VENTILATION CONCEPTS FOR BUENAVISTA ROAD TUNNEL

Wagner Harald, D2 Consult Linz / Austria
Pucher Karl, TU-Graz / Austria

ABSTRACT

The Buenavista Tunnel is located in the Eastern Cordilleras at the transition to the wide plains of Metha Province. Its length is 4,520 meters. It consists of one tube with two lanes for each direction. It also has two pedestrian lanes which are lateral arranged. The original ventilation concept has been part of the original design from 1986. It has been equipped with longitudinal ventilation using jet fans. The tunnel profile has been designed accordingly. Construction of the project has been done in two contracts, executed by different consortia. The first contract has been executed between 1995 and 1997, whereas approximately 20% of the works have been completed. Final completion including ventilation and safety installations within the second contract is expected by approx. middle of 2002. Criteria of design between 1986 and today’s requirements of the completed structure were changed dramatically. Traffic loads, increased safety requirements, environmental conditions and engine emissions are different than 20 years ago. The paper reports how these changes are considered in the course of the realization of this complex infrastructure project. Those ventilation concepts are explained, which finally led to the decision of the Ministry for the chosen hybrid solution using jet fans together with ventilation ducts in the roof equipped with ventilation dampers.

Key words: jet fan, damper, emissions, traffic load, fire life safety

1. LOCATION OF TUNNEL AND PASS ROAD

The Tunnel is located approx. 120 km East of Bogotá. It is the most important traffic link between the plains of Los Llanos with its widespread green land and the capital of Colombia with its population of approx. 8 Million. The existing road in the area of the tunnel is crossing over various hills near the city of Villavicencio.

The Bogotá-Villavicencio road is transferred within the frame of a concession contract to Coviandes, a special Consortium which is also responsible for maintenance and operation. The length of the tunnel is 4.5 km, thus representing the Eastern link between Bogotá and Villavicencio. The tunnel shortens the time in comparison with the existing road by approx. 15 minutes.
2. ORIGINAL TUNNEL PROJECT WITH 2 TUBES

The original tunnel project has been developed between 1980 and 1985. There have been two parallel tubes each of them to be used unidirectional. Ventilation has been designed with longitudinal jet fans for each tube. The project has been considered to be well feasible under those conditions especially using lower traffic loads at that time.

3. DECISION FOR CONSTRUCTION IN 2 PHASES

The Ministry for Transport has decided in the following years to execute construction in 2 phases. In Phase 1 it was foreseen to construct one tube for bi-directional traffic.

4. MISSING ADOPTION OF VENTILATION CONCEPT IN PHASE 1 WITHOUT ADOPTION

It has been overlooked, that the ventilation concept has to be adopted to the changed phasing of construction. This includes construction of rescue tunnel which are needed in accordance with the Austrian Guidelines. Rescue tunnels or alternative parallel galleries should provide access at minimum 3 – 4 locations to the outside. Regardless of such rescue possibilities it is necessary for the fire case in the tunnel, that also for this configuration a special solution should be provided.
5. PROPOSAL OF HOWDEN WITH REVERSIBLE SEMI-TRANSVERSAL VENTILATION WITHOUT SHAFT WITHOUT ADOPTION

On the basis of the project as constructed with one tube for bi-directional use, the Howden company has submitted an improved proposal. This proposal represents a ventilation concept on the basis of a reversible fresh air semi-transversal ventilation without shaft. Fresh air demand as calculated by Howden is less in comparison with fresh air demand as calculated by the authors of this paper. However, there is more than the fresh air demand on the basis of CO emissions as calculated by Ingetec company.

The Howden proposal needs a concrete ceiling for the whole length of the tunnel separating the space for the vehicles from the roof of the tunnel, whereas there is a cross section of approx. 7 m² available for fresh air supply. The height of the traffic area has been 4,3 m, whereas 4,7 m are required. There are 2 ventilation sections starting at the very portal and dividing the whole tunnel into two half tunnels. Under normal conditions the required fresh air will be pressed through opening equipped with dampers and arranged in the ceiling above the traffic space. Bad air will be mixed with fresh air in the traffic section for pushing through the portals to the outside of the tunnel.

In the case of fire the fresh air channel is converted into a bad air channel. In the area of the fire the dampers will remain open in order to suck off the smoke. All other dampers in the ceiling outside of the area of the fire will be closed.

![Figure 2 Semi-transversal ventilation scheme without shaft, System Howden](image)

6. PROPOSAL D2 CONSULT / PROF. PUCHER WITH REVERSIBLE SEMI-TRANSVERSAL VENTILATION AND CEILING

This proposal has foreseen a reversible semi-transversal ventilation with ceiling and major bad air dampers. The rough calculation of fresh air demand, using the required height between carriage way and ceiling of 4,7 m results in a necessary channel cross section of 5 m² between roof of the tunnel and ceiling, using the existing profile geometry. Two variants have been in closer consideration.
Variant 1 has foreseen a shaft with four ventilation sections. The shaft should be located approx. in the middle of the tunnel. There should have been two quarterly sections each at both sides of the shaft for supply of fresh air.
Variant 2 has foreseen construction of one (or two) parallel gallery reaching from the eastern portal to approx. one third (or two quarters) of the tunnel. Ventilation sections 1 and 4 should be supplied from the portal respectively from the parallel gallery.

Both proposals could not be realized as they have been rejected for reasons of time and cost.
8. **INGETEC PROPOSAL WITH LONGITUDINAL VENTILATION AND ADDITIONAL SUCK OFF TUBE**

Finally the Ministry has decided for the ventilation concept of Ingetec company. This ventilation concept provides tunnel ventilation with longitudinal jet fans, whereas traffic load estimate in normal conditions is assuming less traffic than estimated by the authors. If traffic load is increasing (e.g. during Semana Santa = Holy Week) the tunnel will be used in one direction only, whereas the traffic in the other direction will use the existing pass road.

It has to be stated, that in case of a tunnel fire this cannot be controlled in accordance with existing Standards and Guidelines unless the second tube will be constructed. Furthermore it is presumed today, that the second tube will be constructed until the year 2007 with subsequent use of both tubes in one direction only.

9. **FRESH AIR DEMAND CALCULATION ACCORDING TO PROF. PUCHER**

When calculating fresh air demand it is to be considered, that truck and vehicle emissions in Colombia are higher than in Austria. Exhaust tubes of trucks of light to medium heavy types big and black exhaust is almost always evident. Heavy trucks mostly imported from the USA do show less emissions. Calculation of necessary fresh air is impossible in accordance with Austrian Guideline RVS 9.261 and PIARC Requirements 1995 / 1991.

Calculation in accordance to PIARC 1987, standard D (no effective emission control) corresponds only with emission situation of Colombia.
Following table shows calculated fresh air (summary of uphill and downhill lane) per second and kilometre for the Buenavista Tunnel, located in 700 m above sea level and having an inclination of ± 2.6 %. Truck portion is approx. 25 % from total traffic load of approx. 900 vehicles per hour. Fresh air demand maximum results from visibility emission at 40 km/h of speed.

<table>
<thead>
<tr>
<th>$q_{CO}$ (Basic emission CO) m³(h/veh.)⁻¹</th>
<th>$q_{r}$ (Basic emission visib.) m²(h/t/veh.)⁻¹</th>
<th>Necessary Fresh Air m³(s/km)⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>25</td>
<td>153</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>120</td>
</tr>
<tr>
<td>0.7</td>
<td>16</td>
<td>90</td>
</tr>
</tbody>
</table>

These values correspond with fresh air demand as installed during the 1980’s in tunnels. In accordance with RVS 9.261 as valid in Austria the specific fresh air volume would result in approx. 35 m³(s/km)⁻¹.

9.1 Calculation of ventilation in normal conditions

When designing the ventilation fresh air volume has been used in order to provide necessary thrust of jet fan ventilator (internal diameter $D_i = 1250$ mm, capacity 52 kW for each ventilator). In normal conditions the number of necessary jet fan ventilators amounts to approx. 25 with a total capacity $P_{tot} \sim 1300$ kW.

9.2 Tunnel operation under conditions of fire

In order to suck off the smoke in case of fire there are two tubes with an internal diameter of 1.4 m arranged in the roof of the tunnel, each of them leading from the middle of the tunnel to the portal. In certain distances there should be controllable dampers arranged on the tube in order to be opened in case of fire. Smoke should be sucked off via respective dampers in the tube. Smoke should be moved with a strong ventilator, located at the portal to be blown out into the atmosphere.

When sucking off smoke with a relative small tube and respective ventilator, there are problems of material as well as problems of aerodynamic and thermal aspects. With increasing suck off volume these problems are increasing as well.

9.3 Material and cost problems

- When using stainless steel in accordance with Austrian Guidelines the cost for such steel tubes are extremely high
- Very high ventilation capacity will be required (approx. 15.000 kW)

9.4 Aerodynamic problems

- Because of relative high speed of air in a rather small tube there are high pressure losses expected ($\Delta P = 20.000$ N/m² - 100.000 N/m²)
- Because of high under-pressure there are high problems of tightness resulting in false air at closed dampers
9.5 Thermal problems

- Necessary heat resistance in case of a fire
- Expansion problems because of temperature differences in normal and fire conditions

10. CONCLUSIONS

From all perspectives it is evident that the Ingetec ventilation concept with the suck off tube in the tunnel roof cannot be considered as being technically sound in the case of fire. Final cost are considered to be in the same range as the semi-transversal concept proposed by UT DIS/EDL-D2 CONSULT. It is recommended not to realize this solution and instead start immediately with the construction of the second tunnel. With this, one would return to the original concept with two tunnels and sound safety system, whereas both tubes should be operated uni-directional and should be equipped with longitudinal ventilation.

11. REFERENCES


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