Reduction of Surface Subsidence and Brine Inflow Prevention in Potash Mines by Subsequent Backfilling

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ABSTRACT: The slurry backfill technology has been successfully used in potash mines since 1908. The presentation summarises the results of several investigations on slurry backfill in German potash mining during the last 40 years. The positive effect of subsequent slurry backfill on the reduction of dangerous rock movements and surface subsidence is shown with examples.

1 INTRODUCTION

The worldwide annual potash extraction of approx. 23 million tons K$_2$O (e.g. as in 1999) by conventional mining methods creates mine openings of millions cubic meters. Because of the most ductile mechanical behaviour of the potash ore and the surrounding host rocks, these mine openings close themselves by time-dependent convergence processes. The related mass movement leads to subsidence at the Earth’s surface, above the mine openings, though the amount and rate of subsidence is controlled by geological (e.g. thickness and tectonic styles of cover rocks) and mining parameters (e.g. depth, overall extraction ratio, room and pillar geometry, extraction rate). The dynamics of this subsidence process influences the land surface (topography) and its natural and/or artificial dewatering systems as well as the buildings and infrastructure of the towns and villages by the slope gradient and ground deformations.

Inside the brittle cover rocks, this subsidence is mostly realised by frictional sliding on pre-existing faults and joints and occasionally by fracture propagation. Both mechanisms influence the hydraulic regime inside the groundwater aquifers.

On the other hand, the amount of residues from potash ore processing, compared with another mining branches, is relatively high. Therefore, the potash industry traditionally uses these residues as a backfill material.

In the German potash industry, backfill was used to reduce the surface subsidence above the mine fields, as well as for the reduction of mining losses. During the more than 140 years of production, different backfill technologies were developed due to the technical challenge.

In general, two different materials - rock salt from the development of long-life drifts and galleries or, as previously mentioned, residues from the potash ore processing - are used as backfill material. The processing residues are transported in a dry or wet form by downward shaft hoisting and/or conveyor belts (“dry backfill technology”) or as a suspension by pipelines (hydromechanical transport, the so-called “slurry backfill technology”).
2 ROCK MECHANICAL PROPERTIES OF DIFFERENT BACKFILL MATERIALS USED IN POTASH MINES

The effect of subsequent backfill on the reduction of the surface subsidence as well as on the increase of the exploitation rate, is controlled by its rock mechanical properties. The infill of solid material into the stopes or rooms after the excavation leads to a fast stabilisation of the pillars and the roof. So, the mining induced rock movements can be slowed down and limited by their absolute amount. As a result, the surface subsidence will decrease.

How can we influence the rock mechanical properties? They are controlled by three main factors:
- Mechanical strength,
- Grade of filling,
- Initial density of backfill.

The mechanical strength of backfill is determined by the compaction and solidification of the in-filled material. As the rock masses exert onto the backfill massive by convergence, the near-contour zone will stop its dilatation. The grade of refilling limits the extent of the roof convergence, whilst the initial backfill density limits the movement of the pillars.

During the history of the German potash industry, the following materials were used for subsequent backfill after the ore extraction:
- Residues of the potash processing and
- Rock salt from the drift development.

Both materials are of good mechanical properties to achieve a positive effect on the pillar and roof stabilisation. However, the differences can arise from the initial consistency of the material, as well as from the transport and infill technology. The advantages are on the processing resi-

![Figure 1: Triaxial strength of solidified slurry backfill in comparison with potash ore](image)

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**Figure 1:** Triaxial strength of solidified slurry backfill in comparison with potash ore
dues side, because of the moisture and better granularity of the material during the infilling, which leads to a fast compaction and consolidation.

As a result, a compact backfill massive, with a strength, comparable to the surrounding natural rock massive, is created. Figure 1 shows the uni- and triaxial strength, depending on the confining pressure, for solidified slurry backfill from German potash mines and for natural Silvinite and Carnallitite, following laboratory tests by Fulda, Jaeger et al. (1988).

Further investigations and laboratory tests on long-term consolidated slurry backfill material from several potash mines during the last years have shown the effect of a higher (triaxial) strength on the backfill material. Figure 2 shows the typical stress-strain-behaviour during a multistage triaxial test, following Sitz et al. (1999).

The following proven technologies have been used for subsequent backfill in the German potash mines:
- Slurry backfill,
- Dry backfill by slinger, pneumatic and drop stowing infill methods,
- Improved dry backfill by the moisturisation and compression of the material during the infill operations.

The latter method has been especially developed for the delayed backfill operations in the abandoned potash mines in Germany, because residues from the potash ore processing (needed for an effective stabilisation of the roofs and pillars) were not available since the shut-down of the mines.

The slurry backfill technology operates with the processing residues using two possible methods of transport:
- Shaft hoisting and haulage by conveyer belts or
- Pipeline systems from the surface to the stopes.

Figure 2: Differential stress and axial strain of solidified slurry backfill in a multistage triaxial test
The grade of refilling for the slurry backfill technology with pipeline transport can reach up to 95 % by volume, depending on the incline of the refilled stopes. On the other hand, the conventional dry backfill technology can only reach a maximum filling grade of 90 % through the use of slingers or pneumatic stowing systems (see figure 3).

The formerly used dry backfill technology with simple drop stowing can be improved by the addition of brine and the mechanical compression, e.g. through overdriving the infilled material with mobile equipment and/or stuffing. So, an initial density of the backfill material of about 1.65 t/m³ can be reached. By using the slurry backfill method an initial density of about 2 t/m³ in the backfill massive is reachable (see figure 4).
Which factors can be influenced by the rock mechanical properties of backfill? According to the general protective aims of mining operations, they are:
- Surface subsidence,
- Amount of seismic events or rock bursts,
- Damage of (hydrological) protective horizons by subsidence, leading to brine inflow.

The surface subsidence above potash mine fields is a time-dependent process, following the convergence of the underground stopes. Its horizontal expansion exceeds the edges of the mine fields, and depends on the strata and behaviour of the overburdening rock. The total amount of subsidence is controlled by the parameters (height, width) of the underground stopes, occurring gradually over several hundred years.

Until around 1968 in the Southern Harz potash district it was required by mining legislation to refill the potash stopes after mining. Therefore, since 1908 in most cases the slurry backfill technology was used. After this time the stopes, due to economical reasons, were left open.

Long-term measurements above the German potash mine fields show the effect of subsequent backfill and its influence on the stability of the overburdening rock and surface. Particularly slurry backfill has shown good results, in relation to the surface subsidence behaviour. Figure 5 shows the influence of slurry backfill on the time-dependent subsidence above potash mine fields as an example, following Bodenstein & Schreiner (1999). Particularly the effect of the time-span between the end of mining and the beginning of backfill on the amount of total subsidence is visible.
Another safety aspect for the using of subsequent slurry backfill as a high-effected backfill technology is the possibility to reduce the number and particularly the amount of seismic events, which can be induced by the mining operations. An effective refilling of the stopes will prevent the inducing of dangerous rock bursts.

Reducing the rock movements above potash mine fields by subsequent backfill can prevent the failure of the protective layers, because they often lose their integrity by breaking up under high amounts of subsidence, which leads to brine inflows into the mine. Figure 6 shows the results of modelling on the behaviour of the protective layer for a potash mine as an example, following Schreiner (1996).

4 SUMMARY AND CONCLUSIONS

In summary from the results of the aforementioned investigations on subsequent slurry backfill the following conclusions can be drawn:

- Subsequent slurry backfill can reduce the surface subsidence and, at the same time, improve the exploitation rate for the potash ore,
- Subsequent slurry backfill helps to prevent dangerous brine or water inflows into the mine field, due to its excellent mechanical properties,
- Subsequent backfill methods are well known from the history of German potash mines,
- The effect of subsequent slurry backfill is verified by the results of long-term investigations,
- Proven technologies for high-effected slurry backfill operations are available.

REFERENCES