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Water Rock Interaction [WRI 14]

In-situ and laboratory tests to evaluate the impact of water table fluctuations on stability of underground chalk mines

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Abstract

Shallow underground mines can be flooded if there is a rise in the water table, which reduces pillar strength and increases risk of collapse and surface subsidence. To prevent this, INERIS is studying rock behavior in two underground chalk mines in northern France. In the first mine, the water content of a flooded pillar is almost constant (~20%) in its internal zone, while it varies from 14% to 22% in its external zone, due to variations in the groundwater table. In the second mine, the pillar is episodically flooded and, even if no flooding occurs, the groundwater table variations cause simultaneous fluctuations of the pillar extension rates due to capillarity: from 4-5% in the middle to 10-14% in the external zone. In parallel, laboratory tests have been carried out on chalk samples. They show differences between the geomechanical behavior of these chalks: one is dolomitic and has a higher inherent strength (i.e, more resistant to water) than the other, which has a glauconitic composition.

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1. Introduction

In France, there are about 500,000 known mines, and many of them are located in the chalk, limestone, or gypsum of the sedimentary Paris Basin. After abandonment, degradation occurs and internal collapses may appear and progress to the surface inducing subsidence bowls or sinkholes. Catastrophic collapses of abandoned underground mines have already occurred, particularly in the chalk of the Paris area: Château-Landon (7 deaths in 1910), Clamart (21 deaths in 1961), Chanteloup (1 death in 1991), Bagnolet (2 deaths in 1993). Most of these mines extended down to the groundwater table. Therefore, any significant

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fluctuation of the groundwater table can lead to their flooding or dewatering. The question arises whether these fluctuations can aggravate or accelerate the ageing and the degradation of the stability, especially if they become more important due to the context of climate change. The research program studies the impact of water table fluctuations on the long-term stability of chalk mines pillars, particularly in the context of climate change. We present here the experimental sites instrumented in the chalk of northern Paris Basin at Estreux (Nord) and Saint-Martin-le-Noeud (Oise), and the first results of the laboratory tests on rock samples.

2. Impact of water in the rock resistance

Rock behavior is sensitive to water content [1], especially in the case of porous rock. The increase of water content causes a decrease of the compressive strength that can exceed 50% for some type of chalk [2]. Chalk is a very porous rock (20-40%) and therefore very sensitive to changes in water content. Laboratory tests had showed that the development of cracks during saturation/desaturation cycles can produce changes in humidity [3]. In the Estreux chalk mine, it has been noted that the variations of the relative humidity of the air from 80 to 100% can saturate/desaturate the rock at the pillar surface [4].

From a hydrogeological point of view, annual cycles of groundwater recharge results in winter high water tables and summer low water tables with about metric fluctuations. However, highest amplitude cycles can occur at multi-year scales and cause flooding or dewatering of shallow underground mines.

To study this water-rock interaction, pillars were instrumented by INERIS in two underground abandoned chalk mines. Chalk samples have also been tested in the Georessources' laboratory.

3. Results of experimental sites in the chalk of Paris Basin

3.1. St-Martin-le-Noeud's mine (Oise)

This mine is about 30 m deep and contains 24 underground lakes resulting from the flooding of the lowest galleries by groundwater. A pillar located into a lake was instrumented in 2009, around 1 m above the lake level, with TDR sensors (Time Domain Reflectometry [5]) to measure the rock water content at 0.2 m and 0.9 m depth. Another sensor measures the variations of the lake water level. It is known from previous studies that these variations can attain 1 to 2 m for over a century [6]: but since 2009, the average variation was only 0.3 m and the lake level globally decreased by 0.2 m due to the actual pluri-annual drought period in northern France.

In this mine, water content is almost constant in the internal zone of the instrumented pillar (~20% at 0.9 m) while it varies from 14% to 22% in its external zone (at 0.2 m). This causes horizontal saturation gradient whose evolution is modeled on the lake level variations (Fig. 1a), indicating water penetrates to at least 0.2 m inside the pillar when the lake level rises. Nonetheless, the lateral deformation rate of the pillar does not show a significant difference between the external zone (1.1×10^{-4} at 0-0.5 m) and the internal zone (9.5×10^{-5} at 0.5-1 m). It must then be noticed that, for technical reasons, the TDR probe and the extensometer located in the external zone are not at the same depth (0.2 m and 0.5 m respectively).

3.2. Estreux's mine (Nord)

This mine is about 20 m below the surface. The groundwater level can be 2 m above and 4 m below the mine: hence it is temporarily flooded when the water rises, i.e. every 8 years on average. The pillar was instrumented in 2004 with two strain gauges (anchored respectively at 0.1 m and 0.7 m deep)