Tunnelling and Underground Space Technology 50 (2015) 516–522

Contents lists available at ScienceDirect

Tunnelling and Underground Space Technology

journal homepage: www.elsevier.com/locate/tust

Technical Note

Ventilation management system for underground environments

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ARTICLE INFO

Article history:
Received 12 May 2014
Received in revised form 30 July 2015
Accepted 1 September 2015

Keywords:
Underground ventilation
Geographic information system (GIS)
Health and safety
Efficiency

ABSTRACT

The management of the ventilation system is crucial to deal with efficiency, health and safety issues in an underground environment. This paper presents the design of a geographic information system – also known as GIS – capable to store, manipulate and extract results from the data collected regarding the ventilation features of an underground mine. The GIS can also be adapted to other types of underground infrastructures or include any additional parameter required.

A database of these parameters, in a case study, has been created taking into account two conditions: The changeable layout of the ventilation system during the evolution of the mine and the location of the control points, so the information can be analysed with the GIS in many different ways and purposes.

Therefore, the system can control the underground conditions in the long term and evaluate any change applied to the ventilation circuit.

The study has given insight of the most sensitive parts of a mine in terms of gases, temperature, air velocity and airflow – either from the principal or auxiliary ventilation circuit – finding a relationship among the airflow quantity, gases concentration and effective temperature.

1. Introduction

Environmental conditions such as effective temperature, gases concentration or airflow have to be controlled and kept within an acceptable range in underground infrastructures where there is a presence of people. These types of space can be found in underground mining, civil infrastructures and tourist mines and caves, being of great concern the implementation of a management system for such purposes (Düzgün et al., 2011; Alfonso Abella et al., 2013).

In general, the most adverse conditions appear in the mining sector, where the control of the underground environment is compulsory. Therefore, it is important the implementation of a methodology for managing this question, otherwise occupational hazards and operating cost rise exponentially either by legal restrictions or by a reduction in the worker's performance. Thus, the system will have to take into account all the ventilation parameters to deal with efficiency and health and safety issues at the same time. However, their connection is usually overlooked. According to Reddy (2009), up to 60% of the mining operating costs are attributable to mine ventilation, while the relationship among hygienic conditions, accidents and worker's efficiency has been previously mentioned by Garcia-Herrero et al. (2012).

Many investigations have been focused on occupational health and safety or efficiency (Allen et al., 2008; Kurnia et al., 2014), and some of them use a software to optimise or modelling parts of the ventilation system (Hargreaves and Lowndes, 2007; Toraño et al., 2011; Cheng and Yang, 2012; Likar and Čadež, 2000). Moreover, the usage of GIS in mining is quite frequent, varying from management (Düzgün et al., 2011) to pollutants emission (Puliafito et al., 2002) or subsidence (Kim et al., 2006) among other applications. However, it is rarely used for the management of ventilation matters (Liu et al., 2004; Salap et al., 2009) and not even mentioning the efficiency concept. Despite that, a geographic information system is able to provide the tools, frameworks and understanding of the real situation inside a mine (Saleh and Cummings, 2011) so programs and procedures can be implemented to ensure health and safety objectives (Akcil, 2006) through a database of the underground environment features such as airflow, gases or air pressure drop.

The aim of this paper is to propose a system for managing an underground environment that is able to analyse the real conditions in the long term and provide insight for controlling the current situation and future improvements in terms of working conditions and efficiency of the mine. Its creation will also give a new utility for a GIS.

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http://dx.doi.org/10.1016/j.tust.2015.09.001
0886-7798/

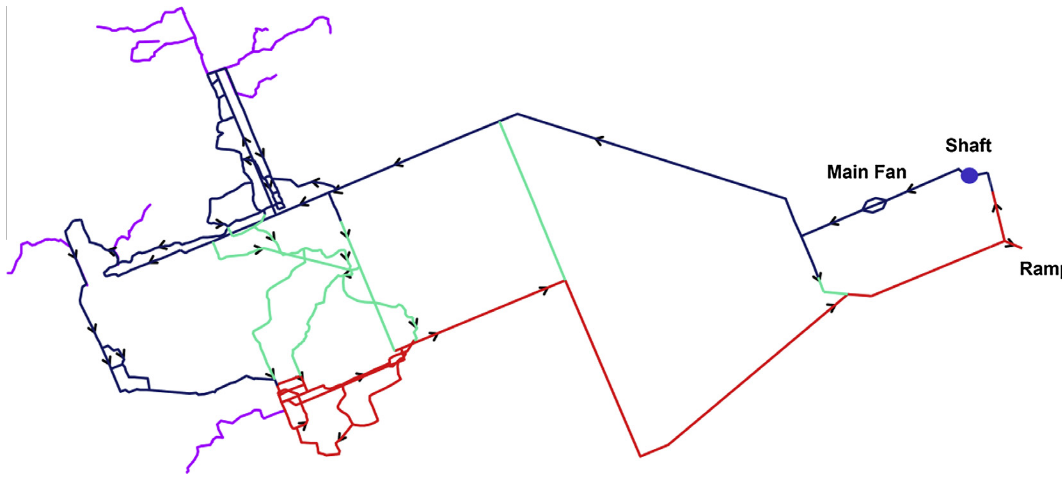

Fig. 1. Scheme of the ventilation circuit.

The software fits perfectly with what is demanded in a place that spreads out every day and generates a huge quantity of interconnected spatially referenced information from monitoring a dynamic environment (Gibert et al., 2006). Having the possibility to analyse the data and finally extract conclusions in the form of tables, graphs and even convert the information to other software formats.

2. Case of study: Mine description

The investigation has been focused on a Spanish mine, which is exploiting potassium from the Catalan basin. The resource is exploited by means of a room and pillar system 500 m below the surface and the connection underground-surface is done through a shaft (intake) and a ramp (return). The main fan is placed at the beginning of the ventilation circuit, leading the airflow by temporary stoppings, curtains and doors. Meanwhile the auxiliary circuit provides clean air to every working face through a duct system. Fig. 1 is a scheme of the mine described above with the most important elements labelled. The image is one of the configurations created using the GIS and it displays the parts of the ventilation system in different colours: The intake is in colour sea blue, the return red,[1] the leakage sky blue and the auxiliary system pink. The airflow direction has also been indicated.

Initially, the staff of the mine had not stablished the position of the ventilation control points and an adequate analysis of the data collected was almost impossible when the factor time was included in the assessment, being needed a systematic method.

Salap et al. (2009) exposes an interesting approach for managing this type of environments, but it does not take into account all the parameters required for fully control the environmental conditions in this case, so it has been created a GIS based on the factors mentioned by Cheng and Yang (2012) and McPherson (2009) regarding efficiency and safety variables.

3. Methodology and database

Among all the software available, it has been chosen the ArcGIS because of its user-friendly platform, it is widespread in many different sectors and can be employed in any underground space apart from mines. The version used is the 9.3, but anyone would suit.

[1] For interpretation of colour in Fig. 1, the reader is referred to the web version of this article.

3.1. Data collection

First, several points standing for the real conditions of the whole ventilation system have been determined based on the following rules:

- Principal circuit: Important places from the intake, return and leakage airways.
- Auxiliary circuit: Variable position corresponding to the continuous miner location in the working faces.

Parameters used in the paper were obtained in situ and measured by conventional methods. They were taken during the same period of time in two consecutive days every month, one for the principal circuit and other for the auxiliary. Overall, 753 points have been stored in an Excel file since April 2009, 594 from the principal and 159 from the auxiliary.

The validity of the analysis depends on the method used for obtaining the data. The lower the reliability of the outcome is, the more difficult it is to detect the effects of an intervention (Lipsey, 1990), typically because of instability in what is measured and variations in the instrument (Shannon et al., 1999). For this reason, the equipment is calibrated regularly and measures are taken twice.

3.2. Data format and characteristics

The initial information consisted of several maps in dxf format (AutoCad) containing the layout of the mine along the time and the database in xls (Excel) with the ventilation parameters. Both files were merged and transformed to a shape file through ArcGIS, connecting the information from the key points with their position in the ventilation layout using the Universal Transverse Mercator projection (UTM) as a reference system. The merger process requires a standardised format for the database, otherwise problems can arise in the pre-processing stage.

3.3. Pre-processing

For the construction of the GIS file, these maps and ventilation data have been divided in different layers regarding two conditions: principal and auxiliary circuit with regard to every ventilation layout. This division makes the database management easier since they have different features and therefore separate analyses are required. Next step was to adequate the database storage from