1 INTRODUCTION

Road tunnels have several systems to ensure a good exploitation of the tunnels, both in regular and emergency conditions. These systems must be inspected periodically to verify whether they work properly. In Spain, these kind of inspections are mandatory every 3 years, as stated in Brazilian legislation, ABNT NBR 15661 “Proteção contra incêndio em túneis”. In Spain, these inspections are compulsory according to Royal Decree (RD) 635/2006 about minimum safety requirements in Spanish road tunnels. Within this context, in June of 2010 the Road Department of Ministry of Public Works (DGC) gave the start for the contract “Tunnels’ Inspection, according to RD 635/2006, Zone 1 (North) of Spanish road tunnels”. In this paper a summary of the inspection works is presented, developed between 2010 and 2012, in tunnels of the Spanish Road Network (SRN) located in the North of Spain.

2 INSPECTION OF TUNNELS INCLUDED IN SPANISH ROAD NETWORK

To perform the tunnels’ inspection works, DGC divided the tunnels in three big areas, as shown in Table 1.

<table>
<thead>
<tr>
<th>Zone of Spain</th>
<th>No. of Tunnels</th>
<th>No. of Tubes</th>
<th>Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North (1)</td>
<td>111</td>
<td>176</td>
<td>107</td>
</tr>
<tr>
<td>Centre – South (2)</td>
<td>77</td>
<td>128</td>
<td>78</td>
</tr>
<tr>
<td>East (3)</td>
<td>133</td>
<td>169</td>
<td>77</td>
</tr>
</tbody>
</table>

The geographic distribution of each inspection area is shown in Figure 1.
Figure 1. Geographic distribution of inspection areas.

Figure 2 shows the level of compliance with the inspection of tunnels in Zone 1, from August 2010 to April 2012.

The inspection works of a tunnel include the review of the following points:
- Documentation: Operation manual, self-protection plan, detailed design, electrical refurbishment, general reports, etc.
- Civil works: Lining, structure, pavement, sidewalks, drainage, exits and evacuation routes.
- Safety equipment: ventilation, lighting, electrical installation, fire detection and suppression systems, communications, etc.
- Maintenance and exploitation conditions: Plans and protocols, staff and workteams.

3 LEGAL FRAMEWORK

RD 635/2006 about minimum safety requirements in the Spanish road tunnels is an adaptation to the national law of the European Directive 2004/54/CE on minimum safety requirements for tunnels in the Trans-European Road Network, which establish as compulsory to carry out inspections in tunnels with periodic intervals of 5 years.

Inspections are carried out following the Spanish Order 27/2008 about tunnel inspections’ methodology, developed and approved by DGC, setting out the items to be inspected and describing the guidelines for inspecting each equipment.

Based on this Order, procedures were developed for each installation, establishing the actions to follow for a complete inspection of a tunnel.

4 TUNNELS’ INSPECTION METHODOLOGY

In order to carry out tunnels’ inspection, Geocontrol have studied thoroughly the Ministry of Public Works’ methodology, and tailored it to make them feasible in a perfect cohabitation along with tunnel operators.

Thus, drivers suffer minimum affection during these works.

Tunnels’ inspection has three different phases:
- Initial Phase: Data compilation, previous analysis of the data and development of a preliminary report, including a planning of each inspection, coordinated with the tunnel operator.
- Development Phase: Performance of inspection tests needed to verify the correct operation of the equipment, infrastructure, maintenance and exploitation conditions.
- Evaluation Phase: Processing information from inspections, and development of an evaluation report.

4.1 Initial Phase

This first phase begins with gathering all possible data related with the tunnel:
- Detailed designs.
- Refurbishment projects in accordance with R.D. 635/2006.
- Safety instructions.
- Inventory sheets.
- Reports from tunnel’s safety responsible.
- Definition of tunnel’s IT architecture.
- Applicable regulations at time of design and construction.
- Routine inspections undertaken by the company responsible for the maintenance and exploitation of the tunnel.
Within this phase, the tunnel is classified according to RD 635/2006 in terms of four parameters:
- Length.
- Volume of traffic.
- Traffic type: unidirectional or bidirectional.
- Location: urban or non-urban.

The minimum equipment for each tunnel to have is set in accordance to these characteristics. It is also developed a comparative analysis between the actual tunnel systems and its classification, evaluating at a first stage the conditions of the tunnel, that will be completed in the following inspection.

4.2 Development phase

At this phase a tunnel inspection is carried out with three types of tests, according with the level of affection to traffic.

Activities Type 0. They do not involve any alteration in the traffic inside the tunnel:
- Control Centre inspection.
- Technical sites inspection.
- Collection of data not collected at the Initial Phase I.

Activities Type I. They involve partial or total affection of the right traffic lane of the tunnel.

Activities Type II. Activities that require total affection of the left lane. They’re undertaken at night in order to avoid traffic affection during the peak hours.
- Ventilation and lighting testing.
- Left lane systems’ inspection.
- Galleries’ inspection.
- PA system tests.

4.2.1 Ventilation inspection

The main goals of this inspection are to verify:
- Equipment condition.
- Operation of jet fans in direct and reverse actuation, in manual and automatic mode.
- Operation of environmental detecting elements.
- The air velocity reached is equal or higher than the theoretical critical velocity.

In order to check this system, in tunnels with longitudinal ventilation, the air velocity is measured in different points with different configurations of ventilation, as shown in Photograph 1, from no jet in operation until the totality of jets in operation, comparing it with the figures from the tunnel’s anemometer to check its performance.

Photograph 1. Performing a manual measure of air velocity.

The variation of air velocity is recorded by a fixed anemometer, as shown in Figure 3, which allows analysing the influence of each fan in the ventilation system.

Figure 3. Air velocity in the transversal section of a tunnel.

The sensors are verified applying standard gases (CO, etc.) on each equipment, checking the readings on the control system as well as the correct ventilation procedures.

4.2.2 Lighting inspection

This inspection verifies that the light levels obtained in the interior of the tunnel are adjusted to the values presented in the design project or to the values recommended by DGC.

A measurement mesh that comprises a module from the lighting system is drawn on the floor, near to the tunnel entrance. Illumination data are compiled within this mesh, using a luminancemeter, as shown in Photograph 2.
Additionally, in the same knots of the mesh used for luminancemeter, measures with a luxmeter are taken.

All these values are processed to obtain their medium values and uniformity, in order to compare with the values obtained in the original design.

To verify the correct and progressive adaptation of the light level to the needs of the human eye, a longitudinal measure of the whole tunnel with a luxmeter is done, obtaining its illuminance curve, as shown in Figure 4.

Finally, the sensors that provide information to the control system to regulate automatically the light are reviewed, i.e. photocells, luminancemeters, luxmeters.

4.2.3 Electric inspection

A thermographic inspection is performed as shown in Figure 5, as well as a visual inspection of the installation elements, and it is verified that the installation has been reviewed by an Authorized Control Agency.

4.2.4 Fire protection inspection

This inspection verifies the operation of fire detection and suppression elements, analysing the following elements:
- Deposits.
- Pumps.
- Hydrants.
- Fire Hoses.
- Fire Extinguishers.
- Fixed firefighting systems.

4.2.5 Surveillance and control systems’ inspection

It involves all the installations related to the monitoring of the tunnel:
- Control Centre and communications network.
- Surveillance systems: CCTV and automatic incident detection.
- Traffic control.
- Tunnel closure equipment.
- Signs, markings and road signs.
4.2.6 Inspection of communication systems
This inspection concern equipment used to communicate with the users in the tunnel or with the emergency services, such as:
- PA system. This test verifies if the level of audibility of the system in the tunnel is appropriate.
- SOS Stations. Their conditions and operation are reviewed, checking the possibility to make calls and their correct reception at the Control Centre.
- Radio communications. Radio transmissions used by emergency services and emission of messages by radio channels to tunnel users are verified.

4.2.7 Inspection of civil works
It is carried out mainly by visual means, being out of the initial scope of this inspection the geotechnical and structural control, which may be needed later depending on the results of this first inspection.
Possible defects and pathologies are detected, dimensions are checked, and conservation and maintenance of the tunnel are reviewed.

4.2.8 Inspection of the conditions of maintenance and exploitation of the tunnel
The compliance of the different plans established in the safety documentation is verified, such as: preventive and corrective maintenance, circulation of heavy goods, staff training, etc.
The correct application of the integral management system of the tunnel is checked for the main actuation procedures (cutting of a lane, tunnel closure, fire, etc.). It is also checked if the tunnel is equipped with the necessary human and material resources for a correct operation.

4.3 Evaluation phase
For each system there are established three levels of compliance with regulatory requirements: favourable, when they fulfil their function, favourable with remarks, when they fulfil the function but present minor anomalies, and unfavourable, if there are failures that won’t allow the system’s correct function.
With these criteria, it is developed a complete report with the compliance of the regulatory requirements for each system, and an estimate budget needed for upgrading the tunnel to safety standards, including a drawing where there are showed the main installations of the tunnel, and the results of the inspection through a colour code as shown in Figure 5.

Figure 5. Summary of the inspection of a tunnel.

The report concludes with a final statement about the inspection results, according to the established criteria.

5 COMPUTER APPLICATION FOR INFORMATION MANAGEMENT
It has been developed a computer application called BIT 2.0, which includes a complete inventory of each tunnel, the relevant data of all significant safety events that occur in them, reports of the periodic inspections, as well as the specific documentation of each tunnel as shown in Figure 6.

6 CONCLUSIONS

Road tunnels require many safety systems for their exploitation in regular conditions or in emergency situations. To ensure that this equipment works properly it is needed an adequate maintenance and periodic inspections, systematically and independently undertaken.

In order to review the equipment, civil works, conditions of maintenance and exploitation of the tunnels, DGC is doing periodically inspections of the tunnels in the Spanish road network. The need of these inspections, as well their frequency, is set according to RD 635/2006 about the minimum safety requirements in Spanish road tunnels.

From the inspection so far, it can be concluded that both the maintenance and overall exploitation of the tunnels are satisfactory. Currently, many tunnels are still to be upgraded to RD 635/2006 standards, so there are some defects in certain installations, noticeable especially in old and long tunnels.

REFERENCES


