OVERCOMING EVACUATION LIMITATIONS OF THE UČKA TUNNEL BY IMPROVEMENT OF FIRE SAFETY MEASURES

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ABSTRACT
This paper considers a possible upgrading of existing single-tube tunnel with the primary objective of the fire safety improvement. The practical application is illustrated on the Učka Tunnel (5062 m), built in Croatia in 1981, which is undergoing a process of intensive modernisation, in order to overcome evacuation limitations due to single-tube design.

The approach relies on complementary safety measures which include both replacement of old tunnel equipment with new one as well as the implementation of new technologies and software solutions in the area of ventilation control, smoke management, fire detection, video imaging etc. Upgrading of tunnel safety level is done mainly in the area of “active” measures, without any serious reconstruction of the civil engineering characteristics of the tunnel, what will be done in the second phase of modernisation.

Keywords: road tunnel, modernisation, fire safety measures

1. INTRODUCTION
The Učka Tunnel was built in 1981 as a single-tube tunnel with bi-directional traffic, located on the road connecting Istria, the largest Croatian peninsula, with the remaining part of Croatia (Figure 1). At the time of building, it was the longest tunnel in Croatia, having a length of 5062 m. The most advanced solutions at that time were applied concerning both the construction measures and the tunnel equipment.

During the past ten years Croatia has experienced one of the most intensive roads building periods, when the major part of the existing motorway network has been built. On these motorways new tunnels have been constructed, some of them being longer than the Učka Tunnel, e.g. Sveti Rok Tunnel (5680 m) and Mala Kapela Tunnel (5760 m). The beginning of this construction was preceded by a period of detailed analysis of the world and in particular European practice and regulations on road and tunnel building. Finally, the Austrian RVS directives for tunnel construction and tunnel equipment were selected as the main basis for the designing of road tunnels in Croatia. Also, since 2004 the Directive 2004/54/EC of the European Parliament and the Council on Minimum Safety Requirements for Tunnels in the Trans-European Road Network has been applied.

In the light of new regulations and safety requirements, the Učka Tunnel today needs overall modernization. Recognizing the need, the tunnel's concessionaire started in 2007 with the interventions that should after a few years result in a two-tube tunnel equipped in accordance with the existing regulations and the regulations getting into force with the accession of Croatia to EU. During the first phase, in order to achieve the improvement of the degree of tunnel safety as early as possible, and in accordance with the investment dynamics, the safety will be raised to a higher level without radical construction interventions. That will be done primarily by modernization of the equipment and related software support of tunnel technical systems which participate in fire protection (ventilation system, fire detection system, CCTV etc.).
2. OVERVIEW OF THE CURRENT STATE

2.1. General

As already mentioned, the Učka Tunnel is a single-tube tunnel with bi-directional traffic, with one traffic lane for each direction. There are 17 SOS niches on each side of the tunnel tube at a distance of 250 to 420 m, and 3 turning points on the right side of the tube, if driving from the direction of Rijeka to the direction of Pula. There are no separate escape routes connecting the tunnel tube and the exterior of the tunnel. The SOS niches are equipped with emergency phones located within the tunnel space. Power supply system includes 6 transformer stations within the tunnel, and one transformer station at each tunnel portal.

2.2. Ventilation system

The tunnel is equipped with a longitudinal ventilation system, with ventilation units (batteries) containing 3 impulse, non-reversible jet fans per unit. The ventilation batteries are arranged in two groups, each in one third of the tunnel with respect to the related tunnel portal (Figure 2). There are 24 jet fan batteries (3 jet fans per each battery) in each group, the batteries are alternately oriented with respect to the jet fan's air flow direction. The distance between individual jet fan units is 70 m. The jet fans delivered by SOFRAIR, France, have a power of 30 kW, and a thrust of 810 N. The control of ventilation is done via jet fan battery; one unit with 3 jet fans is started as a whole so that jet fans within one unit are automatically started one after another within the time of 12 seconds in order to avoid overloading.
At the same time, while one jet fan battery is being started, it is not possible to start another jet fan battery within the same distribution because of power supply restrictions. Power supply of the jet fans is divided into 2 distributions, each at one side of the tunnel; the middle does not always match the geographical midpoint of the tunnel. Described solution of ventilation system is pretty old and conservative but common for that period.

Figure 2: Schematic presentation of the arrangement of jet fan batteries, air flow velocity sensors and sensors of extinction and CO

2.3. Sensors system

The tunnel sensors include air flow velocity sensors and sensors of extinction and CO. Their location in the tunnel and arrangement in relation to jet fan units can be seen in Figure 2. There are 5 sensors of extinction and CO, and 3 air flow velocity sensors mounted in the tunnel. There are also 2 meteorological stations located at the tunnel portals for the measurement of air temperature, pressure and humidity.

2.4. Signal acquisition system

The air flow velocity sensors and the sensors of extinction and CO are first connected in the tunnel with the local base stations. From them the signals are fed to the measurement stations (acquisition system's sub-stations) which forward the signals to the central station located in the control centre (Figure 3). The connection between the measurement stations and the central station is realized via a copper conductor, the maximum rate of transmission is 600 baud, and thus for the sampling of data from all measurement stations minimally 2 minutes are necessary.
2.5. Fire alarm system

The fire alarm system includes 9 fire detection stations (VC), arranged along the tunnel. The main tunnel tube is monitored by the loops of the collective point thermal detectors. The transformer stations are monitored by point smoke detectors, while the SOS niches and the tunnel portals are fitted with manual call points that are not connected with the fire alarm system, but are connected with the remote control system.

The tunnel is divided into 35 fire detection zones and 7 traffic zones. All fire detection loops are implemented in the collective logic, which means that activation of any detector in a particular loop (the length of one loop is about 150 m) in the main tube is alarmed as a signal that is uniform for that particular loop irrespective of the fact which particular detector has been activated. Due to such logic, there are several cases of overlapping of one fire detection zone with two traffic zones, and in the case of fire detection zone No. 34 with three traffic zones, and thus the activation of a detector in such fire detection loop does not provide unambiguous information in which traffic zone a fire has broken out. The schematic presentation of the fire alarm system is given in Figure 4.

![Figure 3: Schematic presentation of the sensors system and signal acquisition system](image)

![Figure 4: Schematic presentation of the fire alarm system](image)
3. CHANGES AIMED AT THE IMPROVEMENT OF TUNNEL SAFETY

3.1. Ventilation system

- The major change is the implementation of the computer program for the active control of longitudinal air velocity by means of the tunnel ventilation system.

The program will operate in 3 automatic independent modes:

a) **Normal mode** - preventive stabilization of air flow velocity to 2 – 2.5 m/s, in the case of dangerous goods transport or seasonal high traffic intensity.

b) **Fire mode (evacuation)** - stabilization of air flow velocity to 1 – 1.5 m/s, as soon as it possible, in order to establish smoke **stratification**, important for successful evacuation process.

c) **Fire mode (fire extinguishing)** – keeping air flow velocity at critical or higher value (3.5 m/s), in order to prevent smoke “**backlayering**”, which can endangers fire fighters.

- Provide the possibility of independent control of each individual jet fan within a particular jet fan battery. This improvement enables the fine resolution of ventilation control both in the normal and fire mode.

3.2. Fire alarm system

- Introduction of modern fire alarm system for the main tunnel tube based on a linear fibre optics sensing cable.

- Replacement of the collective logic with the analog addressable logic.

3.3. Sensors system

- Sensors of CO of the old generation (electrochemical), are to be replaced by new optoelectronic sensors (CO and extinction in a set).

- Two more air velocity sensors shall be put in the main tunnel tube, in order to acquire more detailed sampling for program for the active control of longitudinal air velocity.

- Sensors S1, S4 and S5 are relocated because of inadequate location; they are positioned between adjacent jet fan batteries which blow the air toward sensors, and that degrades measurement accuracy.

3.4. Signal acquisition system

- Existing measurement stations shall not be used any more because of too slow sampling. Program for the active control of longitudinal air velocity requires air velocity and direction sampling with the time period up to 5 s, so velocity sensors shall be connected directly to the remote control system sub-stations through adapting modules.

3.5. Video surveillance system

- Installation of the new generation video surveillance system with “video imaging” function enables incident recognition (e.g. traffic halting, driving in the wrong direction) and smoke recognition as early (“first”) alarm. This system can give very fast information for the tunnel operators to start computer program for the active control of longitudinal air velocity.
3.6. SOS niches

- New SOS calling devices shall be installed in order to make distance between SOS calling devices around 150 m.
- On every location of the new SOS calling devices cabinets with 2 hand held fire extinguishing apparatus shall be retrofit; cabinets shall be equipped with “micro-contacts” for signalling rising of fire extinguishers.

4. CONCLUSION

All measures described previously represent active fire safety measures. For that reason they have to be put in adequate operation modes to fulfil the design goals regarding the fire safety improvements. Prescribed measures plan to be tested carefully in order to adjust operational parameters during the commissioning phase of the Učka tunnel. Authors of this paper, as fire safety designers, hope that synergy effect of those measures can temporarily overcome evacuation limitations due to the actual construction characteristics of the Učka tunnel, but can not exclude need for finalizing the second phase of tunnel modernization (twin tube tunnel configuration!).

5. REFERENCES

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