drawn from the outside and forced through ducting by fans on the surface, to the working face(s). Flexible ducting has the advantages that it has a lower resistance to flow and is easier to install than rigid ducting. It is also less susceptible to impact damage. As the airflow is away from the working face, activity at a distance from the face such as vehicle movements or maintenance works, such as welding, does not become a source of contamination at the face.

1.2 EXTRACTION VENTILATION (SUCTION) SYSTEM

Contaminated air is drawn from the working areas through rigid or semi-rigid ducting to the surface via fans either fitted in-line, into bulkheads across the tunnel or on the ground at the tops of shafts etc. Dust, fumes or gases from activity away from the face is first drawn to the face before being exhausted to the surface.

The advantage of extraction ventilation is that contaminated exhaust air is drawn directly from the workings without contaminating the rest of the tunnel. Hence extraction ventilation is important when roadheaders are being used.

This system has a number of drawbacks that have to be considered. The main drawback is the much higher energy consumption due to the high flow velocity required in the duct to prevent sedimentation. Other drawbacks, include the slower installation rates for rigid ducting and the additional work required to repair or replace rigid ducting, In addition, material costs are higher than for flexible ducting. More leaks are possible due to the greater number of joints and the need to align and sleeve each joint.

Normally forced ventilation should be used when methane is present to dilute the contaminant however in situations where silica dust is also present and extraction ventilation is chosen to prevent widespread exposure to the dust, additional precautions such as gas monitoring and the use of explosion protected equipment are required in the exhaust ventilation system.

1.3 ADDITIONAL VENTILATION AT THE FACE

Additional local ventilation is necessary at the face when an extraction ventilation system is being used in the tunnel. Additional fans may be necessary in the tunnel to boost the flow in forcing ventilation systems.

1.4 SECONDARY VENTILATION ON TBMS

Forced or extraction ventilation systems are installed locally on TBMs and backup equipment.

1.5 CONTROL OF AIRBORNE DUST

To prevent the dispersion of airborne dust while using excavation plant or TBMs in silica-rich rock, local extraction ventilation may be required at crushers, conveyor belts and materials transfer points.
The extraction ventilation intake should be installed as close as possible to the point of dust generation. The airflow should be passed through a de-duster in which the dust is filtered out and removed from the tunnel through a suitable collection/disposal system.

2.1 MATERIAL PROPERTIES FOR FLEXIBLE DUCTING

Flexible ducting for installation in a tunnel should demonstrate certain properties so that it does not in itself constitute a hazard and that it is fit for purpose.

Flexible ducting should normally be made from a pvc coated textile material. Material properties should meet the requirements of the national regulatory authorities where these exist. These may be based on national standards for strength, fire resistance etc. In some countries the most appropriate standards may be for mining applications rather than for tunnelling.

Where there are no appropriate national standards it is recommended that reference is made to standards such as DIN 21605 and 21606.

2.2 RESISTANCE TO PROPAGATION OF FIRE AFFECTING HORIZONTAL OR VERTICAL DUCTS

All material should be tested for flame retardant properties in accordance with the requirements in the country of use. If no such requirements exist, reference to DIN 4102 may be appropriate. Most standards permit material to burn if exposed to a open flame, but require that the material will not drip, will extinguish within a specified time once the open flame is removed and limit the extent of fire damage. The time specified varies according to the standard applied.

2.3 ANTISTATIC PROPERTIES

For ducts carrying air contaminated with dust in an atmosphere containing potentially explosive gas e.g. methane, all material should be tested for antistatic properties and should have a resistance of $< 1 \times 10^8$ Ohm when tested in accordance with DIN IEC 167. In some countries formal approval of the material by national authorities can be required.

Ducts made from such materials should be marked appropriately.

2.4 RELEASE OF TOXIC COMBUSTION PRODUCTS IN A FIRE

The material should not emit hazardous gases when exposed to fire. General guidance can be found in EN ISO 4589 which is a general standard relating to combustion of plastic materials.

2.5 JOINTING BETWEEN INDIVIDUAL LENGTHS

Individual lengths of flexible ducting should be joined together by the use of couplings. Normally a range of coupling types is available including:

2.5.1 Steel coupling

A steel ring is welded in one end only of each length of ducting. These are then connected to each other by mounting the duct end without steel ring over the tube with steel ring. Then a steel connecting ring is mounted over the two ducts and tied.
A connection system comprising one inner steel ring within a lose duct end, gives flexibility in the different duct lengths which can be connected to each other.

2.5.2 Zip connection

Zip connections have been used since the beginning of the 1980s. The zip is mounted on the tube and is easily connected to the next tube. Zip connections can be used for joining together long ducts and for large diameter ducts. Zip connections are often used on TBM projects.

2.5.3 Fabric fastener-type connection

A fabric fastener type connection can be used for larger diameter ducting to make handling and connecting easier. This material is attached to opposite ends of each duct which is then easily connected to the next duct. It is strong, will not be easily damaged and can be used for many years. Fabric fastener connections are often used on TBM projects.

2.5.4 Flexible end rings

Coupling between two ducts can also be made using flexible end rings. These are made from flexible PVC coated, spring-steel wire. The end rings cannot be deformed permanently and always revert to their initial round shape.

2 >> Flexible ducting

There are two versions:

- For ducts of 1200 mm diameter or less, 7 wires of 3 mm diameter each giving an end ring thickness of 9.5 – 13.5 mm diameter.
- For ducts of greater than 1200 mm diameter, 7 wires of 5 mm diameter giving an end ring diameter of 15 - 18 mm.

  Flexible end rings in combination with either quick release or screw flexible couplings provide a tight and safe connection.

  In addition the flexible end rings can be plugged into each other and then strengthened with an appropriate coupling. This also works when one duct with a flexible endring is pulled into a duct without an endring (see Steel coupling.)

2.6 MEANS OF SUSPENSION

2.6.1 Suspension hooks

Suspension hooks should typically be between 500mm and 1000 mm apart in a single line for ducts of 200mm to 1900mm diameter and 1000 mm apart, in two parallel lines for ducts of 2000 mm diameter and upwards. Every hook should be fixed to the duct by a fabric “strap” which is welded to the duct. The bending force for the suspension hooks should be between 400 and 600 N. The force to pull the suspension eyelet from the suspension strap should be greater than 600N to ensure that the hook is deformed before the eyelet is pulled out, damaging the duct. For ducts in tunnels with significant space limitations the suspension of ducts by two suspension lines can reduce the space occupied by the duct by positioning it closer to the tunnel lining.

2.6.2 Longitudinally welded suspension seam

These can be made of ducting material with reinforced eyelets or self-locking hooks.

2.6.3 Ducts in vertical shafts

Ducts in vertical shafts should have multiple seams and should be supported from wires in the shaft wall at regular intervals.

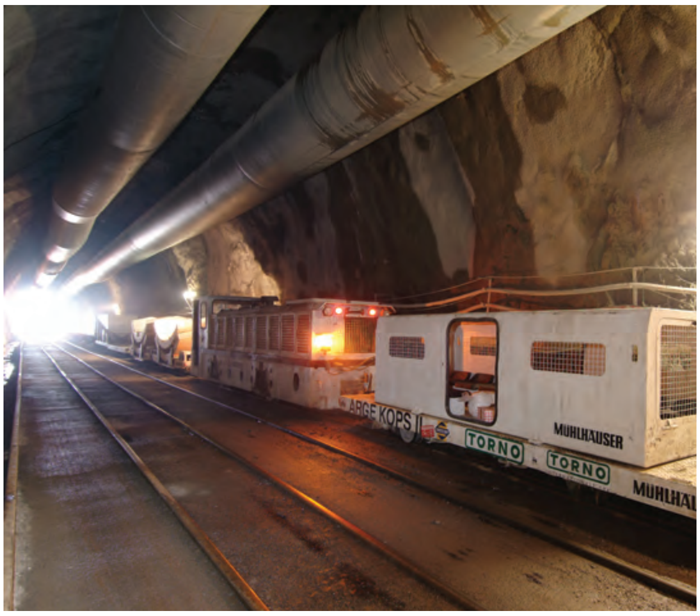
2.7 TEAR/PERFORATION RESISTANCE

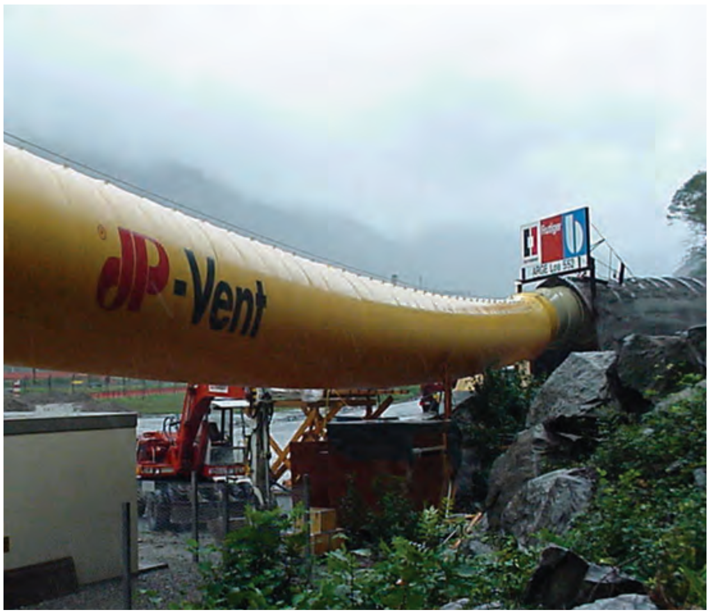
The PVC material should be tested for tear/perforation resistance in accordance with national standards. Where these do not exist, the following can be used:

Tensile Strength	DIN 53 354
Tear Strength Warp/weft	DIN 53 356
Seam strength test	DIN 53 357

2.8 PRESSURE RATING

The manufacturer should undertake tests to demonstrate the safe maximum burst pressure (positive and/or negative as relevant), which the duct can withstand. The safety factor applicable to the working pressure depends on the requirements of the customer but should always be at least 5. Care should be taken to ensure that pressure transients on fan start up do not exceed the bursting pressure of the duct. Information on working pressure and bursting pressure should be made available to the customer.





3 >> Instructions for use

The manufacturer should provide information on the following:

- Installation and maintenance of the duct including the types of support required.
- Design parameters for the duct including pressure and flow characteristics and internal friction
- Alignment parameters including requirements for rigid bends, fittings etc.
- Information on repair and long term storage
- Regular checking of duct capacity during use

3.1 INSPECTION AND MAINTENANCE

As a tunnel is driven and its length increases, the pressure in the ventilation duct is normally increased to compensate for the increased flow resistance. Damage to the ducting due to handling and the operation of equipment will occur. Regular inspection and maintenance should be undertaken to ensure that damage to the duct is identified and repaired.

This includes:

- Deformation in the duct and unwanted deviations in its alignment particularly at significant changes of direction.
- Defective or damaged couplings.
- Correct suspension of the duct throughout its length.
- Freedom for the duct to move along the suspension wire as necessary.
- Defective or loose suspension bolts .
- Correct tension in the suspension wire .
- Correct functioning of fans, other equipment and their respective control systems
- Air speed, duct pressure and fan energy consumption are within prescribed ranges.
- Accumulation of water and dust in the duct

3.2 PREVENTION OF SEDIMENTATION

The air velocity in the duct to prevent sedimentation should be 20m/s. This is only applicable to extraction ducts.

3.3 REPAIR IN USE

3.3.1 General

It is important to inspect and maintain the duct. Repairs should be carried out as soon as damage is identified. The cost of repair is minimal compared to the increased energy used by the fan to maintain the airflow. A 10% increase of the fan capacity could increase the energy consumption by over 20%.

3.3.2 Repair of holes/tears on a mounted Flexible Duct.

The manufacturer should give information on how to repair his material both whilst in use and out of service.

3.4 DISMANTLING, AGEING OF MATERIALS AND CONDITIONS FOR LONG TERM STORAGE

3.4.1 Dismantling

Before taking down the ducting it should be inspected for damage, classified for storage or disposal and where relevant cleaned for reuse. It is preferable that ducting classified for reuse, should be cleaned. This is most easily done before the ducting has been taken down.

Class 1: Ducting with no damage.
Class 2: Ducting with limited damage which can be repaired.
Class 3: Ducting with extensive damage which is unfit for reuse.

Ducting for reuse should be stored on pallets. Each pallet should be clearly marked with details of the material quality, diameter, length and reuse class of each section of ducting stored on it. It is preferable that all lengths of ducting on a pallet are similar in terms of material quality, duct diameter, and reuse class.

3.4.2 Storage

The ducting on pallets should be secured. If stored outdoors the pallet should be covered to protect its contents from dust, heat and sunlight.

References & Acknowledgements

ACKNOWLEDGEMENTS

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REFERENCES

Standard	Title
DIN 21605	Auxiliary ventilation for mining - Flexible plastic ventilation ducts for exhaust and forced ventilation - Spiral ventilation ducts
DIN 21606	Auxiliary ventilation for mining - Flexible plastic ventilation ducts for forced ventilation - Flat ventilation ducts
EN ISO 4589	Plastics. Determination of burning behaviour by oxygen index
DIN 53354	Testing of artificial leather; tensile test
DIN 53356	Testing of artificial leather and similar sheet materials; tear growth test
DIN 53357	Testing of plastics sheets; adhesion test
IEC 167	Methods of test for the determination of the insulation resistance of solid insulating materials

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