Appendix 2.22 - SPAIN – Madrid – AZCA TUNNEL

1. SUMMARY

The AZCA Tunnel is an urban tunnel consisting of two distributor rings on two levels with entrance and exit ramps to the surrounding streets and to the car parks located above it. When AZCA was originally planned, the main idea was to clearly separate vehicle and pedestrian traffic from each other, with pedestrians on the surface and with the construction of underground roads, at different levels, for vehicular traffic. In addition, it was intended to give the maximum utility of the area to shops and offices.

The tunnel is unidirectional, moving in a counter-clockwise direction. The distributor rings have four lanes for traffic on the first level and two lanes on the second level. Figure 1 shows the location of the tunnel and its ramps, and Figures 2 and 3 show the traffic scheme for each level.

Figure 1 - Layout with the entrance ramps and exit ramps to Azca Tunnel

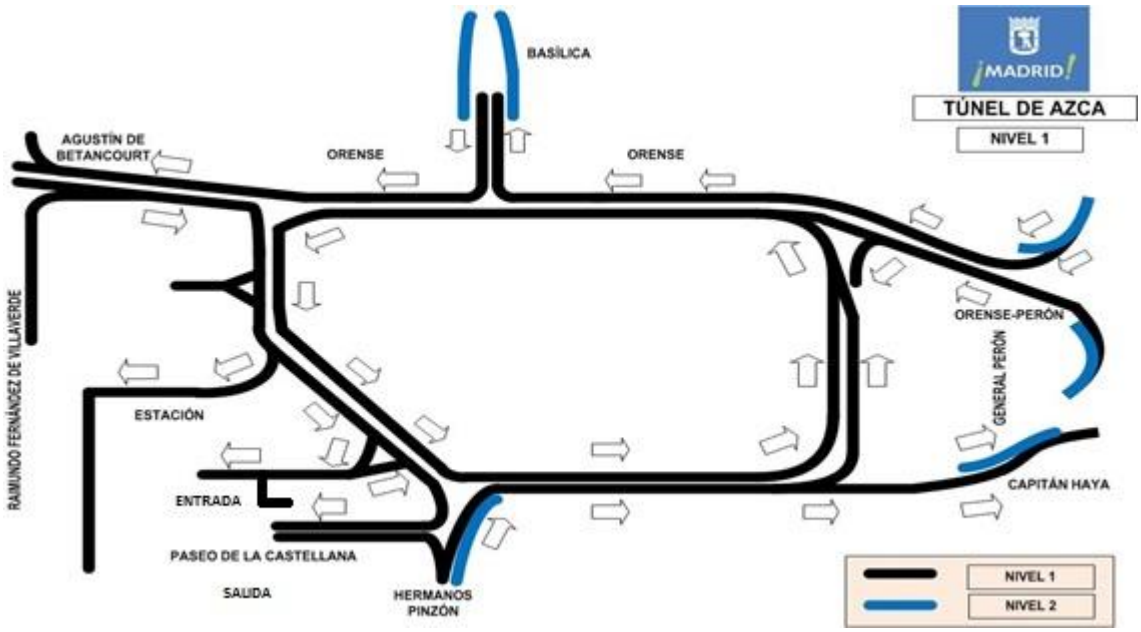

Figure 2 – Detail of ramps and traffic direction for Azca Tunnel at Level 1 (Black colour)

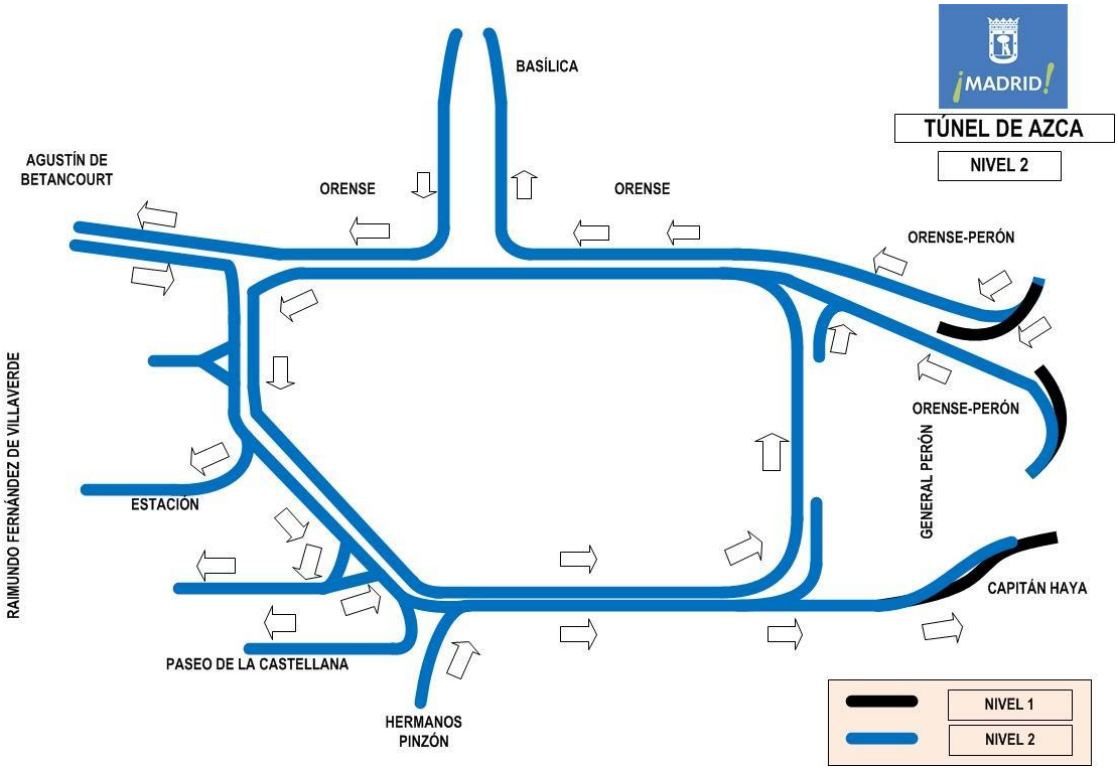

Figure 3 – Detail of ramps and traffic direction for Azca Tunnel at Level 2 (Blue colour)

Inside the AZCA area there are several car parks, both for commercial buildings (as for example El Corte Ingles) and for offices (BBVA Bank, Sacyr Company, Torre Picasso, etc.). The total number of parking bays are estimated to be around 12,000. All these car parks have their own traffic light regulation, independent of the centralised control of the tunnel.

Below the 2nd level there is a service tunnel, approximately 2 m wide, which runs along the entire central ring to permit the distribution of several services, including low-voltage networks and water pipe networks from the Water Supply Company (Canal de Isabel II).

2. MAIN CHARACTERISTICS

2.1 GEOMETRY

- Tunnel Length: 7500 m, including both Levels and Ramps.
- Each Ring Length: 900 m approximately.

2.2 CROSS SECTION

2.2.1 Ring at Level 1

- 4 lanes with a width of 3.50 m each.
- Sidewalks and hard shoulder at each side with a width of 0.7 m.
- Total cross section width: 15 m.
- Vertical Clearance: 4 m.

2.2.2 Ring at Level 2

- 2 lanes with a width of 3.5 m each.
- Sidewalks and hard shoulder at each side with a width of 0.5 m.
- Total cross section width: 8 m.
- Vertical Clearance: 3 m.

2.2.3 Shelters and Lay-bys

The tunnel has 10 safety shelters with emergency exits to the outside.

There are 5 lay-bys distributed between the two levels, but they are not located in the access and exit ramps.

2.2.4 Emergency exit

The AZCA Tunnel is equipped with 4 emergency exits for pedestrians, which are accessible from both levels. In addition, there is a ramp from the second to the first level, also planned as an evacuation route (Figure 4).

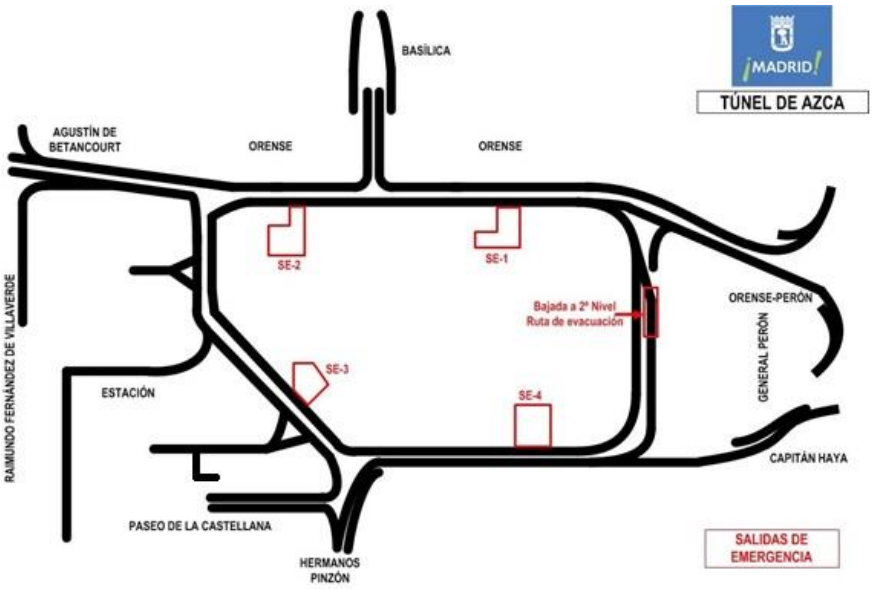

Figure 4 - Layout of the emergency exits

The emergency exits have single-leaf, fire-resistant doors equipped with a panic-bar and magnetic contacts to indicate opening or closing.

All the lobbies of the exits have a pressurisation system.

The emergency exits are signalled as follows:

- Electroluminescent guiding signals on the walls near the emergency doors.
- The electroluminescent signals around the emergency door outline (with the autonomy of 35 min).
- In photoluminescent evacuation signals on the walls every 50 m on both sides, indicating the distance to the nearest emergency door.
- The photoluminescent signs for emergency doors located on each door wing.

Figures 5 and 6 show the emergency exits in the tunnel.

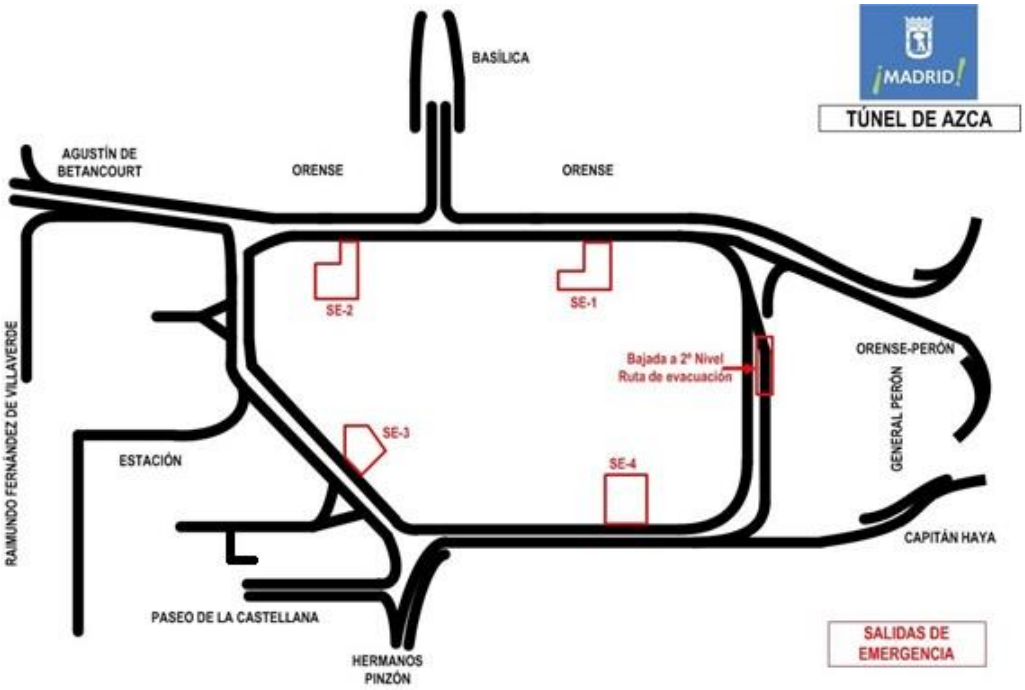

Figure 5 - Layout of the emergency exits

Figure 6 - emergency door and evacuation between the two levels

2.3 TRAFFIC CONDITIONS

The traffic inside the tunnel has three main objectives:

- Traffic entering and exiting the car parks of commercial areas and offices. Most of this traffic occurs during the morning and evening peak hours.
- Traffic passing through the distributor ring of the first level.
- Traffic of delivery trucks that access the unloading docks, mainly from the south (Corte Inglés, C.C. Moda Shopping, etc.).

The estimated traffic in the tunnel is 60,000 vehicles per day, of which 70% is passing through. The traffic through the second level accounts for 25% of the traffic on the first level, without considering the peak hours.

The speed is limited to 50 km/h in the two rings, with some of the exit ramps limited to 30 km/h. As municipal regulations forbid the transit of dangerous goods vehicles through the interior of the City of Madrid, the circulation of these vehicles through the AZCA Tunnel is therefore prohibited.

2.4 VENTILATION

2.4.1 Ventilation system

The AZCA tunnel has two levels of underground parking, which are ventilated by exchanging air with the tunnel on its first and second levels.

The tunnel ventilation system is a transversal type, supplying fresh air through the lower part and extracting the contaminated air through the upper side, expelling it outside through ducts.

There are 136 fans distributed in 8 ventilation stations, which are for supply or for extraction exclusively, that is, they are not reversible.

The fans have two operational speeds, which can be controlled separately by means of the control panel.

Figure 7 shows some of the ventilation stations:

Figure 7 – Tunnel ventilation stations

A limitation of the ventilation system for this tunnel is that the remote control of the fans are carried out by groups of both supply and extraction fans. It is currently not possible to have an independent control for each fan, due to the design of the electrical and control panels.

The electrical and control panels for the fans are distributed in the following eight panels:

- Panel 2 (CTV2): has 21 fans, 9 for supply (5 serving the upper road and 4 the lower road) and the other 12 for extraction (8 serving the upper road and 4 the lower road).
- Panel 3 (CTV3): has 15 fans, 8 for supply (5 serving the upper road and 3 the lower road) and the other 7 for extraction (5 serving the upper road and 2 the lower road).
- Panel 4 (CTV4): has 12 fans, 6 for supply (4 serving the upper road and 2 the lower road) and the other 6 for extraction (4 serving the upper road and 2 the lower road).
- Panel 5 1st level (CTV5): has 11 fans, the total 11 for supply (7 serving the upper road and 4 the lower road).
- Panel 5 2nd level (CTV5): has 11 fans, the total 11 for extraction (7 serving the upper road and 4 the lower road).
- Panel 6 (CTV6-8): has 20 fans, 10 for supply (7 serving the upper road and 3 the lower road) and the other 10 for extraction (7 serving the upper road and 3 the lower road).
- Panel 8 (CTV6-8): has 14 fans, 7 for supply (5 serving the upper road and 2 the lower road) and the other 7 for extraction (5 serving the upper road and 2 the lower road).
- Panel 7 (CTV): has 32 fans, 16 for supply (13 serving the upper road and 3 the lower road) and the other 16 for extraction (13 serving the upper road and 3 the lower road).

2.4.2 Ventilation Control

Ventilation is controlled through the direct measurement of smoke, contaminant levels, opacity, and air velocity within the tunnel.

The measuring equipment is located at the points of greatest theoretical concentration, which guarantee the measurement of the entire profile of the concentration of particles and pollutants.

The sensors have a standard 4-20 mA output and are connected to the Standard Remote Station of the tunnel, except the CO and NO2 detectors that are connected to detection panels that send the information to the Standard Remote Station. The control contactors of the fans are managed according to the information obtained.

Ventilation control has the following detection equipment:

- 52 NO2 detectors,
- 52 CO detectors,
- 26 opacimeters,
- 3 anemometers and an outdoor wind detector,
- 24 indoor anemometers,
- 4 control centres (each with two analysis kits).

2.5 OPERATION AND SAFETY EQUIPMENT

The AZCA tunnel has different fixed security facilities, designed to ensure the correct operation of the systems, which contributes to an increase in safety of the tunnel users, as well as its infrastructure and equipment. Fixed facilities for the tunnel are described in the following sections.

2.5.1 Electrical/Power supply system.

- The electrical system of the entire tunnel is distributed along the low-voltage rooms and in the CTV rooms where the control panels for the fans are located.
- The power for the Control Centre comes from two Supply Company connections, with a power of 100 kW each.
- To ensure uninterrupted electricity supply throughout the tunnel in case of an unexpected outage, such as a power failure from the Supply Company, the critical security systems of the tunnel are fitted with 8 Uninterruptible Power Systems (UPS) of 15 kVA, which allows to have 35 minutes of autonomy to keep the following systems operational:
    - Standard Remote Station of the tunnel and distributed control systems.
    - Fire detection panels.
    - Gas detection panels, including analysis of CO, and NO_2.
    - The anemometers and opacity sensors.
    - SOS System.

- Public Address System.
- CCTV circuit.
- Video receptor equipment.
- Data Collection Stations.
- Communication Switches.
- Variable Message Panels, Cross-Arrows and Speed Signals.
- Lighting for guiding and emergency doors signalisation.
- Second level Access barrier from the first level.

2.5.2 Lighting system.

❑ **Normal Lighting**

The tunnel lighting is provided by 250 W High-Pressure Sodium Vapour luminaries on the first level and 65 W fluorescent luminaries on the second level. There is no reinforcement lighting for the entrances and exits of the tunnel.

Emergency exit stairs have independent lighting activated by presence detectors.

❑ **Emergency lighting**

The tunnel has emergency and guided lighting consisting of 109 units of 36 W fluorescent luminaries, located in the tunnel walls every 20 metres and at a height of 1.05 m above the road level. These luminaries are connected to the UPS located in the ventilation rooms with the autonomy of 35 min.

Furthermore, half of the luminaries and the three luminaries located in each emergency exit door, have an autonomous battery kit installed to provide the lighting for an additional 60 min.

❑ **Security lighting.**

The tunnel's security lighting consists of one third of the total luminaries of the tunnel's permanent lighting, located at the top of the tunnel´s walls. It is connected to the UPS.

2.5.3 Fire detection and extinguishing system.

The fire detection system is a linear system for both levels of the tunnel. In the technical rooms and Transformer Electrical Centre, it is a point detection. Additionally, there is a fire detection system for each of the four Emergency Exits.

The fire extinguishing system consists of the following elements:

- Wet column for Fire Hoses and hydrants.
- Automatic Gas Extinguishing system for the technical rooms and Transformer Electrical Centre.
- Fire extinguishers.

2.5.4 Traffic control systems.

❑ **Signalling system.**

The Variable Message System provides graphic and / or alphanumeric information for drivers in real time about incidents, traffic conditions, etc. The tunnel has the following equipment:

- 4 cross-arrow signs for indication of the lane.
- 2 speed limitation signs.
- 65 tricolour traffic lights (R-A-G) for warning and closing the tunnel.
- 65 bicolour traffic lights (R-G) for warning and closing the tunnel.
- 13 amber one-colour traffic lights for pre-warning.
- 2 amber-amber bicolour traffic lights for pre-warning.
- 1 closing barrier.

The control of the traffic lights are managed by the Municipality of Madrid.

❑ **Traffic measurement system.**

There are 8 Data Collection Stations and 32 measurement traffic points by means of 64 loops.

❑ **Closed-circuit television (CCTV)**

There are 35 fixed CCTV cameras in the interior of the tunnel at a height of 3-4 m and 10 movable cameras in the entrances and exits.

- **SOS System**

  The network of SOS System consists of 26 posts with IP technology, located every 66 m along the right wall and near to the amber-amber traffic lights.

- **Public Address system**

  The public address system has 69 loudspeakers of 30 W with a coverage angle of 50° and amplifiers located in the technical rooms which cover the inner sections of the tunnel.

2.5.5 Communication system

In order to connect all the devices installed in the tunnel to control centre, there is a large capacity Communications Network with TCP / IP technology over Ethernet.

The network architecture is developed with a double ring to improve redundancy, due to the multiple paths for linking the control of the equipment to each other and with the Control Centre (by having several fibre-optic links).

There is also an IT telephone system to cover the numerous critical areas of all the facilities, which ensure communication between the different ventilation rooms and the Control Centre.

2.5.6 Tunnel management system

The tunnel management system (TMS) has 4 hierarchical levels, each with independent and specific equipment for each operation:

- Route Signs on the Road, corresponding to the tunnel security elements (Variable Message Signs, traffic lights, barriers, etc.).
- Distributed Control system, consisting of fieldbus headers to which the Route Signs are connected.
- Standard remote stations and communication systems.
- Control Centre with the SW control application system.
- All those equipment and subsystems existing in the tunnel which are monitored or controlled by the TMS, are considered as part of the TMS Environment.