

Backfill Practices at Çayeli Mine

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ABSTRACT: Backfill is an integral part of the mining operations at Çayeli Bakır İşletmeleri AŞ (CBI). The mining operations at CBI currently create an annual void of around 250,000 m³. Since 1994, more than 1 million cubic meters of backfill have been placed. There are three types of backfill in use at CBI, namely, cemented rock fill (CRF), unconsolidated waste fill (WF) and cemented paste fill (PF). The use of backfill at CBI serves four main functions: (i) to stabilize the ground to permit the extraction of adjacent ore, (ii) to fill voids to provide regional support, (iii) as a working floor for the next lift of stopes and (iv) for disposal of development waste. This paper describes current backfill practices at CBI with emphasis on different types of fill systems in use, transport and placement of backfill, and backfill quality-control practices.

1 INTRODUCTION

Çayeli Bakır işletmeleri A.Ş. (CBI) operates a mechanized underground Cu-Zn mine in northeastern Turkey in the province of Rize. The mine is located approximately 8 km from the coastal town of Çayeli, about 25 km east of Rize and about 100 km west of the border with Georgia (Fig. 1). The mine is a joint venture, with Inmet Mining of Canada owning 49%, Eti Holding owning 45%, and Gama owning 6%. The mine uses a long hole stoping method with delayed backfill to produce 2,800 tonnes of ore per day from the Çayeli volcanogenic massive sulfide (VMS) deposit.

Backfill is an integral component of the mining operations at CBI. Backfill is used at CBI; (i) for stabilizing ground to permit the extraction of adjacent ore, (ii) for filling voids to provide regional

support, (iii) as a working floor for the next lift of stopes, and (iv) for disposal of development waste. The mining operations at CBI create an annual void of about one quarter million cubic meters. Table 1 below details the types of backfill placed during the year 2000.

Backfill is an indispensable component of the mining method. A brief review of the mining method employed and current backfilling practices at CBI is described.

2 MINING METHOD

The mining method employed at CBI is designed for 100% extraction with complete pillar recovery while allowing no perceptible surface subsidence. The mining method is transverse and/or longitudinal long hole stoping with delayed backfill. This is a common low-cost mining method, integrating mining and backfilling systems.

The ore body is accessed from a ramp system located in the hangingwall (HW) and a production shaft located in the footwall (FW) of the ore body. The main levels are at 80-100-m vertical intervals with sublevels at 20-m intervals.

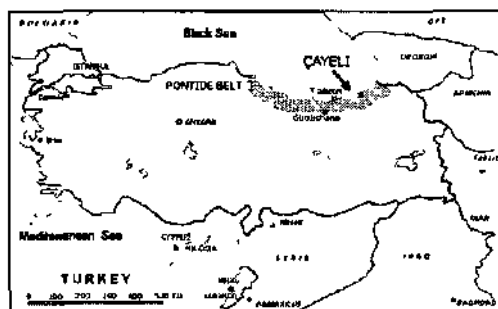


Figure 1. Location of Çayeli Mine.

Table 1 Backfill placed during 2000.

Type	m ³	%
CRF	93,620	42
PF	74,291	33
WF	55,020	25
Total	222,931	100

The ore is developed by driving stake access drifts with a cross-section of 25 m² along the hangingwall or footwall or in the center of the ore body to the boundaries. Stope preparation is carried out by driving sill drifts across the strike to the hangingwall or footwall, or in the case of low-grade areas, to the boundary of the economic cut-off grade. The sill drifts are 7 m wide by 5 m high. The length of the sill drifts depends on the thickness of the ore body and the location of the strike access drifts. The average length of the sill drifts/stopes is presently 35 m.

Stope production comprises the extraction of the 15-m-high bench between two sill drifts. A drop raise is driven between sublevels at the end of the sill drifts. The raise is widened out to a slot to create a free breaking surface. The remainder of the bench is blasted towards the open slot. The ore is mucked from the lower sill drift using remote-controlled LHDs. The open stope is then backfilled to the floor level of the upper sill drift. The backfilled floor becomes the mucking floor for the next lift. Once two adjacent primary stopes are completely backfilled, the intermediate primary pillar can be mined as a secondary stope. The primary stopes then become backfill pillars. The secondary stopes are also backfilled. The uppermost sill drifts in each main level are tightly backfilled to the back to support the back. The sequencing of the mining method is as follows:

1. Retreat from the boundary of the ore body to the central pillar.
2. Retreat up-dip from main levels.
3. Alternating primary and secondary transverse stopes.

4. Secondary stopes are mined between primary stopes after consolidation of the cemented backfill.
5. Completion of a mining area (main levels) by mining tertiary stopes (longitudinal stoping) in the strike direction between strike access drifts.

Figure 2 depicts a partial longitudinal projection of the current state of mine development.

3 TYPES OF BACKFILL

Several types of fill are used at CBI for backfilling mined-out stopes, are summarized in Table 2. These are: cemented rock fill (CRF), cemented paste fill (PF), and uncemented waste fill (WF).

Table 2 Types of backfill in use at CBI

Type	Description	Application
Cemented Rock Fill, CRF	Graded river aggregate plus cement	Primary and tertiary stopes and partially in secondary stopes at access side
Paste Fill, PF	Total mill tailings filtered to 82% solids by weight plus cement	Primary, secondary and tertiary stopes
Waste Fill, WF	Waste rock from surface or underground	Secondary stopes

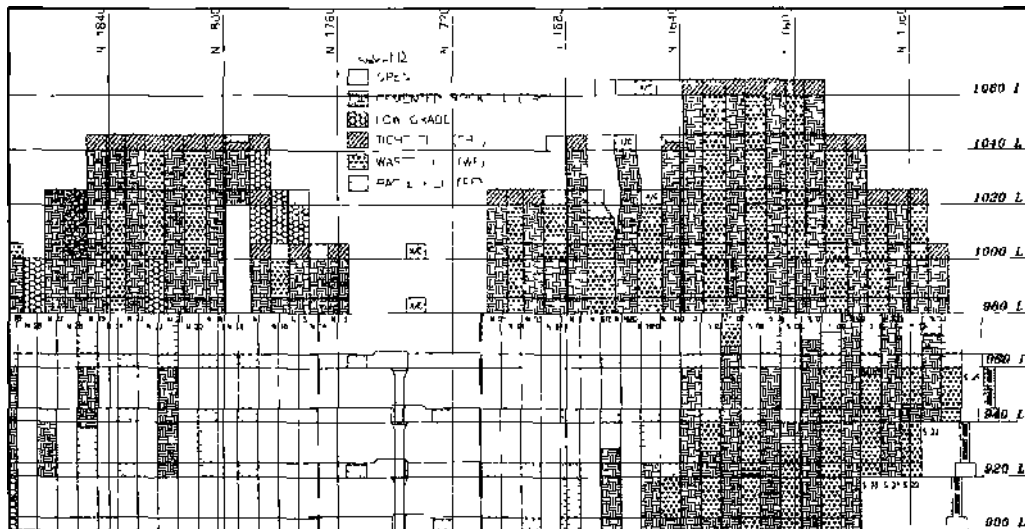


Figure 2 Partial longitudinal projection of the mine showing backfilling and mining method (looking east, not to scale)

Backfill is used to fulfill the following roles. For primary stopes, CRF and/or PF are used. The primary requirement here is to stabilize the ground to permit the extraction of the adjacent ore. The fill is exposed by the subsequent ore extraction, and hence must have sufficient strength to support itself when the constraining ore walls are removed. The primary stopes are filled with cemented rock or paste fill with 5% cement depending on the availability and stope requirements.

Secondary stopes, except for the brow section, which will be exposed during tertiary extraction, are backfilled with uncemented development waste material or 2% cemented paste fill. Here, the voids generated after secondary extraction are filled to provide regional support. Use of WF for the most part facilitates disposal of waste from development mining, eliminating the need to truck or skip the material to surface waste stockpiles. A portion of secondary stope fill will be exposed during extraction of tertiary stopes. In order to minimize dilution, secondary stopes, on the access drift side, are filled with CRF or PF (with 5% cement).

Tertiary and longitudinal stopes are backfilled with cemented rock fill and/or paste fill with 5% cement.

The uppermost sill drifts on main levels usually require the backfill to be tight against the back to minimize spans and to improve regional stability.

Generally, the cement content for CRF and PF is 5% by weight. However, the stope geometry and the prevailing mining conditions usually dictate the final dosage of cement in the backfill.



Figure 4 Photograph showing CRF and PF plants

There are two backfill systems in use at CBI (i) the CRF system and (ii) the PF system (Figs. 3-4) A brief description of the two systems is presented in the following sections.

4 CEMENTED ROCK FILL SYSTEM

During the early years of the mine's life, the mine was shallow; hence, trucks moved backfill underground from a temporary surface mixing station. In mid-1996, a new surface slurry plant and two underground mixing stations were commissioned.

CBI's cemented rock fill (CRF) system comprises a surface slurry plant, a slurry pump, dual 1.5-inch slurry delivery pipe lines, aggregate backfill raises, and two underground mixing stations. A brief review of the backfill system is described here (Figs. 3-4).

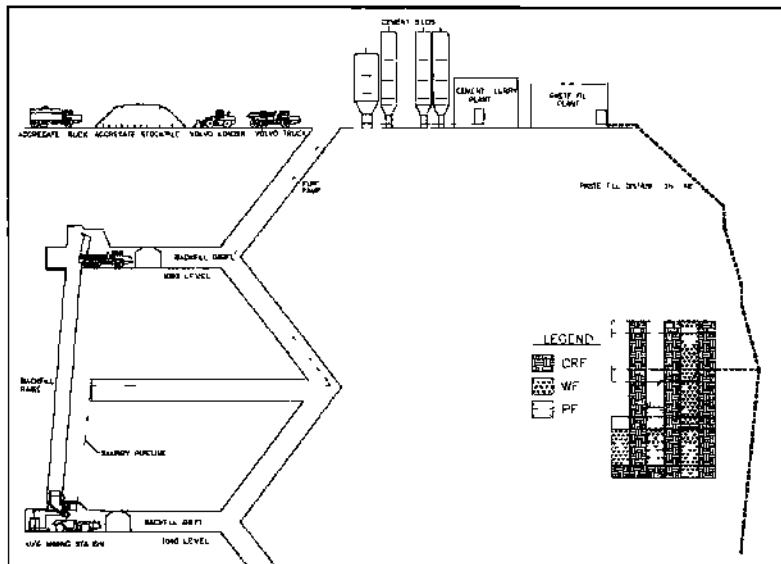


Figure 3 Schematic diagram showing the cemented-rockfill and paste backfill system at CBI (not to scale).

4.1 Surface Cement Slurry Preparation Plant

Figure 3 depicts the backfill preparation system in use at the mine. The cement slurry plant, located near the Kurt portal, comprises a programmable logic controller (PLC) system that is totally automated. Basically, the components of the slurry batch plant include two 75-tonne-capacity silos for holding cement, a mixing tank, and the necessary controls for the PLC. The bulk cement is brought to the site by truck, and is unloaded pneumatically into the storage silos. The bottom of each silo is equipped with a rotary valve that feeds into a screw auger. The PLC system delivers the proper amount of water and cement into the mixing tank. The mixing tank has been sized to provide 4 m³ of cemented slurry, enough for 5.5 truckloads of CRF. Once adequate mixing has been achieved, the entire batch is pumped underground using a Schwing KSP25 poppet valve pump via a 1.5-inch reticulation pipeline to the mixing station, where it is stored in a 4-m³-capacity agitating tank for discharge. A single batch of cement slurry consists of 1,200 kg of cement and 720 kg of water. This yields a water-cement ratio of 0.6 and a slurry pulp density of 62.5%.

When the trucks are loaded at the underground mixing station, the cement slurry is sprayed on top of the aggregate via a spray bar mounted on the lip of the chute. Additional mixing is achieved during subsequent transportation. The mixture is then transported by truck and dumped into the stope from the upper sill drift. The mixture of cement, water and fines coats the coarser aggregate and creates a strong bond at contact points. The result is a cemented rock fill of sufficient static strength to be self-supporting, and of enough dynamic strength to resist blast vibrations from adjacent secondary stopes.

4.2 Underground mixing stations

There are two underground mixing stations, one on the 1040 level and one on the 1020 level.

At the 1040 backfill station, the slurry is pumped to the spraybars which are arranged around the lip of the chute. The aggregate and cement mix as they fall together into the truck box and undergo additional agitation and percolation during truck haulage to the filling stope.

The 1020 backfill station utilizes the same surface slurry plant and pipeline. At the mixing station on the 1020 level, an agitator and pump identical to those at the 1040 station are used. The backfill is prepared in batches and the mixing is by a 3.5-m³ twin-shaft paddle-type concrete mixer. This was chosen to ensure complete distribution of cement throughout the aggregate. The 1020 station is more complex and modern, but is currently used as a standby station.

Both stations have aggregate supplied to them by means of dedicated backfill raises regulated by a standard chute arrangement. The slurry is kept in agitation in an intermediate holding tank.

4.3 Aggregate

Surface rocks in the vicinity of the mine are highly weathered and are therefore regarded as unsuitable for backfilling. For CRF, a well-graded river aggregate is used. The aggregate consists of a fine fraction and a coarse fraction. The fine fraction is 0-9 mm and approximately 30% by weight, while the coarse fraction is +9-100 mm and approximately 70% by weight.

On the surface, close to the Kurt portal next to the slurry batch plant, there is a temporary aggregate stockpile with an estimated capacity of 5,000 m³. The aggregate is loaded using a Volvo L1 50 loader and transported to one of the two underground backfill raises, located on the 1080 level, using a Volvo A35 truck (Fig. 3).

4.4 Transport and Placement

For transporting and placing the backfill, Wagner MT 400 series trucks are used. Backfill is dumped into stopes from the top sill drift (Figs. 5-6). Gravity fall is used when the truck initially dumps from the upper drift. The brow is therefore filled by gravity free fall, resulting in compaction of fill at the brow and barricade. Some of the fines are initially washed away due to the impact. Once the backfill reaches the upper level floor elevation, then trucks will dump backfill gently over the tip of previously placed backfill. The angle of repose for cemented backfill is about 35 degrees. Whether filling CRF or WF, the last 1m of stopes is usually filled with CRF using LHDs to finish off the surface for tramming. The low water content of the fill allows the trucks and LHDs to drive on freshly placed backfill.

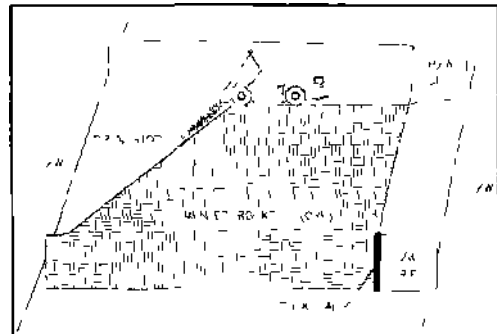


Figure 5. Method of truck-placed backfill at CBI (not to scale).



CRF.

The stopes are mined up-dip until the top of the ore or sill pillar is reached, as seen in Figure 2. The uppermost sill drifts, such as those on the 1060 and 960 level are tightly backfilled against the back (locally known as rightful). In order to minimize subsidence and to maintain the structural integrity of the back when the adjacent stopes are mined.

Based on 2800 tonnes production per day, the average CRF rate is 700 m³ or 70 trucks per day. To date, the record is 1000 m³ per day.

4.5 Bulkhead

Bulkheads are used at the base of open stopes to retain backfill in open stopes. Bulkhead design at CBI is such that bolts are drilled and installed around the perimeter, and then cables are woven vertically and horizontally, tied to the perimeter bolts. Wire mesh is then laid out to contain the backfill. Two horizontal and vertical U beams and two pipe poles are used to carry the deadweight. A portion of the pipes, cables and U beams are usually recycled for use elsewhere after the stope is filled and backfill set. The bulkheads are monitored by visual inspection.

4.6 Quality Control

The need for a comprehensive quality-control program for CRF is recognized. However, CBI does not have an on-site laboratory, as it is prohibitively expensive and impractical. For this reason, a more hands-on approach is taken for quality control of cemented rock fill. Proper filling and slurry preparation procedures have been set up to produce a high-quality fill product and these practices are monitored on a regular basis.

Slurry quality is a fundamental component for a high-quality fill product. The objective is to strike a balance so that there is enough water added to the slurry for the mix to coat the rock adequately, but not so much water that the strength of the final product is compromised. Below a pulp density of 50% solids by weight, the slurry will be too thin, there will be excess free slurry in the fill, and the final product will be well below the design. If the slurry density is too high (above, say, 80%) difficulties with slurry coating and transport result. The design target pulp density at CBI is 62.5% solids by weight. In order to maintain this density, spot checks are made through routine follow-ups and regular calibration of cement and water metering load cells. At underground mixing stations, the operator controls the quality of the final CRF mix to be delivered to the stope.

Spot checks are made to control cement consumption. As a rough measure, approximately 1.0 tonne of cement is used for one backfill truck. At the end of each shift, the U/G backfill operator and the surface slurry plant operator will report the number of trucks placed and the total tonnes of cement consumed for the shift. Furthermore, month-end total aggregate consumption is used to cross-check bulk cement consumption for backfill.

In addition, the slurry plant supervisor regularly checks the quality of aggregate delivered by the supplier. If the product is substandard, it is sent back to the supplier.



Figure 2. Good exposure of high quality cemented rockfill in adjacent stopes

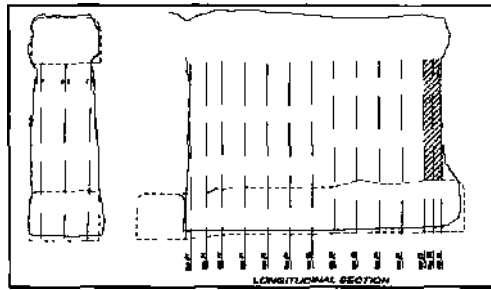


Figure 8. Planned stope versus actual stope extraction as captured by CMS survey.

The two notable properties of cemented rock fill at CBI are its free-standing ability and low contribution to dilution (Fig. 7). Dilution from backfill is around 4% and is due primarily to damage caused by close-proximity production blasting. The backfill mix provides an unconfined compressive strength in excess of 1.5 MPa at 28 days.

Procedures for correct drilling and blasting practices and the use of light explosives at stope ribs minimize dilution in secondary stopes. CBI purchased a cavity monitoring system (CMS) instrument in 1999 and since then has been monitoring the performance of stope blasts with CMS surveys. This instrument has made it possible to delineate and identify stope overbreaks/underbreaks. Figure 8 compares an actual stope cross-section with the planned stope blast layout.

5 PASTE BACKFILL SYSTEM

CBI commissioned a paste backfill system in 1999 to allow backfilling of underground voids using de-watered full plant tailings. The benefits of the paste fill method include: (i) low operating costs, (ii) ease of operation, (iii) environmental friendliness, (iv) homogenous and consistent quality, and (v) allowance for tight filling of stopes and uppermost sill drifts on main levels.

A full description of the paste backfill system is beyond the scope of this paper. Only a brief description of the main components of the system follows.

The design capacity of the plant is 90 dry t/h of tailings or 42 m³/h of paste containing about 82% solids. The plant receives total mill tailings through a 4-inch pipeline at a solids concentration of 65%. The tailings are then thickened in a 16-m-diameter thickener, agitated in a storage tank and then fed onto two vacuum disc filters. The filtrate is reversed to the tailing thickener and together with the overflow sent to the discharge head tank.

The filter cake is discharged on a reversible conveyor belt. The solids content of the filter cake is

around 86%. The filter cake is fed to a conditioning surge hopper where the solids concentration is adjusted by adding make-up water. In a second mixer, cement is added at a predetermined rate of 2-9%. From the mixer, the paste is extruded to the feed hopper of a pumping and pipeline system. There are two interchangeable positive displacement pumps with s-swing tubes and two underground distribution systems, of which only one will operate at any one time. The fully automated paste plant produces a 7-inch slump paste and pumps it underground through a steel 5-inch-diameter surface and underground distribution line.

The paste plant is currently operating at about 25% of its design capacity due to restrictions in the tailings disposal system. A project is currently underway to address restrictions in the tailings disposal system and allow the paste plant to operate at full capacity.

5.1 Transport and placement

Paste is distributed and discharged through a DN 125-mm surface and underground pipeline system. The discharge piping runs on the surface horizontally for approximately 20m and then down a ramp at a 17% gradient for 220m. Thereafter, the pipeline runs down through a series of boreholes at 60 to 70 degrees to various levels. There are take-offs at active levels. The last 100m of the flat runs on the levels consist of 5-inch HDPE piping. The stope is filled from the upper sill drift by gravity. Real-time CCTV is installed and signals are sent through the underground leaky feeder system to the paste plant control room. This helps the operator to monitor the flow through the pipeline.

The last one meter of the paste-filled stope is also usually filled with CRF in order to provide a base for the next lift.

5.2 Bulkhead

Bulkheads are used for retaining paste fill in stopes. The simplest form of paste fill barricade at CBI is constructed from a pile of waste rock dumped in the draw point with a small wire-mesh-reinforced shotcrete fence sealing off the top of the rock pile. The other commonly used design consists of two layers of cable slings woven vertically and horizontally, wire mesh, and 20-cm-thick shotcrete.

5.3 Strength and Quality Control

For paste fill, there is a strict quality-control program in place. Paste fill samples are taken during operation for laboratory UCS strength testing. The typical strength of paste fill with 5% cement after 28 days is in excess of 1.0 MPa, about twice the strength required for the self-supporting of paste fill when exposed. Slump is also measured on a regular basis throughout each shift.

6 CONCLUSIONS

Backfilling is an important component of underground mining operations at CBI. Backfilling costs account for 15-20 percent of the total mining costs.

CBI has successfully integrated backfilling into the mining cycle, and since start-up, more than 1.0 million m³ of backfill has been successfully placed. Cemented primary stope pillars have proven to be stable and allow 100% extraction of secondary slopes without any major failures. Paste fill has re-

cently been introduced to recycle mill tailings for backfilling mined-out areas underground. The use of combinations of PF, CRF and WF optimizes costs.

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