HYDRAULIC BACKFILL TECHNOLOGY FOR THE CLOSURE OF THE ABANDONED SULFIDE MINE IN MÁTRASZENTIMRE

J. FAITLI[1], *R. WEISZ*[2]

1. Introduction

The Mátraszentimre underground base-metal mine is found 100 km east of Budapest, in the Mátra Mountains near the town of Gyöngyös. The mine used to produce about 100-150 kt of low grade Pb-Zn ore, annually. The total ore production of the mine was 3.6 Mt, with 33 kt Pb and 102 kt Zn metal content. In 1985 ore production was halted. The most hazardous environmental effect of the mine – during operation and after the temporary closure – has been the effluent acidic mine water. For a long time the effluent mine water has been treated with lime additives. Final closing of the mine requires backfilling of most of the open mine cavities, because the present high concentration of pyrite causes the Acid Rock Drainage (ARD) process. So far extensive research has been carried out by many companies and institutes [1–7]. Utilization of Hungarian fly ashes from different dumpsites was investigated by Csőke et al. [3] and Mucsi et al. [4]. Pozzolanic activity of fly ash from Mátra Power Station was examined in order to develop a new hydraulic binder with the addition of lime. As results of the different examinations it had been decided that the backfilling material should be lignite fly ash from the tailings pond of the nearby Mátra Power Plant.

The decided target volumetric concentration of the designed fly ash – water dense slurry was 35%, with the addition of 3 mass % of powder form lime, compared to the dry mass of the fly ash. The process engineering design of the hydraulic backfilling technology was carried out by the Institute of Raw Materials Preparation and Environmental Process Engineering, and the mechanical design and the construction was carried out by the GeoFaber Zrt. The system had been constructed, and after industrial size test experiments, the backfilling of the mine has begun. This paper reports on the above-mentioned hydraulic backfilling technology.

2. Determination of the pressure loss

In 1996 the Mátra Power Plant was forced by the Hungarian Authorities to improve their dilute slurry fly ash pipeline system, because of the environmental impact of the deposited dilute slurry. The Institute of Raw Materials Preparation and Environmental Process Engineering carried out the previous experiments, and the Tarján–Faitli: fine suspension–coarse mixture flow model was introduced [8-10]. The hydraulic transport system, with 50% by mass (about 34% by volume) transport concentration was designed based on this model. Since then, this pipeline has been in operation and now this is the

[1]Associate professor, Head of Institute, Miskolci Egyetem, Nyersanyagelőkészítési és Környezeti Eljárástechnikai Intézet. 3515 Miskolc-Egyetemváros. ejtfaitj@uni-miskolc.hu
[2]Project Leader, Geo-Faber Zrt. 7633 Pécs, Esztergár u. 19. robert.weisz@freemail.hu

backfilling material source for the Mátraszentimre project. In the power plant, different fly ashes and slag are generated in the different dust separator and heat exchange process units. The original pipeline system was designed for the so-called R4 mixture (5% ECO, 20% Ljungström, 67% electrofilter and 8% slag by mass). Figure 1 shows a pressure loss curve chart for the designed 1:1 by mass, solid–liquid R4 fly ash–slag and water dense slurry. It was the final result of the 1996-98 research.

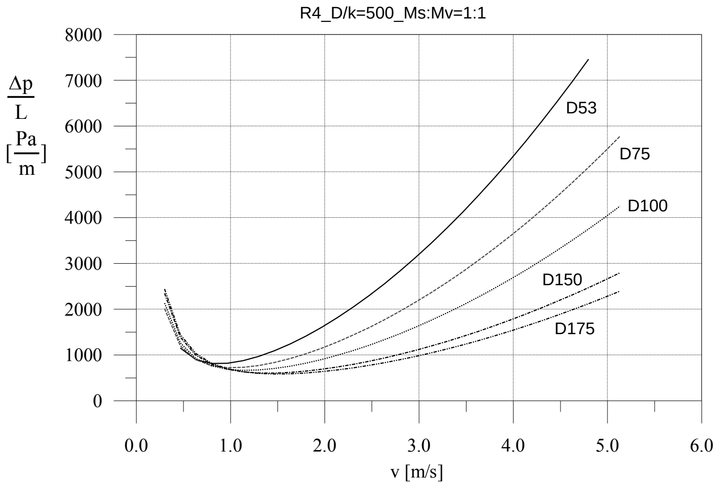


Figure 1. Calculated pressure loss curves ($\Delta p/L - v$) of fly ash–slag water mixtures of the Mátra Power Plant. Parameter: pipe diameter. (Research report 1998.)

In the last 4-5 years, during the fundamental research before the design of the backfill technology, the physical characteristics of the recent outflow of the Mátra fly ash pipeline were tested extensively. Regarding the particle size distribution, particle density and rheological properties of the water mixtures of the <160 μm fly ash suspensions (typically Bingham Plastics), the parameters are quite similar. The pressure loss could be calculated by the fine suspension–coarse mixture flow model, developed in 1998 with the application of the measured material data.

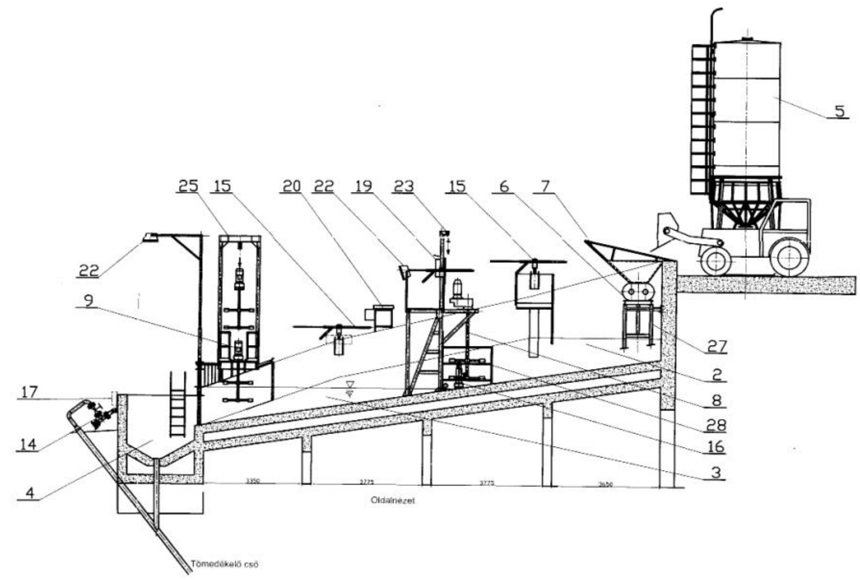
3. Concentration setting

The fly ash is transported from the tailings pond in Gyöngyös to Mátraszentimre by truck. This fly ash is wet, it contains lots of water. The hydraulic transport and particularly the backfilling require a precise concentration setting (designed as 35% by volume). This means that the amount of the excess (washing) water has to be precisely determined. The question is how to measure the moisture content of the raw fly ash. The laboratory standard method of drying at 105°C in a heat chamber is too time consuming. A quick and simple physical method was needed to measure the coarse moisture content. One possible solution might be an electric conductivity sensor, such as the TRIME [11] sensor, to measure the volumetric moisture of porous materials. The fly ash load of a truck is a three-phase disperse system, there are solids, water and air in it, and therefore the bulk density must be known for the calculation of the dry mass of the fly ash. The measurement of the bulk density is even more difficult than the measurement of the volumetric moisture, because if the material is manipulated (a sample is taken) the bulk density changes. A simple physical method was developed with a glass volume column and a weight balance. The developed method is applicable if the particle density of the solid is known. The particle density of the fly ash can be measured by a picnometer. The particle density of the outflow fly ash of the Mátra pipeline (typically 2100 kg/m^3) has been tested over a long time and has been found to be quite stable. Of course it is tested regularly.

A sample is taken into the glass column and the weight of the wet raw sample is measured. Then a known mass of excess water is poured into the column, into the raw sample. After some mixing, the air has to be removed, and now the mass and the volume of the solid–liquid slurry can be measured. From this data, the mass of the fly ash and the coarse water moisture of the load of the truck can be calculated. If the mass of the solid and the water is known, the amount of the necessary washing water can be calculated and the exact concentration can be set.

4. The hydraulic backfilling technology

The hydraulic backfill technology in its present form is the result of long-term experimental development; some other previous versions were tested as well. The most important part of the hydraulic backfill technology is the mixing system. A schematic drawing of this system is shown in Figure 2.



2 - first mixing pool, 3 – second mixing pool, 4 – last pool with pipeline input, 5 – lime silos, 6 - 27 – fly ash breaker, 7 – sieve, 8 – 9 - 28 – mixer, 14 - 17 – washing water valve, 15 – 19 – water jets, 16 – slurry pumps

Figure 2. Schematic of the mixing system

The raw fly ash coming from the tailings pond by truck is deposited in the mine yard. The lime (CaO) additive is temporarily stored in two lime silos. The water used for washing the fly ash is mine water, pumped temporarily into water tanks. A wheel loader with a 1 m^3 bucket is used to load the raw fly ash into the sieve and the breaker. The installation of a disintegrator was necessary, because the aggregated fly ash has to be broken. The disintegrated fly ash moves into the first mixing pool. Washing of the fly ash is solved by high speed water jets; there are three installed water guns here. The washed fly ash slurry flows to the bottom of the mixing pool, where two rotating mixing blades are installed. Generally the determined quantity of washing water is not enough to suspend all of the loaded fly ash and previous experiments showed that the material has to be mixed and worked by the impeller of a pump as well. Well-mixed slurry behaves differently in the pipe, settles differently and the final settlement (backfill) will be different. Therefore, two submersible slurry pumps were installed. These pumps hang on cranes; the position of them can be easily set. In this way the mixing pumps can be positioned in a given concentration layer and good mixing can be performed even after the washing water has run out.

Previous experiments showed that 3% by mass lime has to be added. Lime is necessary for the adequate strength and hydraulic conductivity of the backfilled material. Lime is stored in two silos. In the bottom of the silos, there is a valve and a feeding chamber. From the feeding chamber compressed air transports the lime into a steel pipe, where a water jet pump is installed. The mixed lime suspension is fed into the first mixing pool next to the mixing blades.

When mixing of a batch (about 56 tons) is completed, the mixture is allowed to flow into the second mixing pool by opening the sluice. There are two mixing pools installed, because continuous backfilling was planned. While the mixed batch from the second pool is allowed to flow into the pipeline, the preparation of the next batch is being carried out in the first pool. The mixed fly ash from the second pool can go through another sluice into the last (third) pool. In the bottom of this pool there is the input of the backfilling pipeline (150 mm inner diameter) with a valve. After a 40 m long inclined pipe section, there is a vertical pipe section in the main mine shaft followed by a horizontal section. Depending on which level and which stope of the mine is being backfilled, the total height of the pipeline might be 320 m, and the total pipe length might be 1000 m.

After backfilling, the slurry pipeline must be washed. For this reason a separate water washing system was installed. Through the valve, the washing water can lead into the pipeline. Another important point about washing is that the quantity of the washing water going into the backfilled stope has to be minimized. For this reason the deepest point of the pipeline lies near the mine shaft, before the horizontal pipe section. From this deepest point the washing water can be discharged through another valve into the mine dewatering plant under the shaft. In this way the washing water in the pipeline (quite a large amount) does not go to the backfilled area. The above description clearly shows that this hydraulic backfilling technology requires sophisticated operation. The operation of valves and other equipment should be coordinated, and this requires a good communication system among the different working places.

5. Operational tests

At the time of writing this paper, the described hydraulic backfilling technology is in normal operation. So far about 2,000 tons of fly ash has been backfilled. This technology is the result of long-term experimental development; many operational tests were performed. In this paper two interesting things are pointed out:

The mixing system described in Section 4 was designed for semi-continuous backfilling; we stated that the flow of one mixed batch and preparation of the next batch is carried out at the same time. However, the operation has showed that the mixing of one batch (about 56 tons) of fly ash slurry in the first pool requires about 30-50 minutes, and this mixed slurry goes through the pipeline in about 5-6 minutes. The flow rate in the pipeline cannot be controlled; it is determined mainly by the geodetic height and the length of the actual pipeline. Therefore, the two parts of the system cannot be synchronized; continuous backfilling cannot be performed in this way. Backfilling can be performed periodically, but the pipeline has to be cleaned after each mixing and backfilling cycle. With good coordination and with the above-mentioned deepest point valve the quantity of washing water getting into the backfilling has to be minimized.

The other experience described here is about the pressure loss of the system. During normal operation, the main parameters of the hydraulic transport system are known. The pressure loss of a given operation is known as well. The pressure loss is equal to the hydrostatic pressure of the slurry of a height between the inflow and outflow. The hydrostatic pressure of the air can be neglected. The main parameters of a given backfilling setup were as follows: geodetic height 290 m; total pipe length 870 m; quantity of filled slurry 56 t, 40.4 m^3;, density of slurry 1385 kg/m^3; and time of run in the pipe 6 min. The calculated values are: hydrostatic pressure (39.4 bar), flow rate (404 m^3/hour), average flow velocity (6.35 m/s) and the specific pressure loss (4528 Pa/m).

One remark has to be made about the flow velocity: the 6.35 m/s value is extremely high. The typical working flow velocity of drinking water pipelines is 1 m/s, because pipe wear is minimized. Pump driven fly ash hydraulic transport pipelines are generally operated near the minimum point (energy minimum) of the pressure drop curve and it is typically around 2 m/s. Larger dredging pipelines are generally operated around 4 m/s. Another remark is about the pressure loss. The measured specific pressure loss of the system is 4528 Pa/m and if we look at Figure 1 in the 150 mm pipe and extrapolate the specific pressure loss for the 6.35 m/s velocity the result is pretty much the same. The pressure loss chart in Figure 1 was made in 1998 for the Mátra pipeline by the Tarján – Faitli fine suspension–coarse mixture flow model. In the recent backfilling process the fly ash from the same power plant is used and the same concentration is set so it is a very good result. During factory-like operation the parameters are recorded and this database serves for the calibration of the model. In this way the material parameters can be determined. After some time, when the lower levels of the mine have been backfilled, the geodetic height, the driving force will be lower. The question is if the slurry will go through the long horizontal pipe section if the height is lower. From the model this can be calculated. If the height is known, the pressure loss is known. The flow velocity can be calculated in a reverse and iterative manner. If this flow velocity is higher than the deposition velocity limit, the slurry will go through. If not, a slurry pump will have to be installed.

6. Conclusions

In 1985 the Mátraszentimre underground sulfide mine was closed and only the vertical mine shaft was backfilled. Because the mine stopes remained open, the ARD process resulted acidic water outflow. Some 10 years ago the work on the final mine closure was started, and so far about 2000 tons of fly ash have been backfilled in the reopened mine. The installed hydraulic backfilling technology was result of a long time experimental developing process. The Tarján – Faitli: fine suspension – coarse mixture flow model was developed in 1998 based on the examination on the Mátra Power Plant fly ash. This model well fits on the measured data on the Mátraszentimre hydraulic backfilling pipeline.

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