DESIGN, REFURBISHMENT AND OPERATION OF THE VENTILATION IN THE ROAD TUNNEL COMPLEX IN PRAGUE

Jiří Zápařka, Jan Pořízek, Ludvík Šajtar
Satra spol. s r. o., CZ

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ABSTRACT

In this article we would like to present the history of the ventilation system of the city tunnel complex in Prague. We will focus on fire ventilation, ventilation to reduce the environmental impact and also on the operation of the tunnel complex.

The existing part of the tunnel complex is 8.7 km long and was commissioned in stages between 1997 and 2015 and is in operation today. The project of the last section in the eastern part of the city circuit, 7.1 km long MO-LS "Eastern link", is currently in the phase of documentation for planning permission. When the last section of the city circuit is completed, 16 km of tunnels will be in operation.

Keywords: tunnel complex, ventilation, fire, environment, tunnel operation

1. INTRODUCTION

The first tunnel on the City Ring Road was the 2 km long Strahov tunnel, opened in 1997, designed in the 1970s and replicating the Alpine tunnel system with full transverse ventilation aimed at ensuring clean air during normal operation. Another concept for the 1.2 km long Mrázovka, opened in 2004, and the 5.5 km long Blanka, opened in 2015, was longitudinal ventilation with the transfer of polluted air from the exiting tube into entry tube and exhaust by nearest machine room, in order to reduce pollution outside the portal.

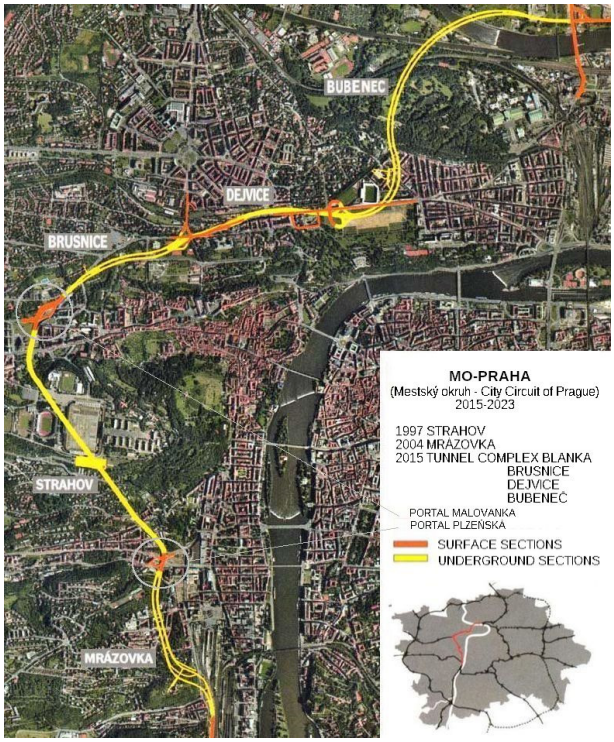
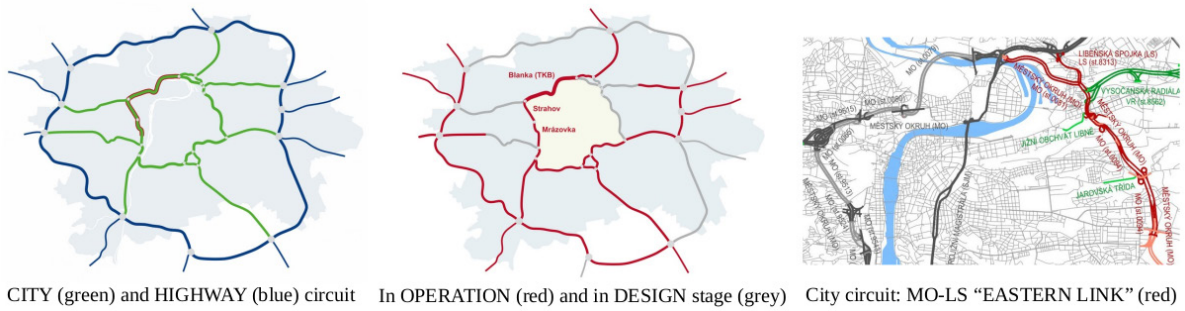


Figure 1: Location of tunnels including sensitive locations

2. TRAFFIC AND VENTILATION OF CITY CIRCUIT TUNNELS

2.1. Two rings traffic concept in Prague

The traffic concept in Prague after 1989 was decided as having 2 circuits. Highway outer circuit for transit and inner city circuit for local transportation. The functionality is limited because only part of the traffic system is completed.



CITY (green) and HIGHWAY (blue) circuit | In OPERATION (red) and in DESIGN stage (grey) | City circuit: MO-LS "EASTERN LINK" (red)

Figure 2: City and highway circuits in Prague

2.2. Traffic

Traffic intensity is 50 000 vehicles/1lane with traffic composition 96-97 % personal cars and 3-4 % trucks up to 12t.

2.3. Ventilation

Fire ventilation has been upgraded to the extent that the longitudinal speed can be controlled in all the tunnel. The critical condition in the Strahov tunnel has been corrected, but the upgrades in Strahov and Mrázovka are not yet complete.

In normal operation, the tunnels are ventilated naturally. The Blanka tunnel complex is equipped with an expert system that is used when exhaust protection is switched on.

The tunnels are in the center of Prague and close to Prague Castle, so the choice of locations for the ventilation stacks was limited. In both cases, the location was about 600-700 m from the portal, so an additional machine room was designed near the portal (about 50 m before the end) to transfer the polluted air from the outgoing tube to the inlet section of the second one (similar to the M5 in Australia or partly Engelberg in Germany).

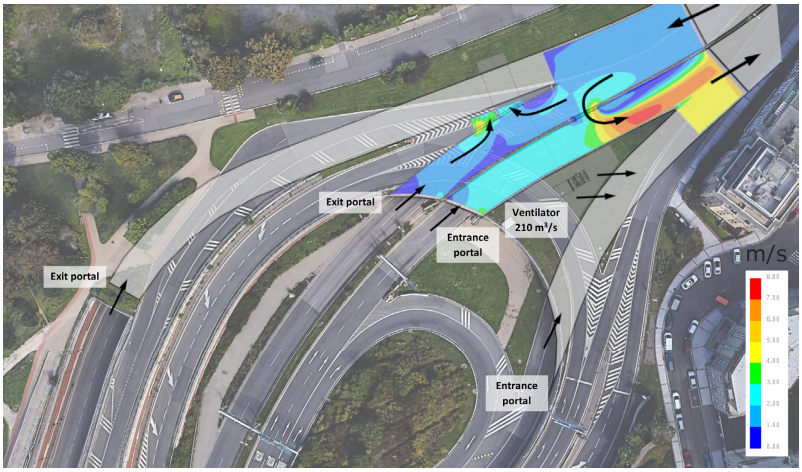


Figure 3: Malovanka portal

3. PARTIAL UPGRADE OF FIRE VENTILATION IN STRAHOV

First, a major reconstruction was necessary in the oldest Strahov tunnel with transverse ventilation due to the longitudinal slope of the tunnel. The ventilation system was converted to longitudinal ventilation with extraction at the end of the tunnel instead of extraction along the entire length of the tunnel. Jet fans were installed for longitudinal smoke control.

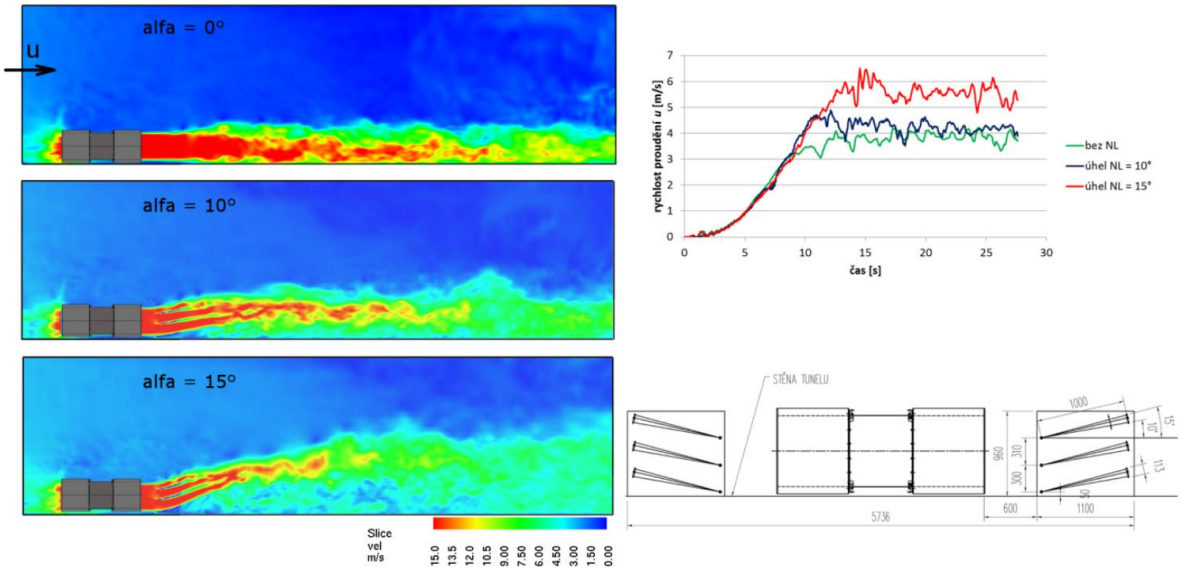


Figure 4: Jet fans with outlet blades were installed.

4. OPERATIONAL EXPERIENCE WITH VENTILATION REGARDING ENVIRONMENT

At the time of the design for the building permit of the Mrázovka tunnel (1997-2001), the objective was to reduce the critical short-term NO_x value to 200 µg/m^3 outside the tunnel (Law 309/1991)[1]. At the design stage, traffic in the portal area of the proposed Mrázovka tunnel was congested for most of the day and based on the 1998 model (ATEM; 2000), after the opening of the Strahov tunnel, even without emissions from Mrázovka, the short-term NO_x concentration in the vicinity of the "Portal Plzeňská", was 865 µg/m^3. The limit was exceeded at least twice at all selected locations in the vicinity of the portal. This was confirmed by measurements in 1998-9, when the maximum was more than 900 µg/m^3.

All other pollution limits were met, but the short-term limit for NO_x was exceeded at 10-24% compared to the 5% maximum required by law. This led the City Council to require a method of ventilation to ensure that no polluted air exits the portal.

Since 2006, the focus has turned from NO_x to NO_2 and the annual concentration of IHr = 40 µg/m^3 has become an issue as the (ATEM; 2006) indicates that background concentrations were higher in 2006.

The annual average concentration at the Plzeňská and Malovanka portals in 2006 was 47-63 µg/m^3. The requirements of the municipality for Blanka remained the same as for Mrázovka.

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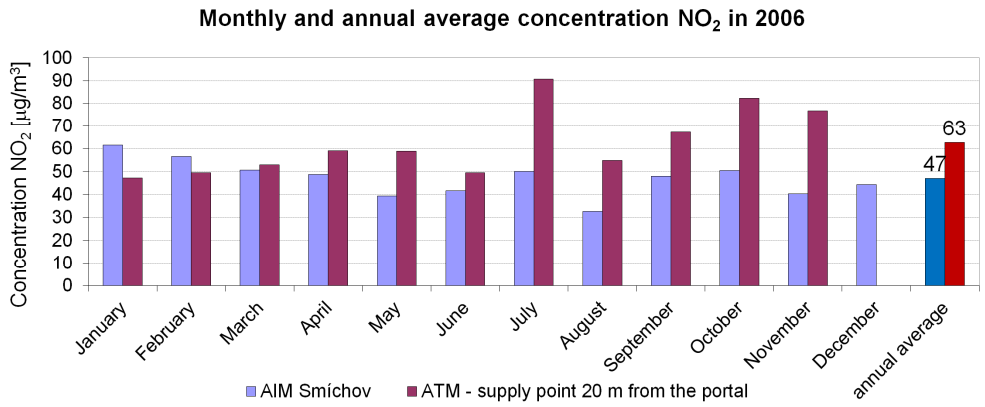

Figure 5: Plzeňská portal monthly and annual avarage NO2 (µg/m3) in 2006

The effectiveness of the measure is illustrated in the following figure, which shows how the flow from the outlet portal is stopped when this environment mode is used:

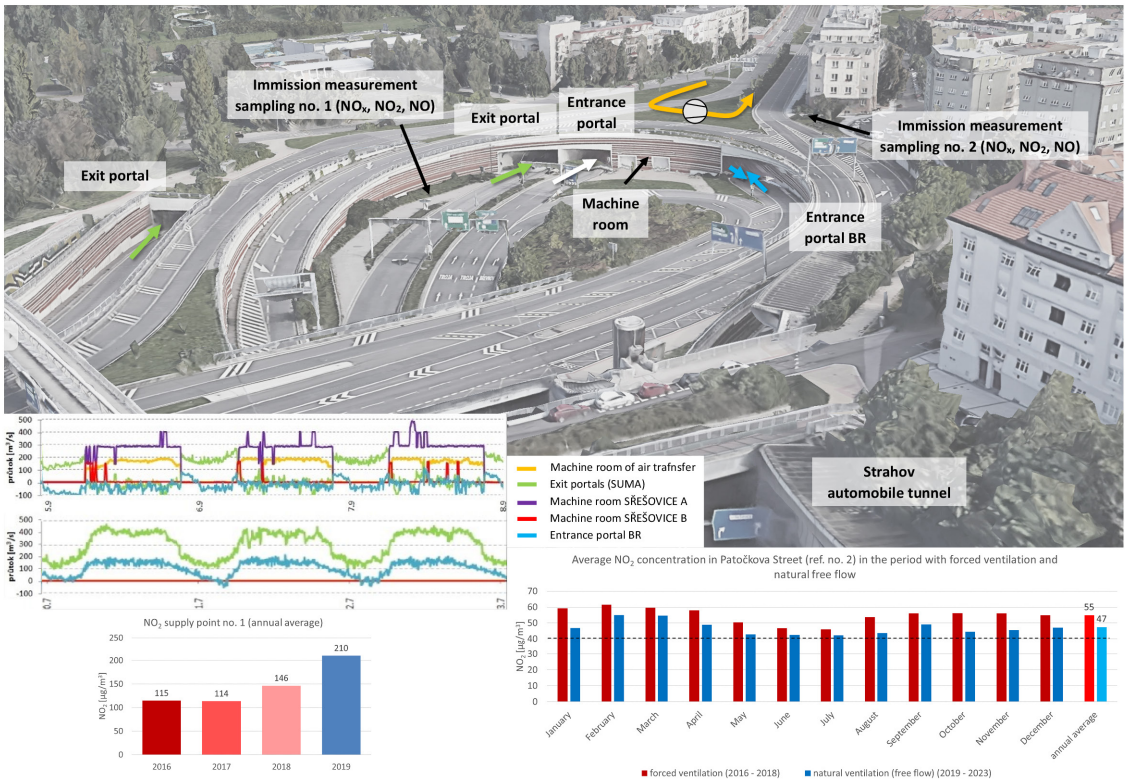

Figure 6: Malovanka portal: environmental mode 2016-2018 vs. natural airflow 2018-2023

The example of three days with portal protection vs. natural flow shows how the airflow from the exit portal, which is normally around 400 m^3/s, drops to 0.

In 2016-2018, the concentration at point 1 was lower with ventilation than with natural flow.

Interestingly, at point 2 (further away from the portal), the measured concentrations are lower during natural flow and not during the environmental regime.

This can be explained by missing airflow near the portal, that would more dilute the pollution during environmental mode. During natural flow 400 m^3/s emits out of the exiting portal and 300 m^3/s is sucked in through entry portal.

In 2020, work started on the zoning decision of the last section of the city circuit MO-LS "Eastern link". Based on the modeled results, the annual NO_2 concentration levels in 2015 are still close to the limit. In 2030 they are at least 10 $\mu g/m^3$ lower than that, not exceeding 30 $\mu g/m^3$.

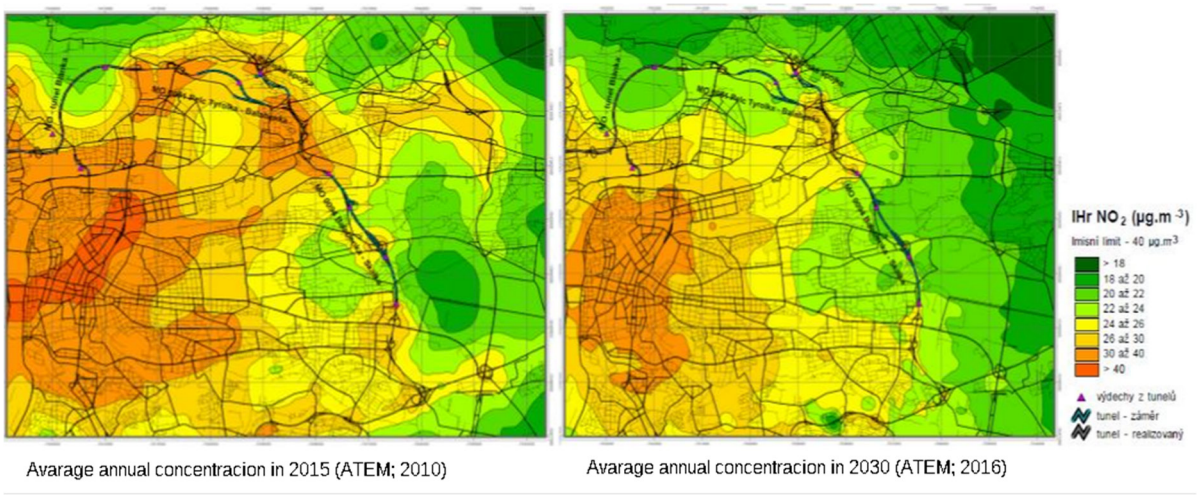

Figure 7: Annual NO_2 concentrations in 2015 and 2030

Figure 8 shows the difference between the environmental mode and natural airflow, without background pollution. During natural airflow, there is only an increase of 1-3 $\mu g/m^3$ near the portal.

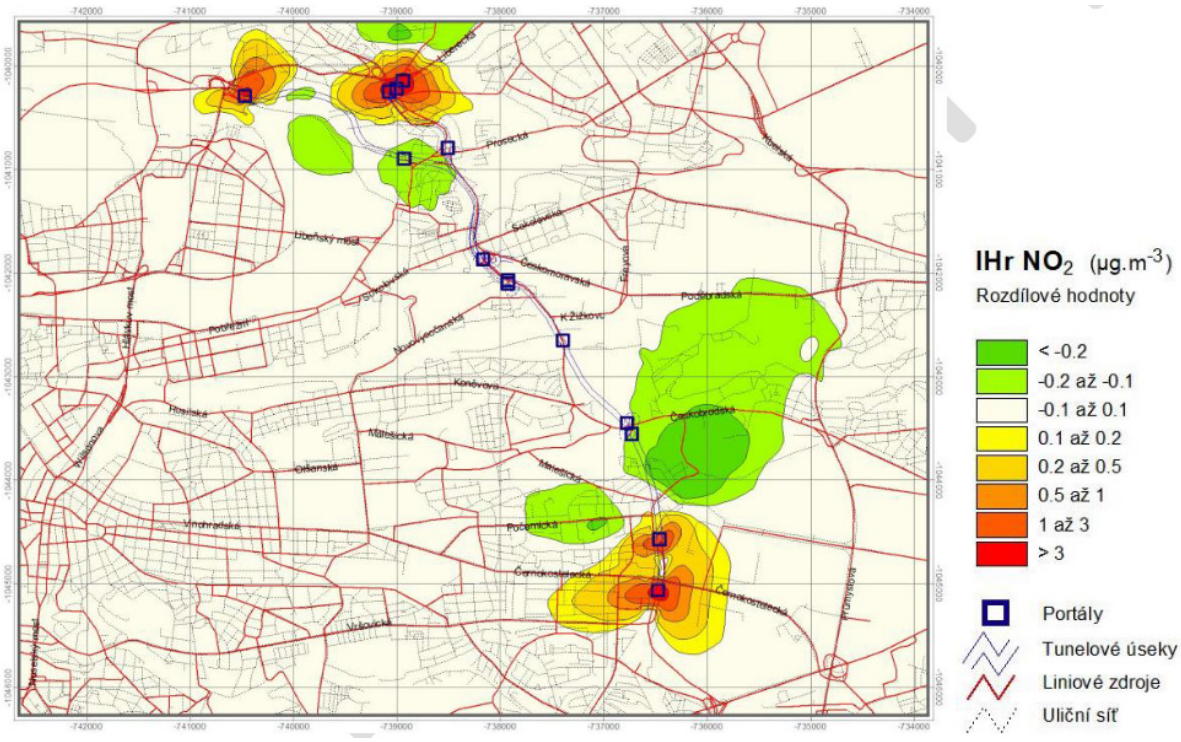

Figure 8: NO_2 difference values between environmental mode and natural flow

5. OPERATION, TRAINING, TESTING

The operation is so far controlled from two centers. One is the police which controls the traffic and the other is tunnel operator which controls the technology. The process is now underway to unify traffic and technology control in a new control center called MOS, which is under construction. This will also improve communication with the emergency services (integrated rescue system such as firefighters, paramedics...).

The different age and corresponding "state of art" of the tunnel control system places greater demands on the operators. In addition to their repeated training and testing, the control system and operator interface are gradually being unified.

Repeated tests of the ventilation system, operators and exercises of the firefighters and all rescue systems are carried out. During some of these tests and exercises, the smoke effects have proved to be very useful. For more on fire ventilation see [2].

Figure 9: Tunnel Blanka

Figure 10: Rescue system exercise in tunnel Blanka

6. SUMMARY AND CONCLUSION

Longitudinal airflow control is now possible in all tunnels.

Traffic control for environmental reasons in Prague is based on NO_2 levels. Previously, NOx was the target pollutant and the short-term limit (1 hour) was decisive for the design. Since the change in legislation in 2006, when the limit was changed to NO_2, compliance with the long-term limit (1 year) is critical.

The "ecological mode", if operated at all, should therefore be based on an algorithm with a long-term target value and not on the actual measured concentration outside the tunnel.

In the latest MO-LS "Eastern Link" tunnel project for 2030, no environmental technology or mode of operation is needed anymore.

7. REFERENCES

[1] Act number 309/1991 about air pollution (Zákon o ovzduší č. 309/1991)

[2] 8th International Conference "Tunnel Safety and Ventilation"