FOLGOSO TUNNEL REFURBISHMENT WORKS: FEATURES AND CHALLENGES

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ABSTRACT

The tunnel of Folgoso is located in A-52 Highway, in Pontevedra, in the northwest of Spain. It enhances the road communication between the central plateau and the region of Galicia.

It is a 2,551-metre-long unidirectional twin-tube tunnel. It was open in 1998, with a traffic intensity of 3,750 veh day⁻¹, being 17.2% heavy vehicles. Traffic of heavy good vehicles through the tunnel is permitted, as well.

In 2006, a project design for tunnel refurbishment was undertaken in accordance with the Spanish standard for safety in road tunnels (Royal Decree 635/2006). The refurbishment works began in 2008, keeping the tunnel within operation.

The tunnel of Folgoso is the longest highway tunnel in Spain that has been revamped to meet RD 635/2006 requirements. There has been a wide renovation of equipment concerning electrical systems, lighting, ventilation, firefighting and communications, mainly.

The tunnel is a pioneer in deploying some features. For instance, it is the Spanish longest highway tunnel with fluorescent lighting, and the first to be endowed with an anti-glaring system. This device avoids the risk of the drivers to be glared by the sunlight, due to the tunnel’s east-west orientation.

Besides, a new Tunnel Control Centre of great architectural value has been built, perfectly merged with the environment. The building hosts the whole equipment that is needed for the tunnel’s control and monitoring, as well as the offices for the personnel in charge of the maintenance and exploitation.

Several challenges were undertaken during the works, since the tunnel remained in operation. Risk analyses were done taking into account different ways to divert traffic through one tube and a county road, in order to assess whether or not the safety conditions of the tunnel were high enough to ensure a reasonable safety level.

Another hindrance for the works raised when the electrical supplier stated that the whole electrical power demand couldn’t be provided. Thus, an electrical optimization study was developed in order to suit electrical demand and protocols to the actual power supply.

All these circumstances altogether bring out the tunnel of Folgoso as a notorious and referential tunnel in Spain.

Keywords: tunnel refurbishment, anti-glare system, risk analysis, fluorescent lighting
1. INTRODUCTION

The tunnel of Folgosó is located in A-52 Highway, in Pontevedra in the northwest of Spain. It enhances the road communication between the central plateau and the region of Galicia (see Figure 1 below).

It is a 2,551-metre-long unidirectional twin-tube tunnel. It was opened in 1998, and it has a traffic intensity of 3,750 veh/day, with a 17.2% of heavy vehicles. Traffic of heavy good vehicles through the tunnel is permitted, as well.

![Figure 1: Tunnel’s location in Northwest of Spain and East Portal of the tunnel](image)

In 2006, a project design for tunnel refurbishment was undertaken in accordance with the Spanish standard for safety in road tunnels (Royal Decree 635/2006). The refurbishment works began in 2008, keeping the tunnel within operation.

2. WORKS DESCRIPTION

The aim of the Project was to refurbish and upgrade the tunnel’s safety conditions to meet the safety requirements stated in Spanish RD 635/2006. This standard is the national transposition of European Directive 2004/54/CE on minimum safety requirements for tunnels in the Trans-European Road Network.

2.1. Civil Works

Though the main activities concerned electromechanical systems, some civil works needed to be done according to RD 635/2006. The main civil works undertaken are listed below.

- Asphalt paving: Due to its bad condition, a complete rehabilitation of the road surface was required. According to RD 635/2006, it is mandatory for road tunnels’ surface to maintain the Skid Number over 60.

- Sidewalks: In order to avoid collisions inside the tunnel, the sidewalks had been beveled to allow a vehicle to climb the curb. This measure also allows disabled people to climb the curb in case of emergency, with little effort.

- Drainage: The works consisted in repairing water filtrations inside the tunnel, conducting this water to the rainwater gutter, along with a canalization of a natural fountain located outside of the tunnel. Both these repairs improved tunnel safety, clearing the water from the road surface.

- Besides, it was built a separated sewage system for collecting dangerous and flammable liquids.

- Aesthetic coating: This system has a double aim, on the one hand improving wall’s reflection properties to make a better lighting of the tunnel, and on the other hand conveying a comfort sensation and better aesthetic impression on the drivers.
So, a mixed solution consisting in 3.5 m high vitrified steel panel in both tunnel walls was deployed. The remaining surface was painted with a special sprayed ceramic coat.

- Landscape integration of both tunnel portals: Since Galicia is a region with lots of vegetation, it was paramount to enhance a smooth integration of the tunnel structure along with the landscape. Local tree species were planted along the portals’ sides. Both portals were hydroseeded at the beginning and at the end of the works.

- Road signs: There was a complete renovation of the road signs, complemented with new requirements from RD 635/2006 and Spanish standard for road signing.

![Figure 2: Tunnel of Folgoso after the revamping works](image)

### 2.2. Safety systems’ works

The tunnel of Folgoso was opened in 1998, so safety criteria were quite different to current ones. Thus, the scope of the project laid mainly in upgrading electromechanical systems.

- Ventilation: a whole new design of the ventilation system was developed, taking into account modern standards and the increase of the traffic flow. A risk analyses-based new algorithm was developed to ensure the system’s capacity to manage tunnel ventilation in case of a 100 MW fire. It is envisaged to carry out smoke tests as a final stage for commissioning of the tunnel. Moreover, a new ventilation monitoring system has been deployed. CO and NO are monitored every 300 m, along with air speed and direction and opacity. The SCADA analyses the inputs from the measuring devices and, in case an incident is recorded, it triggers the start of a ventilation protocol, always under tunnel operator supervision.

- Emergency exits: The tunnel has 8 galleries connecting both tubes. They serve as emergency galleries, free of fire and smoke. Overpressure inside the emergency exits is granted by maintaining its doors closed and a fire resistant ventilation system with fans, dampers and ducts.
CCTV: The tunnel already had an analogical-based surveillance system with Automatic Incident Detection (AID). This system merges with the new extension consisting in technical rooms monitoring and new dome cameras located outside the tunnel providing direct vision of the portals and Variable Message Signs (VMS). Along with CCTV, a new Automatic Number Plate Recognition (ANPR) system was deployed in both tubes. Its aim is to deter drivers to exceed speed limits by recording their plate numbers and their average speed. The system raises an alarm if a driver’s irregular behaviour is detected.

Fire suppression systems: A new water supply connection devoted only to fire fighting was built, complying with Spanish standard. The system has also a new water tank, separated from the former drinking water tank, avoiding both supplies to mix. There are two existing pumps, one at each portal. A new algorithm of pump starting has been designed in order to save energy and false starts. The protocol takes into account not only the pressure that the system needs, but also the water level in each tank. A new linear fire detection system based on fibre optics technology was deployed, substituting the old fusible bimetal type.

Electric supply: According to Spanish standard, the tunnel is due to have a redundant power supply, besides a diesel generator (DG) and an Uninterrupted Power Supply (UPS). Every technical room is equipped with both a DG and a UPS to ensure a minimum emergency supply in case of electric fails. All the transformer stations were modified to allow electric supply from two different high voltage lines, along with a commutation system. The installed power capacity is increased due to the deployment of new equipment. So, new transformers and DG were installed in technical rooms.

VMS: New panels have been deployed every 1,000 m. They show messages in a two-rowed alphanumeric area and a graphic area reserved for pictograms. Lane control signs are used above each traffic lane along with pictograms showing speed limit signals every 400 m. These speed limit signals allow up to 100 km/h of maximum speed and show their pictograms on a blank background, to improve visualization.

Vehicle barriers: New vertical axis barriers were installed, along with the existing horizontal axis ones. Both barrier types working together allow a more efficient lane-cutting procedure, if necessary.

Public Address (PA) system: A whole new PA system was installed, with new equipment and a new zone configuration. This feature allows conveying different messages for each zone, and also allows addressing to emergency galleries and tunnel portals.

Radio Communications (RC): This system enables up four ways of communication, for different purposes. Firstly, it allows some radio frequencies to enter into the tunnel, which may be used for PA as well. Secondly, cell phone communications are also possible inside the tunnel. A radio channel for maintenance purposes is also available. Finally, the system also provides a mean of communication for emergency services through their private radio channels.

3. TECHNICAL CHALLENGES AND INNOVATIONS

Some detailed studies were necessary, given the tunnel’s uniqueness and importance. Innovative solutions were developed in order to meet the safety requirements. The main technical challenges and innovations are as follow.
3.1. Anti-glaring system

The tunnel of Folgoso is oriented from East to West. This fact leads into a rather uncomfortable and dangerous situation, since drivers are glared by the sunlight at dusk during certain periods of the year.

A theoretical approach to this issue was undertaken, since solar trajectories are well known and a geometrical study can determine when and how a driver is glared by sunlight.

Commercial code ECOTEC was used to study several road cross sections to assess which were the critical angles for glaring (Figure 3). The glaring angle is a variable angle formed between the sunbeam for every instant and the driver’s visual plane. The anti-glaring system geometry will avoid each and every glaring angle during the year.

![Figure 3: Map of solar trajectories and projected shadows](image)

Once the ideal anti-glaring geometry has been determined, a structure that may resemble that geometry is designed. The structure must keep the road height and width free from obstacles.

Consequently the structure is formed by a series of equidistant gantries, with a cross beam structure on top. The beams hold a series of ellipsoidal lightweight aluminium blades transversal to the road, which avoid the sunbeams glaring the drivers.

3.2. Lighting system

The revamp of this system aims to upgrade lighting levels to new standards, but also to renew the equipment and taking advantage of new lighting control systems.

Given the length of the tunnel, a lighting optimization analysis was carried out during the design phase, considering several options on a cost-effective base. According to the study, a mixed solution of High Pressure Sodium Vapour (HPSV) and Fluorescent lamps was found the most convenient option for the tunnel.
The threshold zone and transition zone is lighted with HPSV lamps, while fluorescent lamps are deployed along the whole tunnel, providing with the interior permanent lighting. The permanent lighting regime is controlled with a Digital Addressable Lighting Interface (DALI), which enables to obtain a lighting curve that fits closely to the theoretical curve. So, energy savings are assured up to an estimated 25%.

3.3. Electric system

According to Spanish RD 635/2006, the tunnel of Folgoso must have a redundant electric supply, and the design project took that into account. However, since the tunnel’s surroundings are a low populated area and near the end of the power lines, the electrical supplier stated that the whole electrical power demand couldn’t be provided. Thus, an electrical optimization study was developed in order to suit electrical demand and protocols to the actual power supply.
Several hypotheses were studied, taking into account different fire sizes and lighting regimes.

- Normal operation conditions: this case involves the whole power capacity of the lighting system, but the ventilation system is expected to need only as much as 5 out of 14 fans for sanitary ventilation purposes, according to the CFD studies undertaken.

- Emergency conditions: this scenario includes a fire inside one tube. This situation needs the whole ventilation system switched on. Under these circumstances, the portal’s lighting is unnecessary and the permanent lighting level is considered enough for the emergency purposes.

3.4. Tunnel Control Center

There are several tunnels in the province of Pontevedra, most of them in the by-pass surrounding the town of Vigo, some 50 km away of the tunnel of Folgoso. This tunnel network isn’t monitored in a centralized Control Centre, but in small centres for each group of them.

Several new necessities for the already existing Control Centre rose in the design phase of the refurbishment project. The tunnels were not visible from the Control Centre, extra space for new equipment was needed and there was a lack of space for the maintenance and operation staff.

A new Control Centre was designed to suit all these needs, with extra space to host all the operation and maintenance staff. The possibility of a further centralization of all the tunnels in Pontevedra in this Centre is foreseen.

The Control Centre has a large control room with a video wall and a situation room annexed, which enables an access to SCADA application in slave mode.

![Figure 6: Brand new Control Centre](image)

A new 25 km long fibre optic network has been deployed to connect Folgoso’s Control Centre and an existing Control Centre, aiming to a future centralization of the monitoring of Pontevedra’s tunnels.

The Operation Centre of A-52 road also dwells in this same building. For this purpose a new annex building has been built to host a warehouse and shelter the road maintenance machines, and even a salt deposit for maintenance in winter conditions.

When it comes to architecture, the building merges both the concrete structure robustness and the lightness of the first floor volume which, shifted from the ground floor volume, provides with a direct vision of the tunnel’s West portals.

The ground floor hosts common facilities and maintenance rooms, while the upper level houses offices for administrative work, the Control Center and the Situation Room.
3.5. Risk analyses for temporary traffic measures

One of the most difficult issues was to undertake the works without cutting the traffic in the tunnel. Anyhow, some tasks obviously needed a tube without traffic (mounting jet fans, coating, etc.) so, traffic had to be diverted through the other tunnel and the existing and winding county road.

Which was the best traffic diverting alternative in terms of safety was assessed through the well-known Quantitative Risk Assessment Model (QRAM) to evaluate the risks of dangerous goods transport through road tunnels.

![QRAM results showing the risk of every alternative route.](image)

**Figure 7:** QRAM results showing the risk of every alternative route.

4. CONCLUSIONS

The tunnel of Folgoso is the longest Spanish highway tunnel that has been refurbished to meet RD 635/2006 standard. The refurbishment improved of several features concerning civil works and modernization of safety systems.

Due to its singular characteristics, this project was carried out by a multi-skilled team which could provide useful solutions to actual issues through their expert approach.

The main challenges undertaken were:

- Developing a novel anti-glaring system
- Lighting system optimization
- Electric system optimization
- Designing a scalable Control Centre

5. REFERENCES

Directive 2004/54/EC on minimum safety requirements for tunnels in the Trans-European Road Network.

Royal Decree 635/2006, Spanish standard for safety in road tunnels.

Tunnel of Folgoso Refurbishment Project, 2006.