Treatment of old disused mine openings

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TREATMENT OF OLD DISUSED MINE OPENINGS

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ABSTRACT

According to French regulations, the main objectives for the treatment of old abandoned mines consist of : preventing collapses and dangerous subsidence, controlling mine gas emissions and closing old abandoned mine openings.

In the Herault coal basin, underground exploitation started very early, in particular by the way of shallow adits dug in hillsides. Today more than 600 adits have been listed on old maps but a lot of them have not yet been precisely located.

Charbonnages de France and INERIS have analyzed all risks generated by these old openings and have established a methodology able to determine the closure procedure which can guarantee the safety of the opening. This methodology can be adapted to an adit (size, state of...) and to the physical characteristics of the site (gas, water, location...).

In order to limit the number of configurations, two of the above factors have been retained : the state and the location of the gallery. After analyzing all the possible configurations, closure principles have been determined for each of them.

The paper :

- discusses geographical and historical background of the Herault basin exploitation,
- list the specific parameters which influence the choice of process able to secure the adits,
- present the general methodology used.

Finally, the treatment of an adit located under inhabited areas is presented.

INTRODUCTION

According to French regulations, the main objectives for the treatment of old abandoned mines consist of :

- preventing collapses and dangerous subsidence;
- controlling mine gas emission and mine dewatering;
- closing old abandoned mine openings.

As part of the treatment of the Graissessac coal basin, Charbonnages de France and INERIS have analysed all the risks generated by numerous disused adits located in this area. A general method has been established to determine the closure procedure that can guarantee the safety

of the opening. It is adaptable to various configurations (geometrical parameters, present state of galleries, location...) and site physical characteristics (geology, presence of gas or water).

This paper firstly presents the geographical and historical backgrounds of the Graissessac coalfield. Then the specific parameters that influence the choice of a particular process able to secure the adits are calculated. Finally the applied general methodology and the treatment of a particular case are presented.

GEOGRAPHICAL AND HISTORICAL CONTEXTS OF THE GRAISSESSAC COALFIELD

The Graissessac coal field lies in the North-East of the Département de l'Herault, about 50 km West of Montpellier. It belongs to the stephanian coal fields located in the Massif Central of France. It is an E-W synclinal, about 20 km long and 3 km wide.

According to previous studies, the area may have been exploited for its mineral resources since Antiquity. The very first documents relating to coal extraction in Graissessac date back to XIIth century but the extraction process was industrialised during the XIXth century.

For a long time, underground exploitation remained artisanal and generated numerous mine openings. Although the number of mine shafts is quite low (around 10), more than 600 disused adits have been listed from old maps, some of them still not being precisely located. These adits are present in various shapes and sizes and most of them have been dug into hillsides.

Underground exploitation ended in 1964 but coal continued to be extracted by way of large open pit mines which have been definitely closed in 1993. In accordance with French regulations, Charbonnages de France have recently analysed the kind of risks which could result from the presence of these adits and treat them in order to avoid accidents.

The hummocky topography of the site compounded with the low agronomic quality of soils limited the development of cultivated lands in the valley floors, in the vicinity of the few villages founded by miners. Moreover, the hillsides are not easily accessible on account of fairly dense vegetation. On the one hand this prevents to a large extent frequentation of the sites, but, on the other hand, it limits the spectrum of stabilising techniques requiring heavy vehicles.

Even though the Graissessac basin presents a low damage potential as a whole, it seemed necessary, however, taking into consideration the proximity of some galleries to urban areas and to main traffic roads to recommend a number of closure principles.

SITE SPECIFICATIONS

In order to ensure the ease of the process, a methodology adaptable to different kinds of orifices and various environmental contexts has been achieved. Different configurations have been defined to make the classification of galleries as systematic as possible.

For simplification and clarity, the number of basic parameters has been limited to reduce the quantity of crossed cases.

Basic parameters

As far as the Graissessac Basin is concerned, two basic parameters are taken into consideration. These are:

- the perceptible state of the underground gallery;
- the gallery environment (i.e. its proximity with sensitive installations).

State of gallery

This parameter depends essentially on the age of the gallery, its geological context as well as the kind of support adopted. As most galleries have either collapsed, degraded to a large extent or have been subject to some kind of treatment or other, it is now rare to have access to old underground works. Three « States of gallery » were considered to describe adits:

- those of the galleries that are not located. Although their presence is not in doubt (thanks to maps, statements,...), it has not yet been possible to locate them with precision on the ground ;

- those that have collapsed, caved in or have been backfilled. Galleries can collapse as a result of either the natural ageing of the structure or human activities. Some of these are easily percieved. Most of them are naturally or artificially remodeled and can be observed as subsidence phenomena on the surface of the hillsides. Galleries in such a state permit the circulation and emission of the gases, and threaten the safety of the environment ;

- those that are still opened or were only walled in. Open galleries are relatively rare in the basin. Galleries closed off by masonry are quite numerous. Holes in thes walls which are due to acts of vandalism or which have been designed to allow the circulation of water enable also the emission of mine gases. Hence this type of treatment is not considered to be satisfactory over a long period and it is often necessary to remove the wall.

Position of Gallery

The proximity of a gallery opening to sensitive installations such as habitations or traffic roads greatly influences the nature of risks susceptible to affect the site. Three possible « position of gallery » were defined :

- proximity to urban areas or regularly frequented areas such as stadiums, orchards, gardens.... Such a configuration requires optimal security for gallery openings in order to reach a tolerable level of residual risk.

- galleries that are not located in urban areas but extend under or next to roads. In such cases, levels of risk are lower than for the previous case but the regular circulation of people and the extra loads due to motorised engines have to be taken into consideration.

- galleries located in areas not easily accessible and far from any sensitive structure. The low damage potential in these cases does not imply treatments as severe as those required by the previous cases in order to reach a comparable residual level of risk. In such a case, one should focus on the limitation of gas circulation or accumulation in cavities close to the surface.

TREATMENT TECHNIQUES SPECIFIED TO EACH CONFIGURATION

Each configuration requires specific treatment. Table 1 summarises the configurations in relation to the two parameters as defined above. A slip is associated with each of the 9

configurations. On such a slip, the risk incurred as well as the main objectives to be achieved are gathered. Various techniques of stabilisation are then proposed. They provide principles that have to be adapted to the site.

It should be noticed that in the case of galleries located in an urban area, the configuration should not be expected to be associated with one of these slips as the complexity of the situation as well as structure vulnerabilities, close to or above galleries, are too specific in each case. Hence a specific study has to be carried out for such galleries.

State Position	Not located	Collapsed, caved down or backfilled	Open or lightly walled in
Isolated area	Slip 1	Slip 4	Slip 6
Proximity with a road	Slip 2	Slip 5	Slip 7
Urban area	Slip 3	Requires a specific study	Requires a specific study

Table 1

AN EXAMPLE OF SLIP

Hence for a given configuration the operating company is simply requested to define both « position of the gallery » and « state of the gallery » parameters. This couple is associated with a slip as defined above. The operating company can then apply the recommended treatments explained on the slip to satisfy the French regulation.

You will find further the slip number 4, corresponding to a collapsed gallery located far from any sensitive structure.

EXAMPLE OF A SPECIFIC STUDY - THE SAINT-JOSEPH MINE CASE

Background

The Saint-Joseph mine was dug in 1859 and definitively closed in 1870. Unfortunately there are few documents describing the main entrance gallery.

Geological Context

Only pieces of information on surface geology were accessible and observations are limited to :

- in the gardens located close to buildings called « Les Bâtisses », one can notice the presence of sandstone with soil. Because of dense vegetation making any visual observation very difficult, it has been assumed that the opening of the gallery was situated within this formation ;
- « Les Bâtisses » were founded on fill made of mining materials. If we assume the height of the fillslope being approximately equal to the thickness of the in-situ layer, it is around 5 m thick (fig 2).

Current state of the gallery

Before the visit of the adit, the opening of the Saint-Joseph gallery was closed by masonry presenting a split in its lower part allowing water circulation.

The gallery, slightly inclined, is 2-meter wide and 3-meter high. A visit to the mine in March 1998 showed the gallery to be in a good state of as a whole along the first 600 meters. It was not possible to visit further as the gallery was obstructed by some collapsed material.

SLIP N°4

Configuration

- State of the gallery: collapsed, caved in or backfilled
- Position of the gallery: far from any urban area and not susceptible to extend under a road

Encured risks

- Destabilisation of materials obstructing the opening
- Gas emissions through collapsed or backfilled materials and gas accumulation in voids near surface
- Collapses above residual voids located back from the opening.

Objectives to be reached

- To achieve the closure of the gallery entrance if necessary in order to avoid any penetration
- To limit air circulations and avoid gas accumulations.

Proposed techniques

As the adit is located in an area of low damage potential, it would be uneconomic and useless to proceed to a systematic treatment of residual voids back from the gallery opening. Indeed the probability of occurrence of a residual void, a brittle and rapid propagation of a sinkhole through the soil and to the surface, and the presence of a person on this place, at the right moment is definitively very low and the risk encured can be considered as acceptable.

Hence the treatment would simply consist of ensuring the non accessibility of the gallery and avoiding gas accumulation.

Even if the gallery is partly or fully collapsed, it is however necessary to ensure a sufficient obstruction of its entrance. If the volume of collapsed material at the entrance is not sufficient, one should proceed to either :

- its clearing and a higher quality backfilling of the entrance,
- the collapse of surface material at a sufficient distance back from the entrance,
- according to the topography, a hillock of surface materials may block up the gallery opening. This hillock should keep its obstruction characteristics despite being affected by some residual consolidation or some debris slipping from it.

The necessity of ensuring complete obstruction of the gallery entrance by one way or another is imposed by the second objective, that is avoiding gas circulations. Finally any hollows or dead ends should be treated, as these could enable some gas accumulation and hence, be of great danger.

Land use

The opening of the gallery is located next to a road. Hence vehicle may easily access the gallery and the spectrum of treatment techniques is not limited.

Along the first 100 meters, the gallery is located under private gardens. It then goes beneath some buildings called « Les Bâtisses ».

Hydrogeology

Mine dewatering is achieved through the gallery. The average flow rate is 19 m^3/h and reached around 40 m^3/h in September 1995. Water comes from a source located 10 meters back from the opening. Its average conductivity is low (less than 300 μS/cm), no deposit has been noticed at the exit and the concentrations of typical mine chemical substances are low (these are HCO_3, Fe, Mn, SO_3, Na, Mg...). These arguments may lead us to assume that most of this water is meteoric and does not come from old mine workings. Water is diverted towards *Le Clédou*, a river, for irrigation purposes.

A water source with quite a high flow rate has been noticed 50 meters back from the opening. It is assumed to come from some brook on the surface. Beyond this source, the gallery is dry.

Pit gas emanation

During the exploitation, a fire damp hurt someone in the Saint-Joseph mine area on 25 September 1869. In October 1997, atmospheric measures showed some outward air circulations. They revealed the following concentrations: O_2 8.7%, CO_2 9.3%, CH_4 0%.

Even though in March 1998 the atmospheric conditions were more satisfying and allowed a complete visit of the gallery, these data suggest the necessity to take special recommendations concerning pit gas emission treatment.

Risks encured

- collapse and subsidence are expected to affect both mine and surface. Under this threat, no sensitive installations were build within an area 100 m back from the entrance ;
- the masonry is not sufficient to guarantee no gas circulation and no human penetration.

Methodology and recommended treatments

To avoid a sinkhole developing through the soil and affecting the surface, it was decided to backfill the mine along a sufficient distance to ensure an acceptable level of safety. In order to assess the height to which a sinkhole may extend, some volumetric calculations were carried out. These calculations are based on the principle of a circular chimney that develops until the volume of collapsed material equals the volume available in the gallery (that is a cone) and the volume of the chimney itself by virtue of soil natural bulking characteristics. Hence the main parameters taken into consideration are:

- gallery geometric parameters,
- bulking factor, considered to be in the range 1.25 to 1.35,
- the angle of the cone that is the angle of repose of caved rock within the gallery.

The models used were those of a rectangular and a semi-elliptic gallery to frame the actual result. Calculations showed that the maximum height of a chimney would be between 44 m and 49 m. These yielded quite accurate value and it has been possible to decide from which point no backfill would be required to ensure safety on surface. The same calculations were computed with backfill corresponding to 80% of void volume and to 50% void.

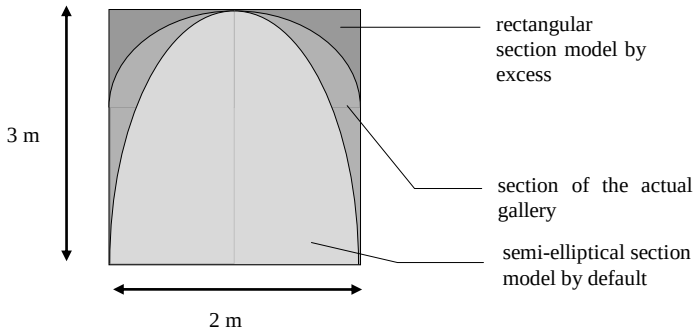

Fig 1 showing the models used for the actual section of Saint-Joseph Gallery

Percentage of void volume backfilled	maximum height of a sinkhole development
0%	44 m - 49 m
50%	23 m - 26 m
80%	10 m

A factor of safety has been chosen taking into consideration the lack of information on parameters as well as the damage potential of surface structures. As two sensitive structures are located above the mine and the thickness of covering materials has been found not to be sufficient, a backfill of the full gallery volume is recommended. As shown on figure 2, it has been possible to propose a « by step » backfilling procedure, each zone backfilled separated from the other by a wall to limit fill dispersion.

As far as the opening is concerned, an integral treatment is recommended to block up the gallery entrance by one way or another as explained before.

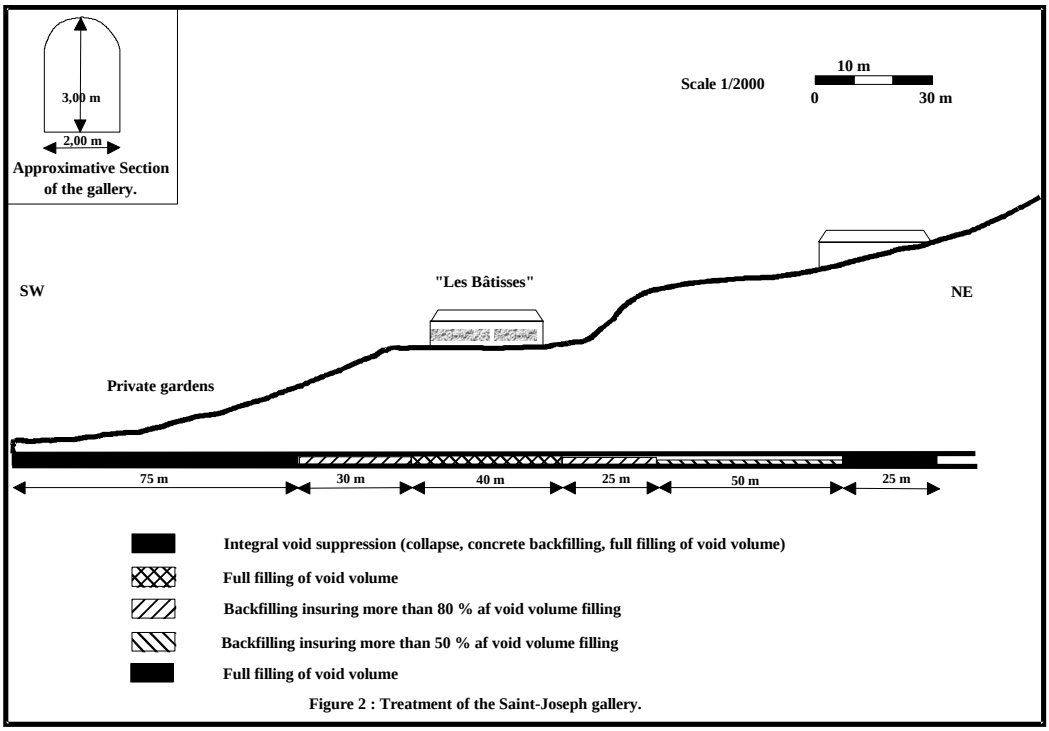

Figure 2 : Treatment of the Saint-Joseph gallery.

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