ABSTRACT:

Mala Kapela tunnel is a major structure designed to overcome the so called Mountain sill on the part of E-59 motorway between Zagreb and Dubrovnik, i.e. on the Pyhrn corridor towards Southeastern Europe and Mediterranean.

The report outlines the design solution and operation of 5.76 km long Mala Kapela twin tube tunnel during its phased construction. The fact that the traffic movement will take place on two separate double - tracked traffic lanes for each direction has been taken into consideration in tunnel design. Phased construction that would bring tunnel to its function has been explored considering that this tunnel, due to its construction time, is critical to opening to traffic of the Zagreb – Split section. Thereby, safety aspects of the traffic movement and tunnel users must not be endangered.

While choosing the twin tube tunnel design and ventilation system the current regulations and practices in EU countries as well as recommendations of expert institutions were followed. The relevant Croatian regulations for design and construction of tunnels have been used as a source criteria.

Key words: Twin tube tunnel, phased construction, traffic flow, safety aspects, ventilation

1. INTRODUCTION

Zagreb-Split Motorway that is its Bosiljevo-Sveti Rok section, is part of the international road corridor Austria-Maribor-Zagreb-Karlovac-Bosiljevo-Split-Dubrovnik which has been classified as European road E59 (Pyhrn corridor). Zagreb - Split Motorway links Adriatic littoral area with Croatian inland and is of vital significance for socio-economic and tourist development.

The motorway is currently under construction and it shall be opened to traffic in 2005. From financial and technical aspect the most important structure within Bosiljevo-Sveti Rok section is Mala Kapela tunnel whose construction cost is estimated at about 5% of the total investment cost for the entire Bosiljevo – Split Motorway route.

2. GENERAL TECHNICAL DATA

2.1. Cross and longitudinal section

The tunnel is designed as a twin tube tunnel with the 25 m axial distance. The cross section has been chosen according to the lane width required for the design speed V=100 km/h. The tunnel cross section has clear opening of 56.17 m2 and permits placement of all necessary equipment and devices. The traffic lanes and marginal strips width is chosen in accordance with Croatian regulations. The total width is 7.70 m (with two traffic lanes of 3.50 m and two
marginal strips of 0.35 m). Inspection sidewalks are foreseen at both sides in the minimum width of 90 cm and are raised 15 cm above the carriageway. Under sidewalks there are installation ducts for service cables and tunnel equipment. The tunnel entrance and exit are in circular arches which are connected with the straight line by means of transition curves. The left tunnel tube is 5,761.76 m long and the right tunnel tube is 5,760 m long. The chosen longitudinal gradients are 1.20 % and 1.50 % towards portals which are optimum considering drainage, the costs of construction, electromechanical devices, transport and maintenance. The tunnel lining shall be made of MB 30 concrete in the minimum thickness of 30 cm. Between the tunnel lining and primary support there shall be a waterproofing layer of PVC foil protected with geotextile. The pavement structure consists of three asphalt layers with Splittmastixasphalt SMA 11s with PmB as a wearing course.

2.2. Drainage

The tunnel drainage system is foreseen by the longitudinal sewers with the 50 cm diameter. The carriageway surface fluid is drained through the system of hollow curb unit and siphon overflow with immersed partition in the longitudinal sewerage. The carriageway drainage is dimensioned according to the volume of incident fluid afflux of the initial 200 l/s at the tunnel length of 200 m and the implementation of the drainage system prevents fire from spreading through sewerage. At the tunnel sides and in the pavement subbase longitudinal perforated pipes with the 150 mm diameter are foreseen. At the tunnel sides manholes spaced at 110 m shall be placed for side longitudinal drains. Manholes are also foreseen in the longitudinal sewerage at the approximate distance of 55 m.

2.3. Ventilation

The chosen ventilation system for Mala Kapela tunnel is reversible longitudinal ventilation. This choice has been made on the basis of cost-efficiency and safety-technical analysis for the normal operation conditions and for the case of fire accidents. Since Mala Kapela tunnel has been designed as a twin tube tunnel with each tube providing for one-way traffic, the longitudinal system has numerous advantages keeping the safety of passengers in case of fire. Economic justifiability of the longitudinal ventilation system is evident not only in the initial investment in equipment and construction works but also in the costs of operation cause in one-way two-lane traffic, the traffic flow in one direction helps the ventilation of the tunnel tube in longitudinal direction making use of the so called "piston effect".

The possibilities for passenger evacuation in case of fire are good since in case of fire in one-way traffic vehicles are permitted to leave the area of accident and the vehicles coming into are alarmed in time to stop. Since we are talking here about two tubes connected by transversal passages for vehicles and passengers the other tube shall be used as the emergency escape to the safe and open area in front of the portal as well as the access for firemen and rescue team to the place of accident i.e. fire.

2.4. Safety Facilities Inside the Tunnel

Designed facilities related to the safety of tunnel users are: lay-bys for vehicles, cross passages for vehicles, cross passages for pedestrians, recesses for emergency call boxes, hose valve stations and recesses for control and surveillance devices.
Lay-bys for vehicles are placed at the right side of carriageway and are used for temporary stopping. The dimensions of the lay-bys are 3.0 m x 40 m. They are spaced at about every 840 m and they also comprise the recesses for emergency call boxes and recesses for uninterruptible power supply.

Opposite of lay-by there is a cross passage for vehicles which can be used for redirection of traffic due to works or congestion, as well as emergency passage in case of accident and fire and for the access of rescue team (fig. 1).

Figure 1. Layout of safety facilities inside the tunnel

Cross passages are blocked with fire fighting walls comprising fire fighting sliding doors that, when open, allow vehicles to pass from one tube to another (fig. 3). Clear opening is 4,50 m high while the carriageway width is 5 m. Doors are designed so they can be opened only by authorised officials. Fire fighting wall is also equipped with the pedestrian exit. The door can be opened on both sides which is signalled in the traffic control centre.

The chosen solution comprises the placement of vehicles lay-bys opposite of emergency escapes opposite of vehicle lay-bys considering that transformer stations are placed in the passage and this will allow for their maintenance and repair without interfering with the traffic going on in the tubes.

SOS recesses with phone device are spaced at 280 m, and are equipped with telephone device comprising the hand-operated fire alarm and two hand-operated fire extinguishers.

Opposite of SOS recesses there is a pedestrian emergency escape permitting evacuation of the endangered tunnel users from one tube into the other i.e. into the safe area over the adequate period of time.

While determining the distance between the pedestrian cross passages the type of ventilation and the length of the evacuation path was considered. In case of fire the movement of evacuating people can be decreased to 1m/s due to the smoke and heat. While calculating the evacuation time we shall also add the time for detection of fire as well as the time required to alarm tunnel users and to allow them to get out of the vehicles. The evacuation time should normally comprise 10 minutes which can be obtained by constructing pedestrian emergency
escapes spaced at 280 m. Pedestrian escapes are equipped with fire-fighting door the opening of which shall be signalled in the traffic control centre. The door can be opened on both sides and the light in the passage shall automatically be switched on and off as the door opens and closes.

The fire-preventing hydrant distribution is also foreseen in the tunnel. It is supplied from the water tank of 100 m³ which ensures enough water for one hour of fire-fighting. The volume of water used shall be 1200 l/min and the pressure at least 6 bars to 12 bars at the most with the automatic monitoring of changes i.e. decrease of the water level in the water tank. Hydrants shall be placed on the walls and spaced at 100m, put in cubicles and equipped with 120 m of hose.

2.5. Safety Systems

Electric power supply for the tunnel shall be provided within two transformer stations (one transformer station on each portal) and six additional transformer stations inside the tunnel. Safety systems comprise uninterruptible power supply (UPS) devices placed in the emergency recesses. Systems supplied from uninterruptible power supply are secondary and alarm lights, alarm lights of passages, lightening for all SOS signs, supply for changeable signs, phones, public-address system, TV surveillance, radio-communication device, operation of fire alarm, remote control and sign work for all systems installed in the tunnel.

The public-address system providing all necessary information and instructions for tunnel users shall be placed in the tunnel as well as TV and radio system.

Lightening of the tunnel access areas covers the approach area at both tunnel portals in the approximate length of 180 m. The disposition of lights and the possibility of adjusting ensures economical and safe operation of the lightening system with the optimum parameters.

Within the ventilation system there are also devices for measuring CO concentration as well as visibility and air flow direction and velocity.

Automatic fire detectors with sensor cable for surveillance of the main tunnel tubes are foreseen while the surveillance of other areas shall be carried out by spot-type detector. Hand-operated fire alarms shall be also placed in SOS recesses. The emergency call system is also placed in SOS recesses.

Changeable traffic signs are foreseen for traffic regulation.

The remote operating system whose function is to operate traffic and to survey tunnel operation shall be placed in the traffic control centre 5 km form the south portal which is also the location of the fire fighting unit.

3. PHASED CONSTRUCTION

Traffic forecast based on preliminary analyses anticipates the traffic load of about 12,000 vehicles a day in the year 2014. 16 % of that load is made by heavy traffic (lorries and buses). During the summer period however the traffic load increase is 70 to 80 % with regard to the average annual daily traffic. Various possibilities of the tunnel phased construction were explored while searching for the optimum choice from financial and traffic aspect. The explored alternatives comprised several constructional and engineering solutions combining various types of ventilation system (transverse, semi-transverse and longitudinal).

The choice of the design solution is based on the fact that the first construction phase calls for the least possible volume of additional works at the final construction stage of the twin tube tunnel with one-way traffic without endangering the safety of tunnel users.
Among various considered possibilities, one solution in particular was accepted as economically justified and acceptable from technological and safety aspect. In the first construction phase both tubes would be simultaneously excavated and supported as a whole final cross section (fig. 2). All cross passages and pedestrian emergency escape shall be built in the first phase. Upon completion of all necessary works the right tunnel tube would be opened to traffic whereas the left tunnel tube would be used in case of incidents in the right tube by means of cross passages i.e. as an access to fire brigades and rescue teams with all the necessary equipment and vehicles.

During the first construction phase the right tunnel tube should keep the longitudinal ventilation system in order to decrease the construction costs and comply as much as possible with the final tunnel solution.

Figure 2. Outline of the phased construction

Considering the required minimum construction time and the use of standard mechanisation and equipment we are anticipating less technological delay than in case of one tunnel tube. Since the excavation will take place simultaneously in both tubes the left tube could be used for the job site needs as well.

The subsequent construction of the second tunnel tube by means of blasting has also been considered provided that the right tunnel tube has been constructed and opened to traffic. Based on previous design experience in similar ground conditions we estimate that the subsequent excavation of the second tunnel tube would take place in two stages with the limited advance length depending on excavation phase by blasting. Assuming that the greater part of the tunnel is in favourable soil conditions where restrictions are not necessary, the stated excavation restrictions requiring several work phases will surely make the cost of the
second excavation phase greater. Variable construction costs which are mostly the same and are not affected by the choice of construction of one or two tubes, in simultaneous excavation of both tubes affect the greater volume of work which subsequently means significant decrease of the excavation unit price. The decrease of the excavation unit price is related to the maximum usability of equipment and mechanisation in the course of simultaneous excavation with two work faces on both sides of the tunnel.

4. CONCLUSION

The studied phased construction of Mala Kapela Tunnel is proposed as the optimum solution with regard to the overall construction costs of the twin tube tunnel and safety for the tunnel users in case of incidents. A disadvantage of this solution is greater initial investment for the first construction phase and an advantage is maximum compliance with the final solution. The second disadvantage is greater costs of operation in the two-way traffic during the first phase than in the case of one-way traffic which is due to the lack of the “piston effect”.

However there are no additional works in relation to the final solution that would considerably increase the costs of construction e.g. the construction of the ceiling for the duct in the semi-transverse or transverse ventilation system.

Considering the two-way traffic in the first phase the priority is to ensure the tunnel users’ safety and to permit timely evacuation in case of fire incidents.

In case of tunnel with longitudinal ventilation system such as this one the procedure in case of fire is the following: upon fire detection the ventilation system allows smoke to stick to the tunnel ceiling thus permitting safe evacuation of passengers. The second stage is fire fighting which is carried out after the users have been evacuated from the place of incident.

The proposed phased construction with longitudinal ventilation system and the arrangement of evacuation passages ensures safe and timely evacuation of tunnel users and access to rescue teams and fire brigade to the place of incident.

Reference:

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