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Challenges in a controlled system to stop the air velocity in case of fire in a road tunnel

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Abstract: Large fires in long road tunnels are greatly feared by the tunnel users as well as the tunnel operators. Fortunately, such fires are rare. The main danger in case of fire is the tight smoke. The smoke can be sucked into the exhaust duct successfully only if the air velocity in the tunnel is very low. Ventilation systems in tunnels are very complex systems. Therefore a control system has to be installed which can reduce the longitudinal air (smoke) velocity to zero very quickly. A theoretical approach and a practical test in the Plabutsch tunnel with a length of approximately 10 km and five ventilation segments is shown.

Key-Words: - -Fire, Road tunnel, Smoke, Control system, Air velocity

1 Introduction

Austria is a mountainous country. So motorways between larger cities often are only possible with long road tunnels. 30 years ago the main road constructions between large cities took place in the mountainous regions. Many tunnels long road tunnels have been built. As the construction of such long road tunnels is very expensive and the amount of traffic at that time was very low, only one tube of motorway tunnels was build. Thus the majority of long road tunnels still today are operated in two-way traffic.

After the bad fire disaster in the Mont Blanc tunnel and in the Tauerntunnel it was decided to build the second tubes of many of these long tunnels. As an example, the second of the 10 km long Plabutschtunnel is in operation for one year and the second tube of the Katschbergtunnel is under construction.

The air velocity in tunnels with two-way traffic is mostly very low, because the piston effect of vehicles going into one direction is eliminated by the piston effect of the vehicles going into the other direction. So the total air velocity in a two-way traffic situation is found to be around very low values ore even zero.

We have totally other situations in a tunnel with one-way traffic. All vehicles go into the same direction on both lines and therefore they produce a very high air velocity in each tube (around 10m/sec). The high air velocity is very helpful in case of normal operation, because a lot of fresh air is sucked into both tubes and there is no need for mechanical ventilation systems in normal case of operation. But the high air velocity is very dangerous in case of fire. The smoke will be spread very quickly in the tunnel, thus severely endangering fleeing people. It is simply not possible to escape the smoke if it is moving at a velocity of 10 m/sec.

There also is another important reason to stop the air velocity in a tunnel in case of fire. Fire tests have proven that the maximum efficiency of smoke extraction into the exhaust duct can be reached only if the air velocity below the smoke damper is zero.

2 Fresh air dampers to stop the air flow in the second tube of the Katschberg-tunnel

The tunnel is subdivided in two ventilation sections. Two parallel fresh air fans blow into one fresh air duct and also two parallel running exhaust air fans suck off the exhaust air from one exhaust air duct. All fans are equipped with variable pitches. Figure 1 shows the cross section of the second tube with the smoke dampers in the false ceiling.

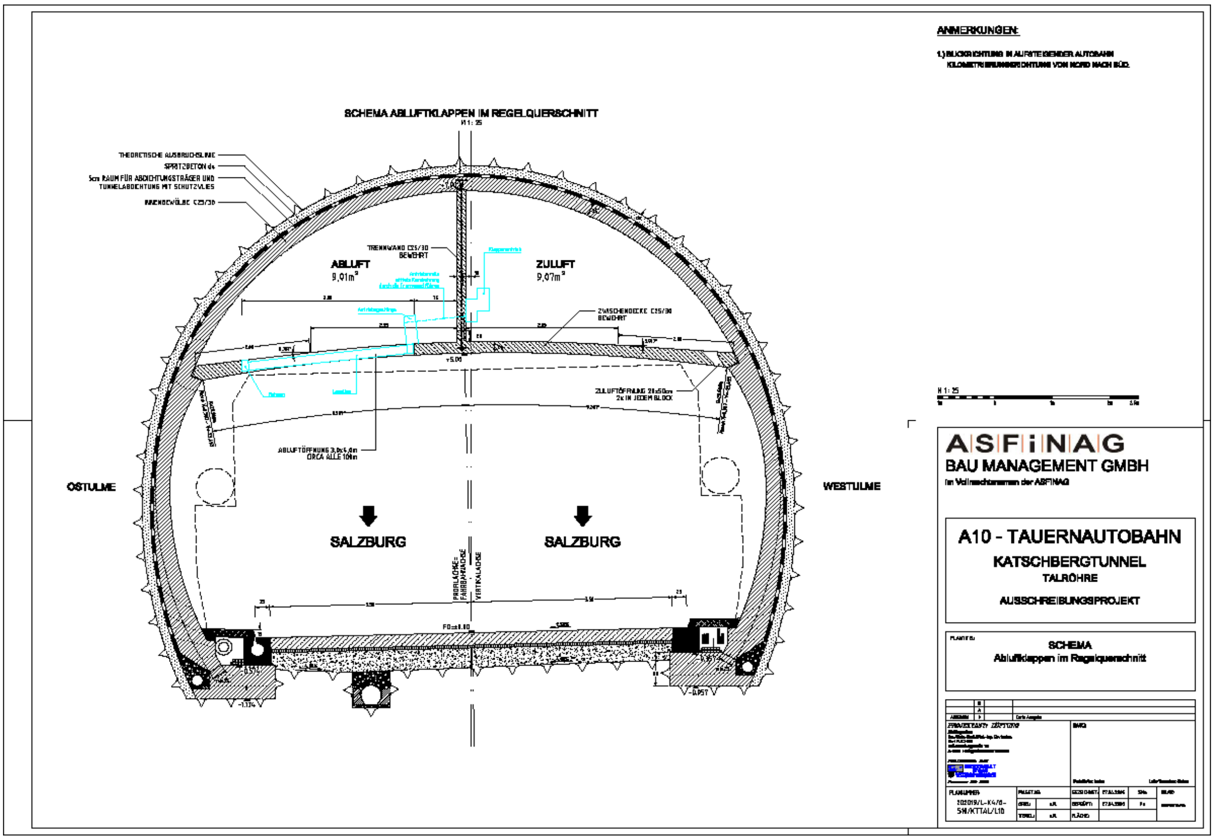

Figure 1: Cross section of the Katschbergtunnel and an adjustable smoke damper

In normal case of operation all smoke dampers are only opened to some percent, depended on the position of the damper in the duct. The flow resistance is adjusted in a specific way to allow equal amounts of exhaust air being sucked off through each damper. In case of fire one damper near the fire is opened fully and all others are closed. This is done by an automated fire detection system in the ventilation section where the fire occurs. The exhaust fans are set to full power. In this way a concentrated smoke extraction is done. Values of 120m3/sec to 250m3/sec are reached, depending on the position of the damper. However the smoke extraction will be successful only if the air velocity in the tunnel is nearly zero below the opened smoke damper. If the air in the traffic room moves with a relatively high velocity, only the upper layers are being sucked away. To avoid this dangerous situation the high velocities of airflow are to be reduced very quickly.

In some tunnels the air flow in the tunnel can be stopped with jet fans. Installing jet fans under the false ceiling needs more space, resulting in very expensive rock excavation, which should be avoided if possible. This was the main reason to think of alternative ways to stop the longitudinal air flow.

To stop the longitudinal airflow two fresh air dampers are used. These dampers are installed in the false veiling each near the two portals. Figure 2 shows one of these fresh air dampers in the cross-section of the tunnel. The dampers are larger (3m x 7m) than the smoke dampers (3m x 4m).

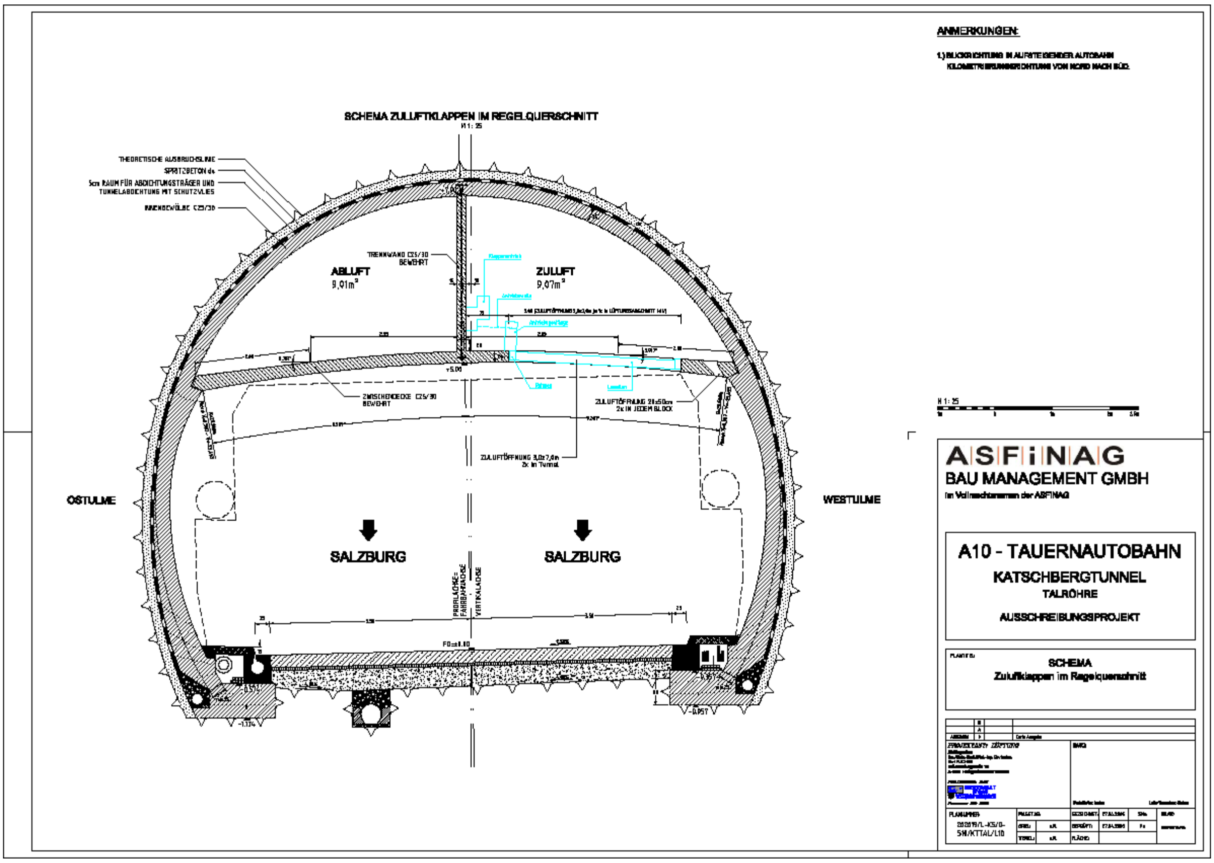

Figure 2: Cross section of the Katschbergtunnel with afresh air damper

The two fresh air dampers are closed in normal case of operation. If a fire occurs it will be detected and localized by an automated system within 5 to 15 minutes. After that a rather complex control system for concentrated smoke extraction starts.

3. Control system for concentrated smoke extraction near the fire in the Katsch-bergtunnel

In the case of fire the first step is to start the fresh air fans from both ventilations sections. The direction of the longitudinal air velocity in the tunnel is known because this air velocity (quantity and direction) is measured in normal case of operation also. To stop this flow the fresh air damper near that portal is opened, where the air of the traffic room flows into the atmosphere. It is important that only these fans are working with full power that can blow air through the open fresh air damper into the tunnel. The fans from the second ventilation section are running with high speed but with closed pitches, so they are in a stand-by mode. The fresh air damper near the other portal is closed. (Fig 3) No fresh air is blown into the tunnel there. This is also important because they might me needed in the case the air flow reverses.

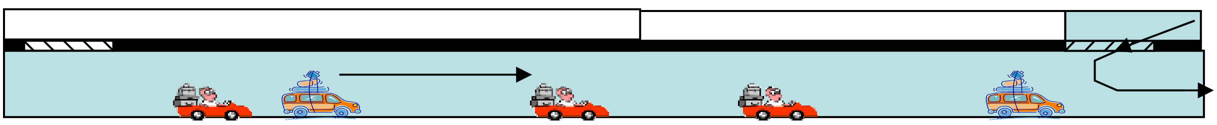

Figure 3 : Stopping the high air velocity (from left to right) with the fresh air damper on the left side.

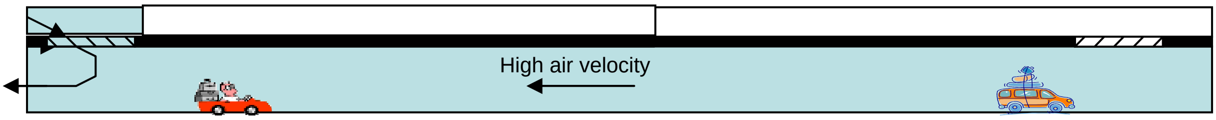

Figure 4 : Stopping the high air velocity (from right to left) with the fresh air damper on the right side.

In case of fire a change of the direction of the air velocity in the tunnel is possible. The closed pitches of the fans must be opened and air has to be blown into the tunnel through the now opened second fresh air damper (Fig.3b). The first fresh air damper has to be closed and the fan must close their pitches.

The system uses a computer program to control the fans and the dampers. The logic is very simple but has to be improved. With this control system the air movement in the tunnel can be stopped. However until now there is no mathematical description of the system, simply because many parameters are only guesses and it is difficult to describe the unknown.

The idea of the control system for the air movement in the tunnel in case of fire looks simple, but there are many factors which must be taken into account. Some of them should be enumerated:

- Air velocity
Problems: The average of the air velocity should be known. But we can not measure through the middle of the tunnel because of the traffic movement. So only a calibration with and without vehicle movement can be done.

- Momentum of the injected fresh air
problems: The maximum of momentum should be used to stop the airflow as quick as possible. The momentum depends on the angle of the injected air through the fresh air dampers and from the fresh air volume. There is a connection fresh air fans and the position of the injection angle of the fresh air damper (1)

- Fresh air fans
Problems: How quickly can the volume flow of the fresh air fans be changed? How large is the time between two measurements of the fresh air volume?

- Circle time of the whole control system
Problems: The circle time of the measurement of the air velocity is high (5 – 10 seconds) in normal case of operation. This high circle time must be reduced to 3 second at least, because otherwise the time to stop the airflow is too long.

Also there are many of other disturbances which influence the control system also. Presently we look for finding a solution which is suitable to for some of the problems. The solution will be intensively tested in the Katschbergtunnel before this tube will be opened.

4 CONLUSION

The control system which can reduce the longitudinal smoke velocity in case of fire in a road tunnel is very important for the smoke extraction. The spreading of smoke inside the tunnel should be avoided as far as possible. Also the smoke extraction system only works at its optimum level iv the longitudinal velocity is low. Presently a new system is under development. This system only uses the existing ventilation system for controlling the longitudinal velocity. Also many of the parameters of the controlled system are yet unknown the results are promising. We hope that we can get a good solution for the problem by using new fresh air dampers in the Katschbergtunnel. The system presently is under evaluation and will be put into operation after extensive tests.

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