USE OF DUST FILTERS
DURING THE CONSTRUCTION OF TUNNEL SYSTEMS

Aigner H., Aigner Tunnel Technology GmbH
Gamsjäger H., Wienerwaldtunnel (Vienna Woods Tunnel) consortium

BASIC PRINCIPLES
During tunnel construction a large quantity of dust develops through the different work process, such as boring, blasting, milling, etc. Aeration systems (ventilation) must be installed to supply the oxygen for workers and the combustion engines, and they are also necessary to ensure compliance with the limit values for dust and/or other components in the work area. Thus the use of filtering dust collectors on tunnel boring machines (TBM) or direct collection with mobile filter units in the work area (e.g. tunnelling with roadheaders) is to be regarded as state of the art. Modern filtering units thereby exhibit a collection efficiency of > 99.9%.

The air requirements derived from the above requirements is vast. In conventional tunnel construction work is usually conducted using pressurised ventilation without the use of filtering systems. Therefore dedusting of the portal with a filter is rarely conducted for numerous reasons, such as space requirement, high energy consumption or costs.

A new concept of portal dedusting was realised for the first time when tunnelling the east section of the Wienerwaldtunnel (Vienna Woods Tunnel). The filter used for this purpose was developed during operation for the purification of exhaust air from road tunnels and it can be used in two different versions; as electrostatic filters ECCO, or without high voltage technology as EccoDust.

1. PROJECT DESCRIPTION
1.1. General

The Vienna Woods Tunnel consortium is constructing a 13.35 km railway tunnel to the west of Vienna. Two tunnel boring machines (10.6 m diameter) with dedusting filters are used in the west, while the tunnelling of the east section is conducted using a mining process with tunnel excavator (with milling cutter) and rock blasting. The length of the east section is 2,350m and its ventilation hole is situated in the residential area of the 14th District of Vienna, whose closest neighbours are located at intervals of approx. 30m.

A commissioned immission assessment (Felbermayer, 2004) suggests the adherence to the contractually guaranteed limit values within the area of the neighbouring units. Nevertheless the Vienna Woods Tunnel consortium decided to construct a filter system with a completely new concept for the purpose of the neighbouring units and the building contract.
1.2. Sources of dust in the tunnel

The most diverse activities cause particle emissions in conventional tunnel construction. In this particular case these include:

Loosening work
- Loosening of the rock mass using tunnel excavators (accessory equipment such as excavator buckets, hydraulic hammers or mounted milling cutter)
- Part face heading machine (fig. 2)
- Blasting

Safety work
- Wet and dry mix shotcrete
- Boring
- Dry boring in the moisture-sensitive rock

Mucking
- Dispersion of dust by debris collection vehicles
- Loading of the debris collection vehicles

Emissions of diesel vehicles
- DME-diesel engine emissions are collected directly by diesel particle filters

Cement dust
- Filling of the cement silos underground
- Dry filling of the cement mixer truck (Mixed in Car System Underground)
1.3. Ventilation concept

1.3.1. Ventilation and purification of exhaust air

A blowing ventilation unit (SIA 196 1998) was selected as the ventilation system. The air is supplied via a suction duct and a metal air conduit with an axial ventilation fan (fig. 3). The supply air is fed into the work area with a flexible plastic air conduit d=2.4 m (fig. 4), which is constantly extended to match the building progress. This ensures that the tunnelling area has a permanent supply of fresh air.

The exhaust air fan is located directly next to the ventilation fan. The air is blown out via the dedusting filter, which is installed in a cover opening.

Volume of supply and exhaust air: 60 m³/s

Exhaust air via filter

Figure 3: Diagram for blowing ventilation in the Vienna Woods Tunnel with additional exhaust air fan and filter in the air outlet section.
1.3.2. Direct collection of cement dust (Mixed in Car)

The process of dry filling the cement mixer truck (fig. 5) also creates an enormous amount of dust. The process of dampening the dust with a sprinkling of water was tested initially, however it did not have a sufficient effect. Therefore it was decided to conduct a direct collection procedure via a suction hood, which was attached above the filling hole.

Volume of air: 4500 m³/h

1.4. Concentrations of dust for filter layout

Standard values for the filter layout could be derived from comparative measurements in the Plabutsch tunnel, Graz (ÖSBS, Schuster A. 2002) see table 1.
Table 1: Dust emissions during tunnel excavation

<table>
<thead>
<tr>
<th>Total dust TSP</th>
<th>Fine dust PM$_{10}$</th>
<th>Fine dust PM$_{2.5}$</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg/m³</td>
<td>mg/m³</td>
<td>mg/m³</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Distance 200 m</td>
</tr>
<tr>
<td>5-20</td>
<td>5-10</td>
<td>1-2</td>
<td></td>
</tr>
<tr>
<td>3-5</td>
<td>3-4</td>
<td>1</td>
<td>Before blasting</td>
</tr>
<tr>
<td>5-25</td>
<td>5-20</td>
<td>2-5</td>
<td>After blasting</td>
</tr>
</tbody>
</table>

The measurements were conducted in the tunnel section, therefore they represent the concentrations in the ambient air. The concentration of dust measured varies depending on the activity conducted and it reaches e.g. the highest values after the blasting procedure. At a distance of approximately 200 m the proportion of fine dust is the same as the total dust, which means that the coarse dust settles and falls to the ground.

As the total dust TSP (total suspended particulate) is approximate to the PM$_{10}$ value (particulate matter), it can be concluded that practically all particles are smaller than 20 µm.

2. FILTER CONCEPT

2.1. EccoDust

In principle the problem would naturally be solved with a classic dedusting filter. However, the space requirement for the relatively large volume of air is significant. Besides this, the pressure loss of 1,500 Pa is not insignificant and it causes a corresponding power requirement of the fan.

EccoDust is an alternative solution with regard to the requirements for residual dust and it has a low resistance of approx. 500 Pa.

The concept is based on the ECCO$^\text{®}$ filter system that has been developed for road tunnels. The separation of ultra-fine particles is also possible with the high voltage technology. However, during tunnel construction the particle spectrum in the dust separation process primarily ranges between 1-10 µm. Therefore EccoDust also makes it possible to dispense with the entire high voltage technology and to use a filter that operates in a purely mechanical manner.

Figure 6: EccoDust
Technical data:
Average filtration efficiency: 97%  Average synthetic dust weight arrestance according to ASHRAE 52.2 – 1999 and EN779
Classification: F5
Dust storage capacity: 360 g/m²
Pressure loss: 500 Pa (whole filter)

2.2. Dedusting system

If the filter is saturated it is cleaned with purge air. Due to the fact that several individual modules are used, this cleaning process can also occur whilst the system is being operated. In doing so the modules are dedusted one after the other. The filter medium is thereby placed in rotation (fig. 7) and the dust is blown out via a high-pressure nozzle. At the same time the dust is sucked in on the opposite side and collected in a conventional dust filter.

The dedusting process is triggered by 2 parameters:
- Pressure loss above the filter
- Setting of a fixed time interval

The dust filter that is required for the dedusting process can also be used for other tasks. The same applies for this as for the direct collection of cement dust during the filling of the cement mixer truck, as described under point 1.3.2. Very high concentrations of dust develop here, which can be controlled efficiently with this filter.

3. MEASURING DATA

The system has been in operation since spring 2005. Two measurements were conducted by the ÖSBS (Austrian Dust and Silicosis Prevention Unit). Different filter media were also tested during the measurements. The crude gas side in the exhaust air pipeline and the clean gas side on the air outlet section were measured after the filter respectively. Two Grimm laser aerosol spectrometers were selected as the measuring method for the simultaneous measurement before and after the filter. Measurements were conducted with a plan filter head probe STE 40 to determine the gravimetric factors.

Figure 7: Purge air cleaning of EccoDust

3.1.1. Total dust TSP

The measurements were conducted using a G4 filter medium, which has a lower pressure loss in comparison with the technical data specified in point 2.1, however it also has a lower filtration efficiency of 94%.

Figure 8 displays the half-hour mean values that were recorded over 2 days during normal tunnelling conditions. The peaks indicate a particularly dust-intensive operation; in this case it was during cutting with the hydraulic milling cutter.

![Figure 8: Total dust TSP during tunnel excavation](image)

3.1.2. Fine dust PM$_{10}$

Even though PM values are immission values, a filter will also probably be evaluated in the future according to e.g. PM$_{10}$ as a result of the fine dust discussion. The proportion of fine dust PM$_{10}$ is displayed in figure 9. With 56.8 % PM$_{10}$ is the largest proportion of the total dust collective.

![Figure 9: PM$_{10}$ fraction, thoracic fine dust proportion](image)
3.2. Measurement from 19-20/12/2005

The filtration efficiency could be improved with the fine dust filter medium as specified in the technical data. The distribution of the residual concentration of dust is clearly more constant in fig. 10 and the filtration efficiency curve also becomes smoother.

The individual particle fractions were determined at the same time during this measurement; an overview of the distribution can be viewed in table 2.

**Table 2: Particle distribution of coarse dust**

<table>
<thead>
<tr>
<th>Particle size</th>
<th>0.3-0.4</th>
<th>0.4-0.5</th>
<th>0.5-0.65</th>
<th>0.65-0.8</th>
<th>0.8-0.9</th>
<th>0.9-1.0</th>
<th>1.0-2.0</th>
<th>2.0-3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion in %</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Particle size</th>
<th>3.0-4.0</th>
<th>4.0-5.0</th>
<th>5.0-7.5</th>
<th>7.5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>&gt;20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion in %</td>
<td>16</td>
<td>14</td>
<td>18</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The largest fraction proportions are highlighted in grey, which clarifies that the determining proportion, with some 65%, is between 1 and 10 µm.

Comments: The data included in the tables and diagrams exclusively comprises the accumulation of dust from tunnel excavation and not the collection of cement dust mentioned.
The proportion of cement dust is naturally the largest with regard to weight. The total weekly accumulation of dust, which also includes the collection of cement dust, amounts to 120 kg (see fig. 11) and it is collected in big bags.

4. SUMMARY

The accumulation of dust during the construction of tunnel systems can cause a strain on the neighbouring units in sensitive areas.

The removal of portal dust with EccoDust filtering systems causes a clear reduction in the emission of fine dust. In comparison with conventional filtering dust extractors, the advantages here are: the smaller space requirements, reduced filter resistance and competitively priced filter material. This results in substantially reduced costs for the operation of the filter system.

5. ACKNOWLEDGMENT

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LITERATURE:

ÖSBS Leoben: Schuster A., Staubmessungen im Plabutsch tunnel Graz (Dust measurements in the Plabutsch tunnel, Graz)
ASHRAE 52.2 – 1999: Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size
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