Appendix 2.16 - SPAIN – Madrid – By-Pass-TUNNEL

1. SUMMARY

The By-pass Tunnel is located in Madrid (Spain), a city of about 3.2 million inhabitants. The M30 is the main ring road that permits to communicate all the neighbourhoods of the city. Two main tunnels have been constructed along M30.

- The Rio Tunnel, which runs along the River Manzanares, underneath the former exterior ring road. The old road has been replaced with a green area near the river.
- The By-pass Tunnel, which was constructed to reduce the distance between the eastern area and the western area of the city (**Figure 1**).

The By-pass Tunnel, in service since 2007, is owned and operated by "Madrid Calle 30".

The tunnel has two different sections:

- The first one, with a length of 3,600 m, was constructed by the TBM method using a 15.2 m diameter boring machine.
- The second one, with a length of 2,000 m, was constructed by the cut & cover method.

This monograph is concerned with the bored section only.

There are two unidirectional tubes with 3 lanes each. The tubes are parallel and are connected by cross passages (**Figure 2**).

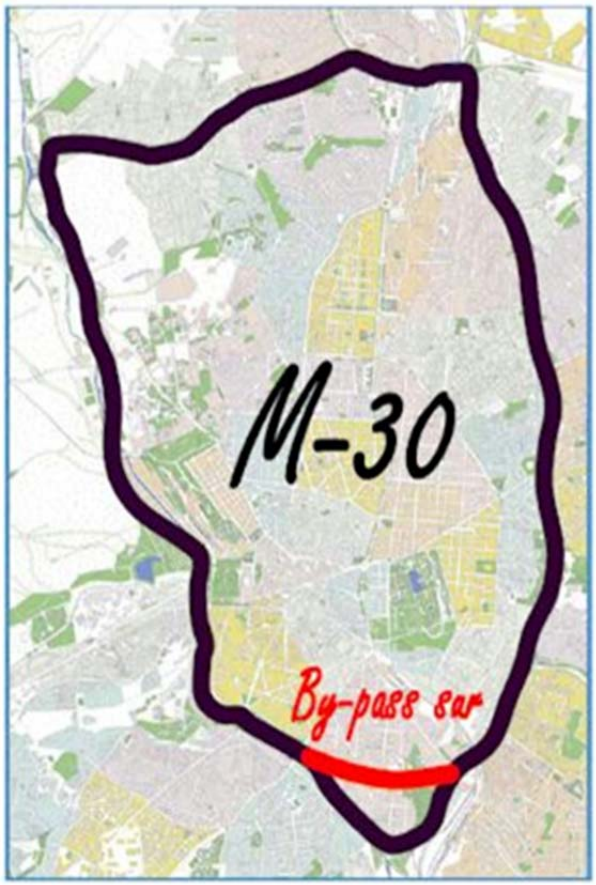

Figure 1 – By-pass Tunnel location

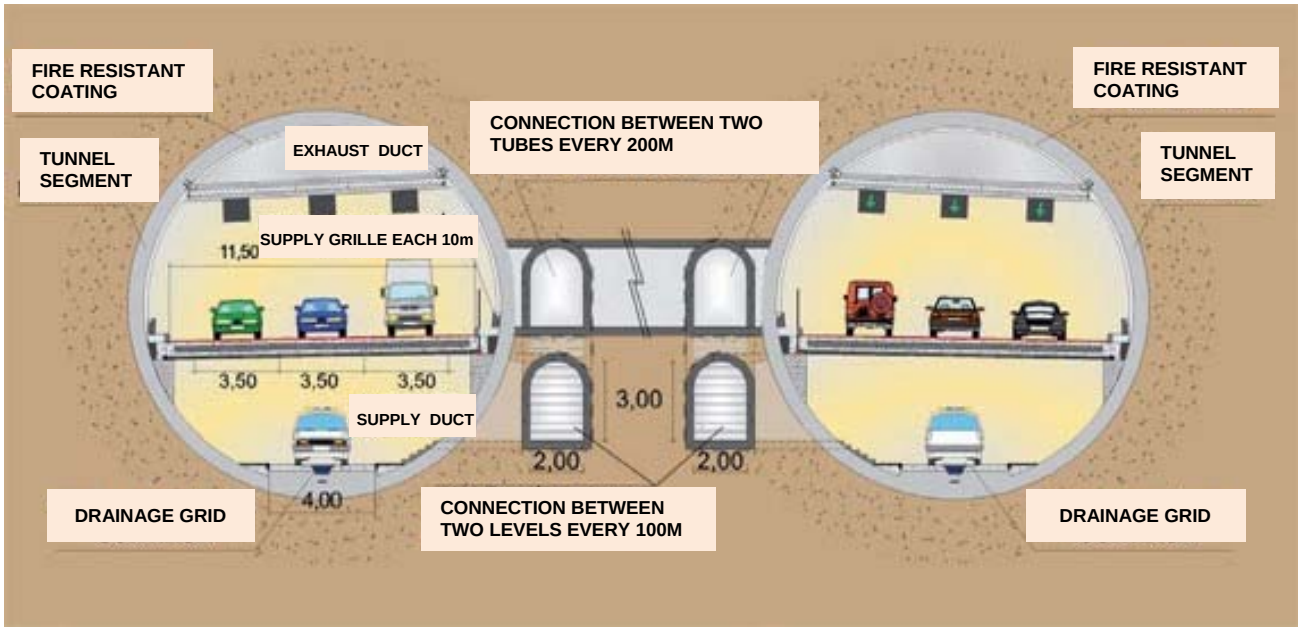

Figure 2 – Cross section. By-pass Tunnel

2. MAIN CHARACTERISTICS

2.1 GEOMETRY

- Tunnel length (only for the TBM tunnel section): 3,600 m;
- Horizontal alignment: radius of 1,682 m;
- Vertical alignment: one half of tunnel has a downhill slope of 5% and the other half has an uphill slope of 5%.

2.2 CROSS SECTION

2.2.1 Road Tunnel

The cross section is shown **Figures 2 and 3** The main characteristics of the cross section are:

- Circular section with internal radius of 13.45 m;
- 3 lanes with a width of 3.50 m each;
- 2 walkways at each side with a width of 0.7m each;
- Vertical Clearance 4.50 m;
- Total vertical height 5.50 m, under a gallery for vitiated air or smoke extraction located in the vault;
- There is a gallery underneath the roadway with a vertical clearance of 3.6 m, which serves as an emergency route and as a fresh air supply duct to the tunnel.

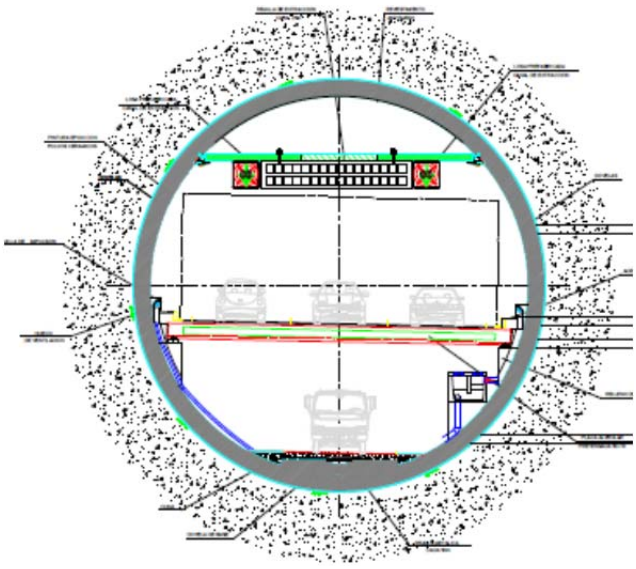

Figure 3 – cross section

2.2.2 Escape route

- There are cross-passages between the two tubes every 200 m. They are connected with the escape route underneath the roadway by stairs for pedestrian use. Every 600m, the section of the cross-passage has been designed to permit vehicles to cross from one tube to the other;
- There are stairs for the exclusive use of fire fighters to connect the emergency gallery and the roadway;
- Cross-passages are closed off by doors and pressurised.

2.3 TRAFFIC CONDITIONS, BREAKDOWNS AND ACCIDENTS

2.3.1 Traffic conditions

- AADT (Annual Average Daily Traffic): 67,750 veh/day in year 2012 for both tubes;
- Heavy vehicles: 0.05%;
- Dangerous HGV traffic is forbidden;
- Vehicles over 7.5 tons are forbidden;
- Speed limit inside the tunnel: 70 km/h for the main road and 50 km/h or 30 km/h for access or exit ramps;
- No regular traffic queuing inside the tunnel.

Hourly Traffic distribution during the day for a weekday: (**Figure 4: northbound**) – (**Figure 5: southbound)**.

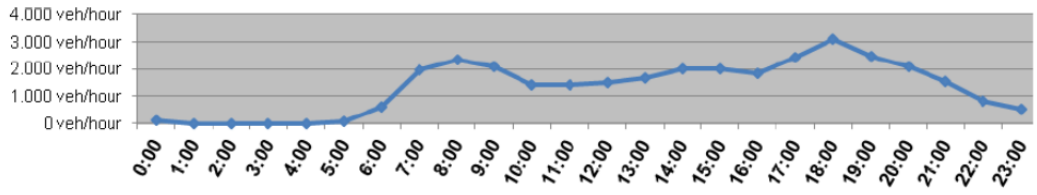

Figure 4 – Hourly traffic distribution – weekday - northbound

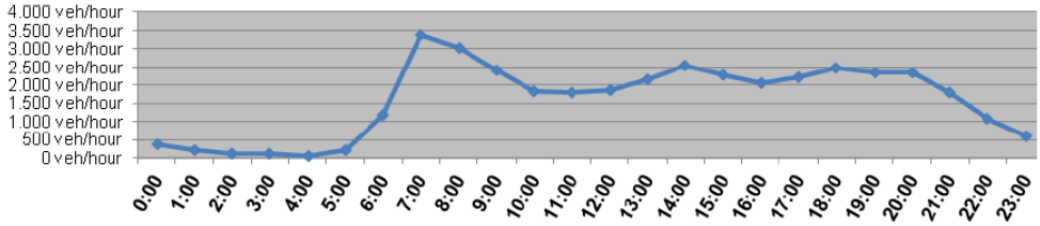

Figure 5 – Hourly traffic distribution – weekday - southbound

2.3.2 Breakdowns and accidents

- Average of 331 accidents per year in all M30 tunnels (40 km of tubes, including the By-pass Tunnel and the M30-Río Tunnel);
- 2,697 breakdowns per year for allM30 tunnels;
- No fires;
- Analysis of the events shows that most accidents occur due to inappropriate speed or driver distraction.

2.4 VENTILATION

2.4.1 Ventilation system

- Transverse ventilation type, with the following objectives: (1) regular ventilation - (2) control of air flow in case of fire and containment of smoke spread;
- 4 ventilation shafts;
- Ventilation sections with an average length of 600 m;
- It is possible to have a high rate of smoke extraction through the 4 ventilation shafts using motorised dampers placed near the shafts;
- The outside air is supplied by grilles placed at each side of the road in the pavement every 10m and the vitiated air is exhausted by grilles placed in the upper portion of the cross section (**Figure 6**);
- Overpressure of 50 Pa within the cross-passages joining the two tubes, permitting swing doors to be opened manually without problems;
- Overpressure of the emergency route underneath the roadway to avoid the ingress of smoke through the supply grilles.

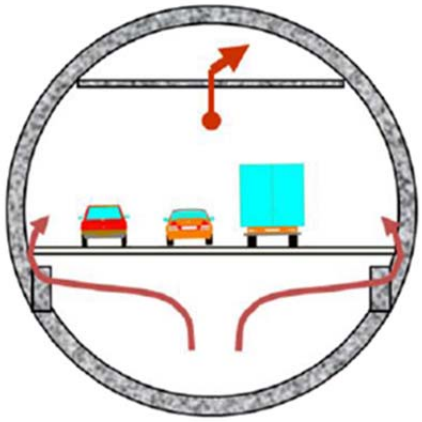

Figure 6 –Transverse ventilation

2.4.2 Main parameters of design

Design fire heat release rate of 30 MW.

Regular ventilation: airflow volumes are designed to maintain the contaminants under these figures:

- CO 40 ppm;
- NO 2 ppm;
- Opacity 4

2.4.3 Ventilation Shafts

The ventilation shafts are equipped with fans for supplying outside air to the escape gallery located underneath the roadway.

They are also equipped with extraction fans that connect the smoke exhaust duct (located above the roadway) to the outside.

The shafts have been designed so that the distance between the entrance of outside air and exhaust of contaminated air (or smoke) is far enough to avoid any cross contamination or recirculation (**Figure 7**).

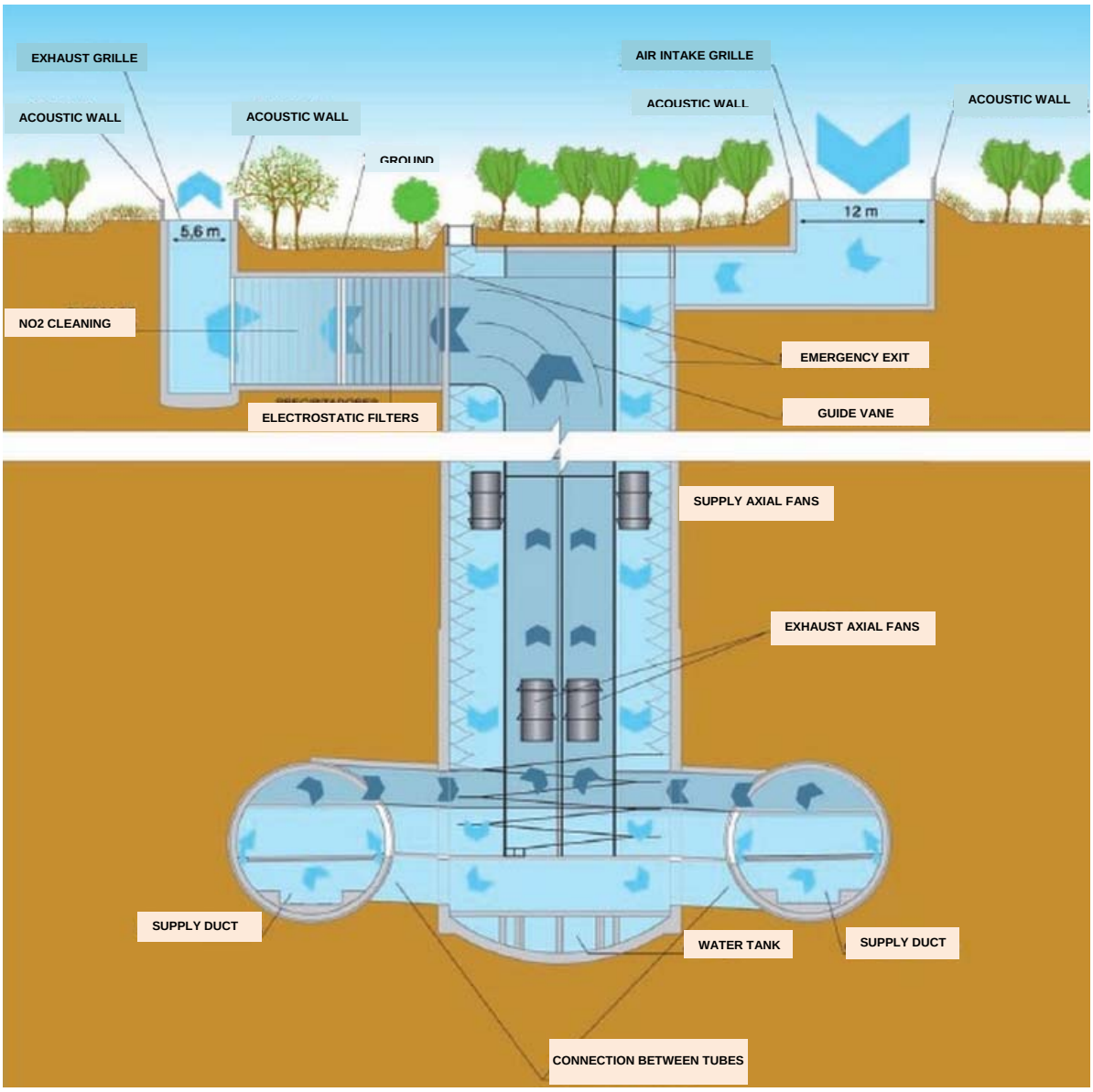

Figure 7– Ventilation shaft for By-pass tunnel

2.4.4 Strategy for regular ventilation system

Supply axial fans and exhaust axial fans operate whenever the measures of the sensors located inside the tunnel indicate that the pollution is higher than the allowable limits.

2.4.5 Strategy for the fire ventilation system

- The ventilation section in which a fire is situated is determined by the linear heat detector or the Automatic Incident Detection System;
- The exhaust fan existing in that ventilation section is switched to the emergency mode, while the rest of the exhaust fans for other ventilation sections are stopped;
- The supply fan existing in that ventilation section is also switched to emergency mode. This is the minimum flow necessary to maintain the pressurisation of the emergency route;
- The supply fan existing in the adjacent ventilation sections operates at maximum flow;
- With this strategy, it is possible to maintain the stratification and containment of the smoke;
- Once the evacuation is finished, it is possible to operate with longitudinal ventilation using the high volume extraction points placed near the ventilation shafts. This system can be used by the fire brigade to exhaust the smoke from the tunnel at high velocity.

2.4.6 Ventilation management

In normal operation, the ventilation system is controlled automatically, with input from tunnel sensors and traffic monitors. The emergency ventilation system is activated and operated manually, based on established procedures prepared for each situation. In emergency operation mode ventilation is managed by the operators located in the control room. There are 149 protocol emergency sheets covering incidents in each section of the entire M30 tunnel system.

2.5 ENVIRONMENTAL ISSUES

2.5.1 Air quality

An air-cleaning system is installed inside the four ventilation shafts. It includes;

- electrostatic filters which are reducing the number of particles;
- NO2 cleaning system.

These cleaning systems operate at the same time as the axial fans extracting polluted air.

In case of fire, the smoke is exhausted through a bypass duct to avoid its entrance to the cleaning systems.

2.5.2 Noise

Sound attenuators are installed inside the ventilation shafts for the following purposes:

- At the top of the shaft, near the street to mitigate the noise of the axial fans to the external area;
- At the bottom of the shaft, to mitigate the noise of the axial fans inside the tunnel.

There are also acoustic walls around the external grilles of the ventilation shafts.

2.6 OPERATION AND SAFETY EQUIPMENT

The Tunnel is equipped with all the usual operation and safety equipment:

- Fire hoses, fire extinguishers and hose connections for Fire Brigade use;
- Linear heat detector;
- Control Lighting with a system named DALI which permits to vary the intensity of the light ranging from 30% in low demand hours, 70% during peak hours and 100% during breakdowns, accidents or maintenance works;
- CCTV with cameras connected to the AIDS (Automatic Incident Detection System);
- SCADA;
- Traffic loops;
- Signalling of the Emergency Exits and the location inside the tunnel.

3. OPERATION

The Bypass Tunnel is operated by two independent Management Control Centres which are staffed at all times (regular centre and standby centre as back-up).

First line of response team and Maintenance Support are located at four points outside the tunnel, with the ability to reach any incident in the tunnel within 6-8 minutes of the first call. The team comprises one fire truck, one incident signalling lorry and one crane lorry to remove broken-down cars.