
Darko Šarić, Institut IGH d.d., Zagreb

Darko Slivar, Hrvatske autoceste d.o.o., Zagreb

Mario Crnjak, Institut IGH d.d., Zagreb

FIGURE 1. A1 MOTORWAY, ZAGREB-SPLIT

FIGURE 2. POSITION OF TUNNEL
1. Structural elements of the tunnel

- Twin tunnel
  - Left tube $L = 1542$ m
  - Right tube $L = 1540$ m

- Cross section
  - Two traffic lanes $2 \times 3.50 = 7.00$ m
  - Two marginal strips $2 \times 0.35 = 0.70$ m
  - Two inspection lanes $2 \times 0.90 = 1.80$ m
  - Crown height $h = 6.90$ m

- Longitudinal fall $i = 1.53\%$ and $i = 1.33\%$

- Entrance – Exit level
  - North portal $h = 496.44$ m
  - South portal $h = 495.18$ m

- One lay-by in each tube, $L = 40$ m, $w = 3$ m

- Tunnel tubes connected with three pedestrian cross cuts

- Tunnel is constructed in accordance with the new Austrian Method

- Price – 36 mil €

FIGURE 3. CROSS SECTION
2. Equipment

2.1. Power supply
Power supply from two independent sources.

2.2. Unbreakable Power supply (UPS)
Supplies the most vital systems in tunnel for 120 minutes.

2.3. Lighting
Central, single line at the tunnel crown, except at the entrance/exit tunnel parts, where the lighting is in two lines for app. 200m length, with increased intensity up to the daylight.

2.4. Ventilation
Longitudinal ventilation system. Each tunnel tube has eight pairs of fans, centrally mounted at the tunnel crown.

2.5. Fire protection system
- Fire detection along the complete length of tunnel:
- Hydrant network;
- Fire extinguishers;
- Fire-fighting vehicles with complete equipment (24/7 presence of fireman nearby the tunnel)

2.6. Video surveillance and video detection system
- Video-cameras cover the whole tunnel;
- Continuous surveillance;
- Automatic detection of traffic stop;
- Detection of driving in opposite direction;
- Vehicle counting system.
2.7. **Traffic signalization**
- Static signs (traffic signs);
- Illuminated traffic signs;
- Dynamic signs (displays and traffic signs).

2.8. **Communication**
- Connection between radio stations inside the tunnel and external radio stations;
- Reception of radio stations HR 1 - 102,3 MHz and HR2 - 97,5 MHz;
- permanent availability of mobile telephone signals;
- Emergency Telephone System - ETS and SOS systems.

2.9. **Control center and systems**
- Completely equipped for transmission - operation – control of all tunnel systems in regular, and extreme, crisis situations.
- The Center is in operation 24 hours, 365 days a year.

**FIGURE 4. DRAWING SHOWING SAFETY SYSTEMS IN THE TUNNEL**
3. Organization

The tunnel is organized to operate in a fast and professional manner in different situations and under different weather conditions.

4. Staff

Degree of education and special training qualifies the staff for handling and operation of equipment and facilities required for performance of their respective tasks.

5. Procedures in regular and special circumstances

Clear and unambiguous procedures are predefined regarding behavior in regular and special circumstances.

FIGURE 5. GENERAL IDENTIFICATION SCHEME
6. Training

- All teams have regular monthly individual trainings for different incidental situations

- Joint trainings – once/twice a year, simulating special incidents (fire, multiple collision, explosion etc.)

FIGURE 6. PROTOCOL TO BE FOLLOWED IN CASE OF FIRE
7. Evaluation of tunnel safety

European Tunnel Assessment Program - EuroTAP (12 motor vehicle clubs from the EU + HAK motor vehicle club from Croatia) lead by the German ADAC, evaluates the safety level in European tunnels.

- Goals, purpose, program -> enhancement of tunnel safety

**EuroTAP 2007:** 51 tunnels were evaluated, length > 1000 meters in 13 European states:
- 18 tunnels were evaluated as very good
- 11 tunnels were evaluated as good
- 12 tunnels were evaluated as acceptable
- 10 tunnels did not pass the test (bad).

**TUNNEL BRINJE WAS NAMED AS THE SAFEST EUROPEAN TUNNEL IN 2007**

<table>
<thead>
<tr>
<th>What is being evaluated?</th>
<th>% in overall mark</th>
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<tbody>
<tr>
<td>- tunnel system</td>
<td>14%</td>
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<tr>
<td>- power supply and lighting</td>
<td>8%</td>
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<tr>
<td>- traffic and traffic control</td>
<td>17%</td>
</tr>
<tr>
<td>- communication</td>
<td>11%</td>
</tr>
<tr>
<td>- emergency exits</td>
<td>13%</td>
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<td>- fire protection</td>
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<tr>
<td>- ventilation</td>
<td>11%</td>
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<tr>
<td>- traffic management and control</td>
<td>8%</td>
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</table>
FIGURE 8. RESULTS OF TUNNEL SAFETY TESTS ACCORDING TO EUROTAP, IN 2007.
TUNNEL BRINJE

Advantages:
- Two tubes with cross cuts as additional emergency exits at every 300 m
- Illuminated traffic signs and information displays in front of the tunnel
- Traffic information broadcasted by radio can be heard along the complete tunnel length and the operator can send messages
- Video control of the whole tunnel
- Automatic detection system of unusual situations in traffic, on lay-bys, use of emergency telephones or fire extinguishers,
- Lay-by in the middle of the tunnel
- Emergency telephones, sound insulated, and fire extinguishers at every 250 m
- Excellent lighting of emergency exits showing the direction of exit and distance to the nearest exit
- Smoke and heat can not penetrate into the external emergency exits
- Automatic fire alarm, automatic activation of ventilation and tunnel closure
- Ventilation system powerful enough to tackle fire
- Tunnel Control Center operated by trained staff 0-24 h
- Radio communication enabled in the tunnel for tunnel staff, (police, fire fighters)
- Regular staff training
- Regular emergency scenario trainings

Disadvantages (improvement possibilities):
- No loudspeakers
- Special emergency vehicles can not cross over to the other side in front of the portals
8. Justification of evaluation results

In order to justify the evaluation results of tunnel Brinje safety, certain statistical data considering tunnel Brinje are given for the years that followed 2007:

<table>
<thead>
<tr>
<th>Year</th>
<th>Traffic (Nº of vehicles)</th>
<th>Nº of accidents</th>
<th>Nº of injuries</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Light</td>
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<tr>
<td>2006</td>
<td>3.935.430</td>
<td>3</td>
<td>2</td>
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<tr>
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<tr>
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<tr>
<td>2009</td>
<td>4.575.275</td>
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CONCLUSION

Modern tunnel construction technologies as well as modern tunnel equipment (power supply, lighting, ventilation, fire protection system, video surveillance, traffic signs and markings, dynamic information signs, radio broadcasting, mobile communication signals, control centers with complete automation and informatics) are practically available to every investor, and make extreme importance on tunnel safety. But even when the same equipment is available, tunnel safety can be distinguished and recognized by:

- Optimal organization of all services and staff
- Well educated and trained teams
- Predefined procedures for emergency situations, and above all
- Regular training and team work where every individual, in every emergency situation, efficiently and professionally performs his task.

This was one of the major reasons why the "Brinje" tunnel was named the best European tunnel in 2007.
FIGURE 9. ROAD CROATIAN ROAD TUNNELS RANKED ACCORDING TO EUROTAP

THANK YOU FOR YOUR ATTENTION!