Assessment of tunnels condition through high efficiency techniques

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Abstract: To ensure commuter's safety and continuous long-term operation, tunnels managers and owners must know and control the condition of their costly and strategic infrastructures at all times. This involves preventive maintenance of which inspection constitutes the essential basis. Remote inspection techniques provide objective, reproducible and comprehensive digital data on tunnels condition while significantly reducing on-site intervention duration and improving data quality. Based on our accumulated experience, this article presents the main features of the ScanTubes® system and mentions upcoming developments.

Keywords: tunnels; preventive maintenance; operation constraints; remote inspection; digital twins; comprehensive & objective data records.

1 Introduction

Periodic inspections are one of the fundamental bases of preventive maintenance of tunnels. The early detection of anomalies and defects, the evaluation of their evolution and their severity constitute essential information for planning and budgeting the actions required to ensure the continuity of operation and to maintain the infrastructure in good condition during all its lifespan. To be fully usable, the results of periodic inspections must be objective, comprehensive and reproducible with durable and easily readable records. However, operating conditions, the evolution of maintenance organizations and human factors can constitute obstacles to achieving these objectives. The ScanTubes® system was developed to facilitate and objectify data collection while significantly reducing on-site intervention time and improving data quality. Furthermore, once collected, the data can be processed for several purposes such as the production of digital twins, inspection, thermal analysis, geometrical evaluation or 3D modelling.

2 The ScanTubes® system

2.1 Hardware

ScanSites® system consists of an active head, an adaptable trolley and a control unit (figure 1). The active head includes a set of digital cameras, a flash system and, when necessary, infrared cameras. The lightweight trolley is adaptable to road and rail; it triggers the cameras and the flash system thanks to a synchronization device connected to its wheels. The system is energy autonomous and the data acquisition speed between 3 and 6 km/h, approximately 10 to 15 times faster than for a traditional inspection. Thanks to its design, ScanTubes® system can be adapted to any tunnel configuration (figure 2).

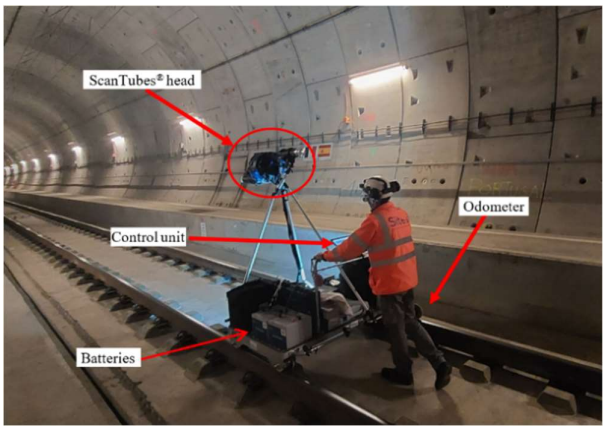

Figure 1 ScanTubes® system on operation in a rail tunnel

Figure 2 Adaptation of ScanTubes® system to large tunnels

2.2 Data processing and digital outputs

Depending on demands, data processing can produce 2D visible / thermal orthophotographs, 2D gradient and depth orthophotographs, 2D sub-pixel overlap, 3D point clouds or 3D textured models. Instead of detailing all these processes, we simply prefer to mention that once back at the office, the tens of thousands of high-resolution pictures recorded on-site are orientated and assembled. Subsequent processing mainly consists of computing point clouds and generating orthophotographs. These initial digital outputs can then be specifically processed to produce the required deliverables.

3 Selection of results

This selection illustrates the different types of information that can be extracted from the data collected on site.

3.1. Inspection

Inspection is done at the office though observation of 2D orthophotography. Defects are accurately identified, characterized and localized (figure 3).

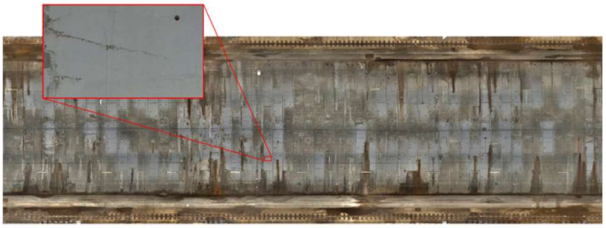

Figure 3 Inspection on 2D orthophotography (excerpt)

The evolution of defects in terms of speed and extend is achieved by a precise overlapping of images coming from successive inspections (figure 4).

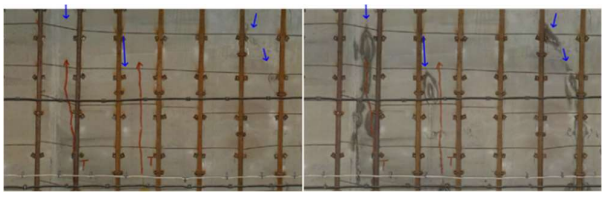

Figure 4 Evolution of water seepages (left: 2021, right: 2022)

3.2 Thermal 2D orthophotography

Using visible and infrared cameras simultaneously provides additional information such as identifying overheating device or differentiating between humid and dry stains.

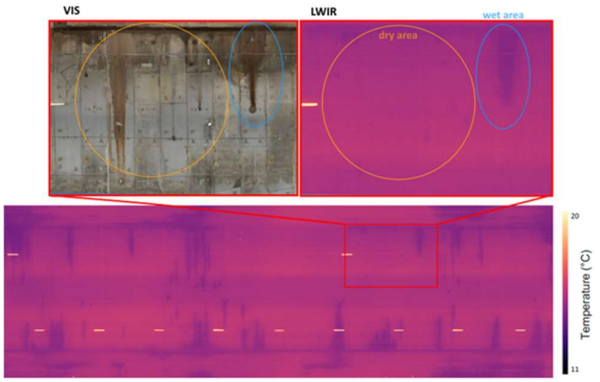

Figure 5 Differentiation between humid and dry stains

3.3 2D gradient and depth orthophotography

Geometrical anomalies are detected and characterized by the production of depth map which allows detecting deviations from reference geometry and highlighting depth gradients.

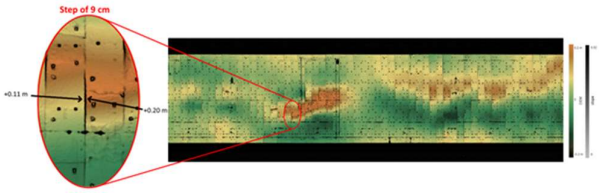

Figure 5 Depth and gradient map

4 Conclusion and prospectives

Our in-depth feedback on different tunnel types and operator requirements demonstrates the benefits provided by ScanTubes® system: objective, comprehensive, accurate and repeatable information is obtained through high efficiency on-site interventions. Improving data processing using IA, increasing the speed of on-site acquisition and adding new assessment devices are some of our next developments.

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