Backfilling for Safety and Efficiency

A large number of mines use backfill for stabilization and safety, as well as for reaching the ore and preserving the environment. Used mainly in sublevel open stoping and cut and fill mining, a good knowledge of fill types, preparation methods and how these are applied is decisive for successful results.

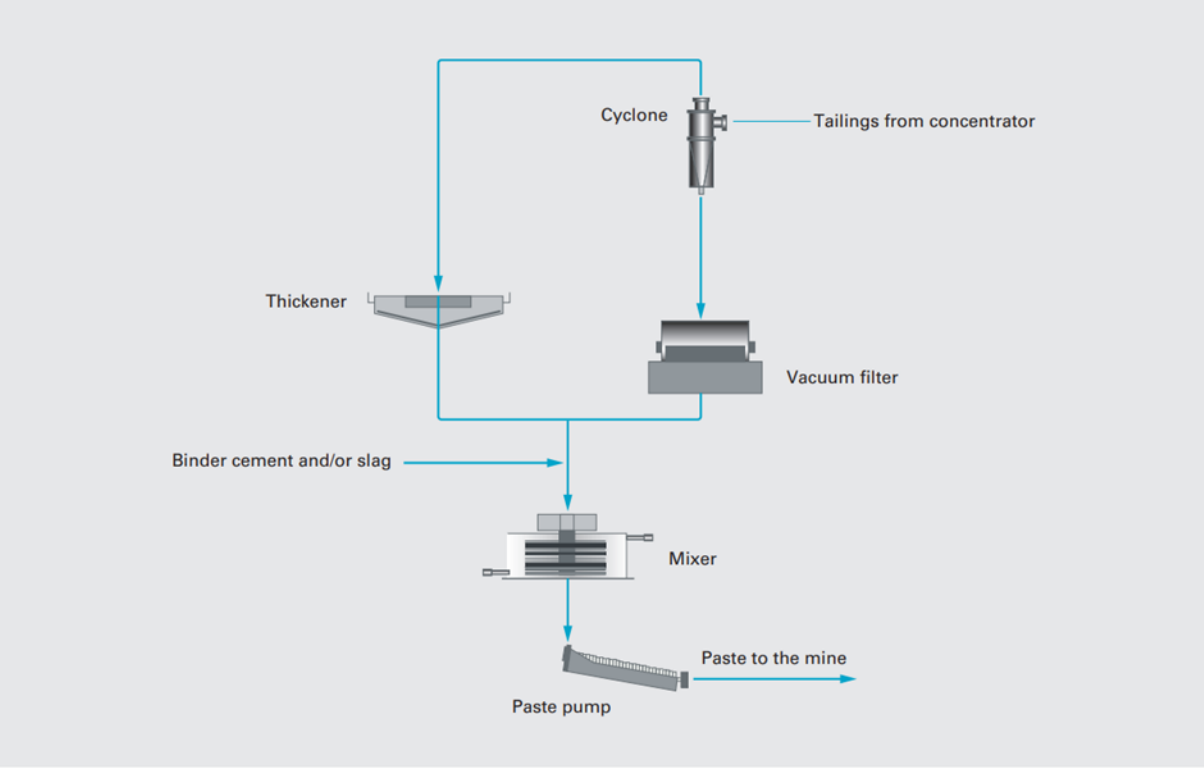

Figure 1: The flowsheet principle in a paste fill factory. Mine tailings are typically mixed with cement or other binders.

Backfill is widely used around the world to fill the man-made voids created in the underground environment once ore has been mined out and removed. Its function is to stabilize the workings, but it can also assist miners in several ways, partly by creating a floor from which they can work.

In addition to reducing open spaces, and thereby the risk of falling rock, the practice also has important environmental benefits above ground; it reduces stockpiles of waste and tailings ponds and minimizes the threat of collapse, which causes subsidence and damage to surface structures and surroundings.

There are also other advantages associated with backfilling. The technique prevents big rock fall and reduces the burden on ventilation systems, which, in turn, results in lower costs for ventilation. Apart from the caving method, where it is not technically possible, backfill is a highly recommended practice in modern mining. At the same time, a good knowledge of the types of fill that are available today and the methods used for producing and applying it underground is essential in order to achieve optimal mining results.

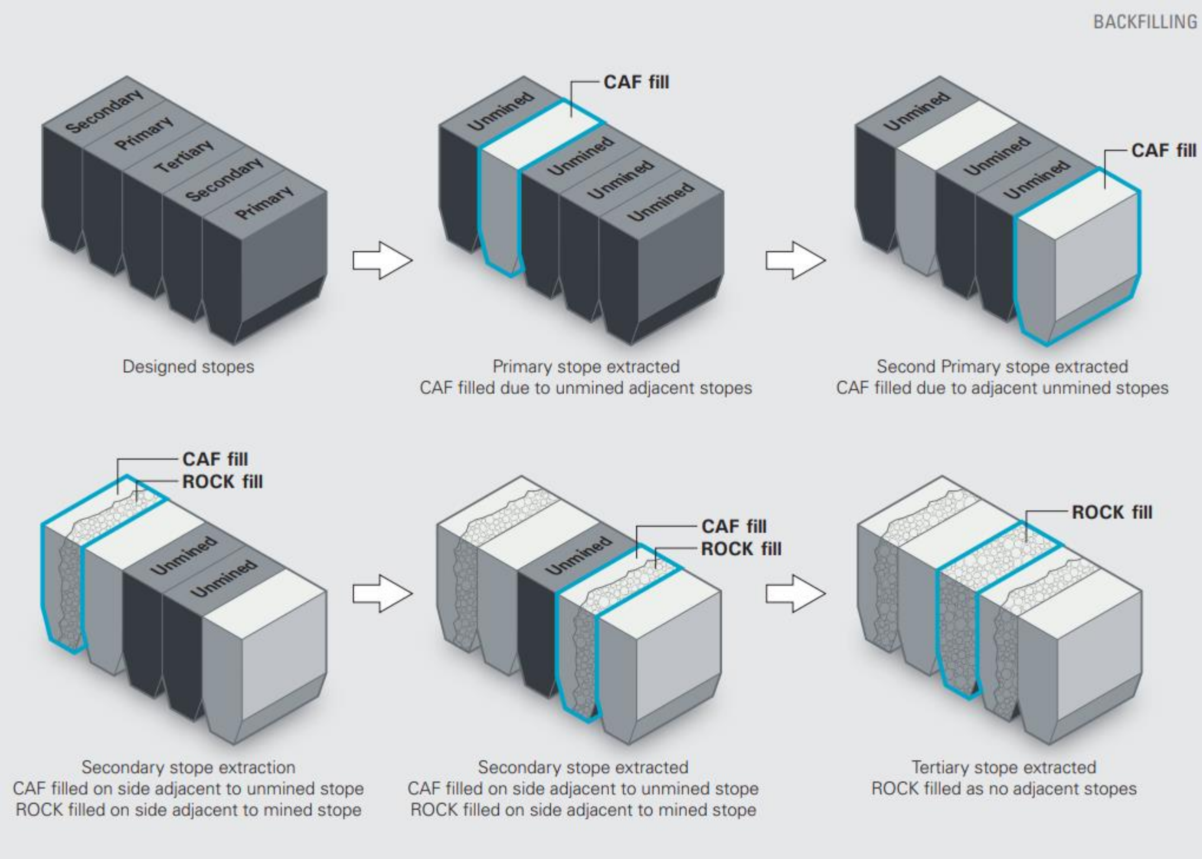

Figure 2: Stope extraction and filling sequence using Cement Added Fill (CAF) at Olympic Dam, Australia.

The Role of Backfilling

The original function of backfill in hard rock mines was to support rock walls and pillars or to provide a working surface for the mining operation. This was initially accomplished by rock fill and, more often in the present day, by hydraulic fill (HF). If cement is added to a hydraulic backfill of concentrator tailings, a smooth and hard surface results. This is useful for mechanized removal of broken ore from the subsequent mining operation and reduces dilution from the fill. Backfill also affords the opportunity for more selective mining and better recovery of ore and pillars, thereby increasing both mine life and total return on investment.

Having been employed for decades, it has become increasingly apparent that backfill has a dual role to play. Apart from substantially improving mining efficiency, it also benefits the environment as much of the waste rock from mining is recycled and utilized underground. Originally, backfill comprised waste rock, either from development or handpicked from broken ore. Some larger mines in the U.S. quarried rock and gravitated it down fill raises to the mine workings.

This method is still in use today, for example at Finland's Kemi mine. However, the most common use of rock fill (RF) nowadays is for filling secondary and tertiary stopes, or in cut and fill mining, and it is usually a convenient and economic means of disposal for waste from development. In sublevel stoping, primary and secondary stopes require stabilized fill and can use either Cemented Hydraulic Fill (CHF), Paste Fill (PF) or Cemented Rock Fill (CRF) for a good result. Some mines can also introduce a third stage, known as tertiary stopes, which can be applied in some sequences of sublevel stoping, as seen in Figure 2.

The cost of backfilling

The cost of backfill typically ranges between 10–20% of the total cost of mining, with cement representing up to 75% of average backfill costs. Increased demands for international safety standards, as well as the need to increase ore recovery, have led to the development of new types of backfill and backfilling practices to meet both safety standards and economical demands.

Paste fill plant at Garpenberg Mine, Sweden.

Choosing the right fill

There are two basic types of fill that are used around the world – loose fill and stabilized fill. These, in turn, are available in several different variations, all of which have distinct advantages and disadvantages.

Rock Fill (RF) is a conventional fill comprised of waste rock directly from mine development and used the way it is or mixed with sand tailings. If necessary, RF can be gravitated or transported down from a stockpile on the surface. The compaction of RF depends on size distribution when applied to the mining room. Cement Added Fill (CAF) is a generic term for all fill types that contain cement. Cemented Rock Fill (CRF) is based on waste rock mixed with a selected concentration of cement. The waste rock is produced either underground or at quarries on the surface. By crushing the rock down to an even fragmentation, it gives better mixing with the cement. CRF originally consisted of spraying cement slurry or cemented hydraulic fill on top of stopes filled with waste rock, as practiced at Geco and Mount Isa mines. It can also be mixed at a mixing station before being dumped into the stope.

Nowadays, cement slurry is added to the waste rock before the stope is filled. Where rock is quarried on the surface, it is normally channeled through a fill raise to trucks or conveyors for underground transportation.

The advantages of CRF include high strength due to its high cement-to-rock ratio. This provides a stiff fill that contributes to regional ground support. CRF is still selected for some new mines and many operators prefer this system. Since the major cost component of backfill is the cement at a ratio of 1:2, this fill is not economical and has been replaced with ready-mix concrete with a cement content of 10–12% for a standard 3 000 psi or 20 Mpa mix, where the rock needs to be crushed beforehand.

Hydraulic Fill (HF) is a loose fill normally used for the cut and fill method in vertical orebodies. It is produced from sand tailings in process plants (milling) on the surface. A cyclone procedure is needed to remove fine particles, which enables the drainage of water (which is necessary to get a firm surface) once the fill has been pumped down through the mine.

The hydraulic fills are composed of concentrator tailings that would otherwise have been deposited on the surface. The mill tailings were cycloned to remove slimes so that the contained water would decant. This fill was transported (very often pumped/gravitated down in backfill tubes) underground as slurry composed of around 55% solids. This is the typical underflow for thickeners and the pulp density normally used for surface tailings lines.

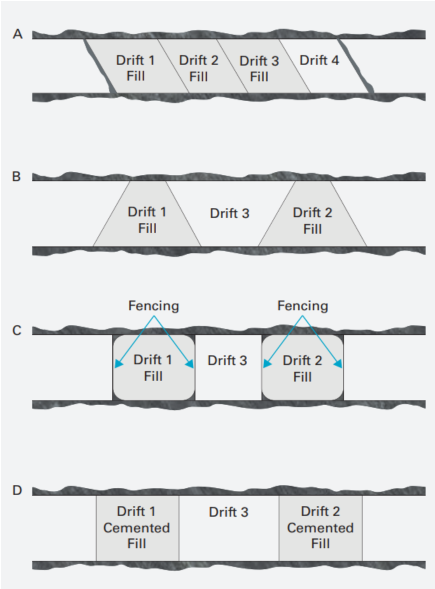

Figure 3: Drift and fill mining sequence.

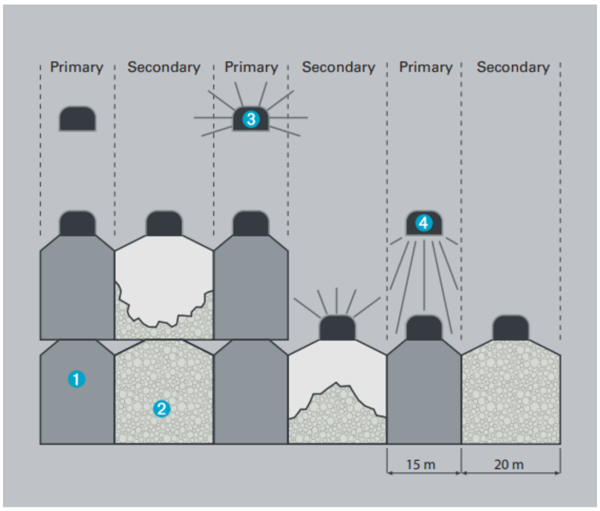

Figure 4: 1 Primary stopes (with cemented backfill), 2 Secondary stopes (with only waste rock fill), 3 Cablebolting with Cabletec, 4 Production drilling with Simba.

When the grind from the mill was too fine for decanting in the stopes, alluvial sand was employed instead of tailings. Particles of alluvial sand are naturally rounded, enabling a higher content to be pumped than for hydraulic fill made from cycloned tailings. This type of fill is commonly referred to as sand fill. Many mines still employ non-cemented hydraulic fill, particularly for filling some stopes or cut and fill rooms. The quantity of drain water from hydraulic backfill slurry containing 70% solids is only a quarter of that resulting from a 55% solids mix. The porosity of hydraulic backfill is nearly 50%. It may be walked upon just a few hours after placement.

Cemented Hydraulic Fill (CHF), also referred to as stabilized fill, consists of tailings mixed with cement in a mixing plant. Water is added so that the fill can be pumped down in tubes. This method requires top drainage since the cement stabilization process will not allow bottom drainage.

Portland cement, added to hydraulic fill as a binder, also adds strength, and this system of fill, in normal and high density, is employed at many mines around the world. A portion of the cement may be substituted using fly ash, ground slag, lime or anhydrite. If cement is added in the ratio of 1:30, the backfill provides better support for pillars and rock walls. If the top layer is then enriched at 1:10, the backfill provides a smooth and hard surface from which broken ore can be loaded and removed. The addition of cement reduces ore dilution from the fill and facilitates selective mining and greater recovery from both stopes and pillars.

Water decanted from cemented fill has to be handled appropriately to avoid cement particles reaching the ore passes and sumps since surplus water from this type of fill often causes increased pump wear, leading to additional water pumping costs. One approach is to reduce the amount of water in the fill, increasing solids content to 65–75% and more in a high-density fill. Additives can also reduce the water decant from fill.

Paste Fill (PF) is another stabilized fill and a popular alternative to CHF. It is typically composed of mine tailings mixed with cement or other hydraulic binders, adding a small amount of water to achieve a thick, mud-like consistency. Paste fill differs from all other fills in that it absorbs water for less waste, with both environmental and cost savings to be gained. The fill is pumpable with a minimum use of water, as illustrated in Figure 1.

Because the slimes fraction of the tailings forms part of the mix, cement always needs to be added into paste fill, with 1.5% as the minimum requirement to prevent liquefaction. Precise control of pulp density is required for gravity flow of paste fill, where a 1–2% increase can more than double pipeline pressures. Paste fill is frequently chosen because it uses unclassified tailings and less water, but the cost of a paste fill plant is approximately twice that of a conventional hydraulic fill plant of the same capacity.

There are also many other benefits to be gained by using paste fill. For example, it involves less handling of water and less wear and tear on pumps as it contains a lower concentration of cement, reducing the impact during pumping. Another property of paste fill is that it can be quite slippery on the surface, and when used as a platform to work from, it sometimes has to be topped up with waste rock to give the desired grip.

Finally, **Composite Fills (CF)** involve a combination of all the above fills and also commonly include loose waste rock from development.

Application and Design

When designing fill preparation and placement systems, boreholes are required for the installation of tube networks through which the hydraulic fill can be pumped down to the various mining areas. Tubes can also be installed along the drifts and ramps, but a modern mine will use boreholes as this considerably shortens the installation distances. Another benefit is increased safety since damaged tubes adversely affect the working environment and production. Installation in holes also reduces vibrations in the tubes.

These holes are often long and must be drilled with great precision. Mining equipment such as raiseboring machines, exploration drill rigs and specialized long-hole rigs are ideally suited for this type of work. It is also common to drill additional holes, often called redundant holes, which can be used if the primary holes should collapse or become blocked. Fill preparation and placement systems should be simple and efficient, with special attention paid to quality control. Two systems are used: cyclic filling and delayed filling. In cyclic systems, the fill is placed in successive lifts, as in cut and fill mining sequences. The fill can form a platform for the operation of mining equipment, mining through or beside the backfill, see Figure 2, or undertaken below, see Figure 5. In delayed backfill, the entire stope is filled in one operation. In this case, the fill must be able to stand as an unsupported wall that is rigid enough to withstand the effects of blasting. It should allow adjacent stopes to be extracted with minimal dilution from sloughing. Ore that is diluted with backfill causes problems, such as ore losses, and creates additional costs for the mine and processing plant.

Many factors must be taken into consideration when designing a backfill operation. The geology and dimensions of the orebody and its dip and grade are important, as are the physical and mechanical properties of both the ore and its host rock. Environmental considerations such as fill material resources, mining method, production capacity and operations schedule all impact on the design, as do the fill mixes and the strength that can be achieved using available materials. It is also important to carefully consider the pressure that may be added on mine walls, especially bulkheads or backfill walls, by some fill types that create large amounts of excess water. The existing pressure on walls can be dealt with by the correct dimensioning of bulkheads and water drainage systems, thereby minimizing the risk of collapse or damage. In this respect, the use of paste fill is greatly beneficial as it does not produce a large surplus of water.

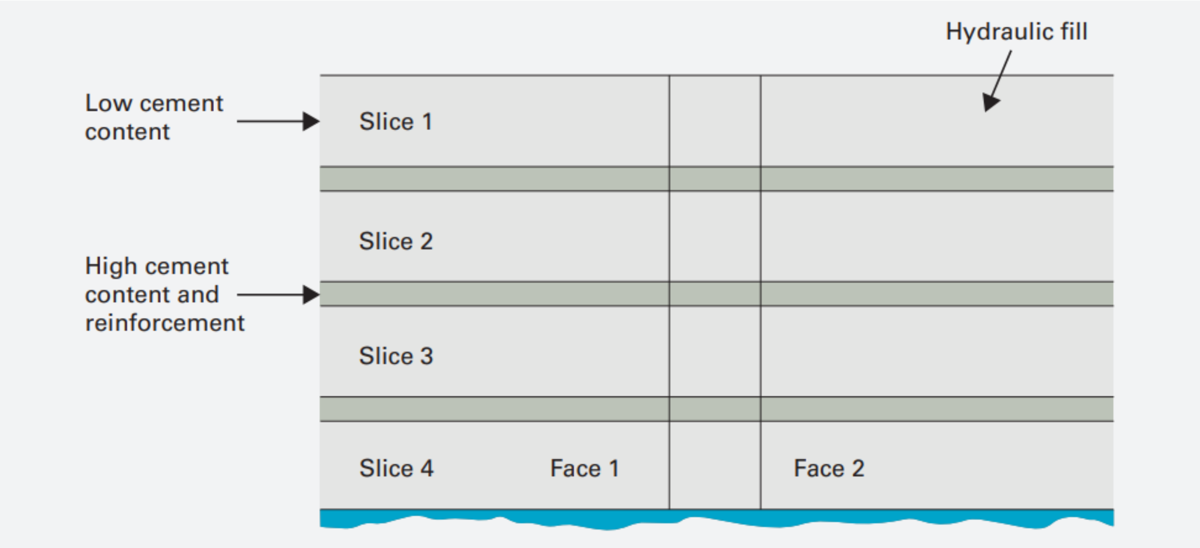

Figure 5: Underhand cut and fill mining may be used in poor rock conditions. The method involves using the fill as a roof, yet requires meticulous preparation in the mining room (cleanliness, adding rock bolts, etc.)

Planning considerations

Mine planners focus on saving costs by only strengthening the fill with cement where it is required, e.g.: close to the next stopes to be mined such as at Mount Isa or at the Olympic Dam in Australia, as shown in Figure 2. When planning a hydraulic fill system, major considerations are water drainage, tube systems, collection, and disposal, particularly in deep mines. If less than half of the tailings are recovered from the mill circuit, a supplementary fill material will be needed.

Other important considerations include:

- Design of fill walls: if a wall is badly dimensioned and poorly designed, resulting in collapse, a very dangerous situation may occur as major water influx can be triggered in certain mining areas. Shot-creting in modern wall design provides a good solution.
- Speed of fill during pumping: if the speed of the paste fill being pumped is too great, excessive wear on the piping system will result.
- Dimensioning of pipes and tilt angle: crucial for optimal speed of fill through the piping system. In secondary stopes, the fill must remain in place during mining of the adjacent area. The height, width and length of the excavated space are key factors in balancing costs.
- Increased costs: problems occur if dimensioning is inaccurate and paste fill leaks into production areas.
- Drainage system: water needs to be pumped to the surface as quickly as possible. Returning large volumes of water back to the surface can be a costly exercise, and installing the infrastructure may be difficult, expensive and time consuming.

With this knowledge of the various backfilling techniques available today, miners will considerably increase the prospect of establishing a smooth-running and, above all, safe operation.