UNDERGROUND MINING ENGINEERING 35 (2019) 57-64 UDK 62
UNIVERSITY OF BELGRADE - FACULTY OF MINING AND GEOLOGY ISSN 03542904

Review paper

PASTE BACKFILL MATERIALS FOR UNDERGROUND MINING - SOME EXPERIENCES IN SERBIA – PART I

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Received: November 19, 2019 **Accepted:** December 11, 2019

Abstract: This review paper presents the backfill method and materials for paste backfill mathod which are used in the world practice of underground mining. The paper consists of two parts. The first part (Part I) provides a brief literature review concerning the presentation of the backfill method, mostly the paste backfill method, its application, advantages and disadvantages, and materials that can be used to form a paste. The second part (Part II) of the paper presents an overview of possible materials that could be used for the eventual application of this method in Serbia. According to available data, backfill method has not been applied in practice in Serbia today, but mostly laboratory tests have been carried out.

Keywords: backfill method; backfill materials; paste; undergound mines; Serbia;

1 INTRODUCTION

The backfill method is used in the world practice of underground mining. This method involves filling underground voids created by mining work with natural materials, such as: mine tailings, flotation tailings or other materials (sand, gravel, aggregates, etc.)

Beside tailings, the practice of preparing materials for backfill involves the use of binders, water and additives in an appropriate ratio. Cement is most commonly used as a binder.

Practical experience shows that the price of cement is most important factor in the total costs of these methods. Costs are variable and depend from the country, the price of cement, market conditions and the cost of exploitation and the applied methods. According to Yilmaz and Yumlu (2017), depending on the recipe cement costs can constitute up to 55-65% of total backfill costs.

From these reasons, it is gravitate toward some other materials, originated from mining and other industries, which are waste and, from this aspect, can be considered as secondary raw materials. These materials include: fly ash from thermal power plants, metallurgical slag, gypsum from the desulphurization process, waste construction

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material, ash from other combustion processes, dust from various industrial processes, etc.

One of the reasons for applying the backfill method is better utilization of the ore deposit (valorization of unexploited ore in the pillars), reducing the consequences of mining operations due to subsidence, reducing the amount of tailings, and thus reducing the need for larger tailings, which is favorable from the environmental.

Technology is constantly being improved from the aspects of the application of appropriate equipment, i.e. of applied processes, as well as from the appropriate materials used for backfill method.

It is very important that the used material has the appropriate characteristics from the aspect of geomechanics, i.e. the better parameters of the strength, the minimum amount of the binder and that there is no bleed water. This water releases binder and reduces its effect, which lead to the pollution of the environment. This problem requires special treatment, and therefore demands higher costs. On the other side, the applied method and technique should be economically rational, and from these reason, the advantage has the available materials, like materials from the mining exploitation (solid tailings and flotation tailings). The application of a flotation tailings, which itself contains a high amount of water, usually requires preliminary preparation, mostly thickening and filtration. The amount of added materials or binders should be as low as possible and the materials must be cheaper. The advantage of using some material (such as slag and fly ash) are proven because of pozzolanic and hydraulic properties, as well as the reduction of costs.

2 BACKFILL METHOD

The implementation of the backfill method also involves various exploitation methods which, depending on local conditions and if necessary can be modified and adapted to the technology. Depending on the applied technology, there are various classifications of backfill methods.

Some of the common methods of backfilling which are used according to economic factors and further goals such as development of mine or abandoning the mine are rock backfill, hydraulic backfill, cemented paste backfill, and silica alumina-based backfill methods (Sheshpari, 2015).

All methods are different and they have their advantages and disadvantages.

Generaly the advantages of these methods are: preventing the surface disturbance which is more enviromentally friendly, exctraction the ore rich pillars and supports, reduction the risk of rock bursts, mainly from binders, improving the ventilation circuit, etc. The disadvantages of these methods are: high costs, highly dewatering of tailing, seepage of tailings effluent into ground water, extra manpower and equipment management, etc. (Tailings.info, 2019).

The most current modern method is the paste backfill method. The advantages of these methods are, among others, in providing the stability of the excavation area and more safety of existing workspace, in more recovery of ore from deposit as well as in using the waste materials, which eliminates the need for disposal.

A typical simplified process flowsheet for the preparation of a paste at paste backfill plant is shown in Figure 1.

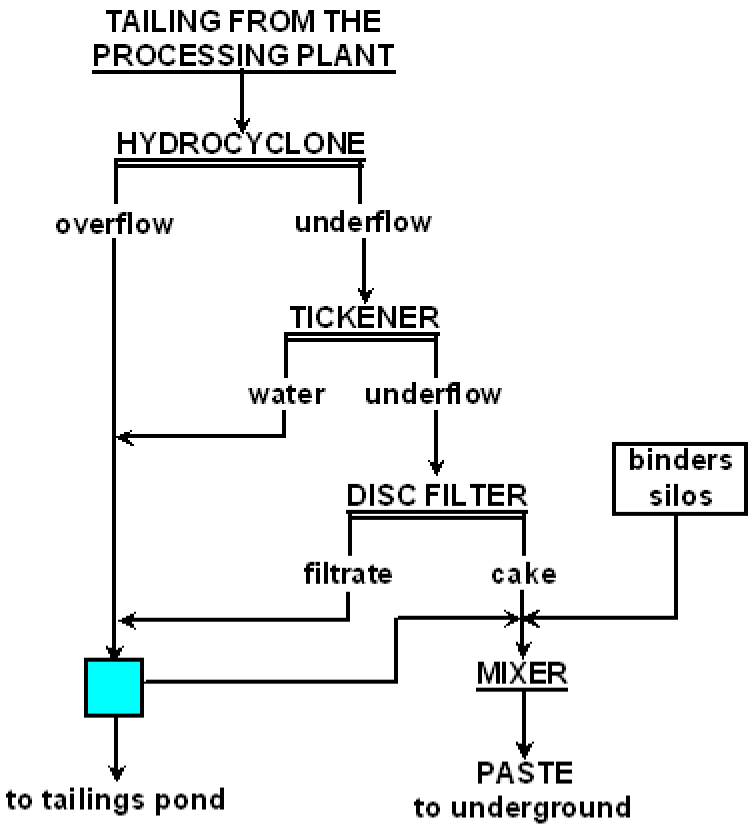

Figure 1 Process flowsheet for paste backfill

Flotation tailings are transported directly from the processing plant to the paste backfill plant. The tailings are dewatering in two stages: first, by thickening in the hydrocyclone, and then in the thickener, and second – by filtering in the disk filter. The hydrocyclone overflow, overflow water from thickener and the filtrate from the filter are combined and discharged to the tailings pond. Cyclones are used to remove some of the fines from the tailings product. The underflow from the thickener with 50-60% solids is agitated within a tank before feeding it to the filter line. Filter cake from the disc filters is conveyed into a mixer. At the mixer water is added to produce fill of the desired consistency and to control paste slump character. Binders from the silos are conveyed into the mixer. All backfill ingredients are fed by conveyors at the appropriate proportions and transported to a mixer. They are then mixed in mixer to form the fill. The final product is then pumped underground through boreholes. For paste fills, piston pumps are usually applied in practice (De Souza et al., 2009).

3 BACKFILL MATERIALS

Backfills can be classified as uncemented or cemented geomaterials such as tailings, sands or waste rocks. The uncemented backfills materials are: hydraulic fills, sand fills, aggregate fills and rock fills. The most common cemented backfills are: paste fills, cemented hydraulic fills and cemented rock fills. These cemented backfills include paste fill, cemented hydraulic fill, cemented aggregate fill and cemented rock fill. Uncemented paste fill is not used in an underground mining operations (Naguleswaran, 2018; Sivakugan et al., 2015).

The contents of binders are variable depending on the required characteristic for the backfill materials. Binder addition typically ranges between 0.5% to 12% by dry weight solids depending on the application. Binder ratios are variable depending on the required strength. For pastefill, tailings with 20%-20 µm is normally produces. Pastefill solid contents is mostly from 74% to 77%. Common fill strength strengths reported are from 0.3 MPa to 1.4 MPa for binder contents of 2.5% and 10%. Modern fill plants are fully automated for batch mixing of tailings, sands, binders and water. Also, proportion of the backfill ingredients are strictly controlled (usually at the conveyors which are equipped with appropriate measurement equipments) (De Souza et al., 2009).

The main components of cemented paste backfill are: binder, tailings and mixing water. The main characteristics of each component that can affect the quality of the paste backfill are: the chemical composition, grain size distribution, density and content of solids of the tailings and, finally, the chemistry of mixing water. Each component plays an important role during the backfill transportation, its delivery and its strength acquisition at curing time (Belem and Benzaazoua, 2004; Benzaazoua et al.,2002).

Ordinary portland cement is usually used as binder, but cement adds significant cost to the backfill even in small dosages (3-6%), there is a recent trend to use blended cement (Naguleswaran, 2018; Sivakugan et al., 2015).

Beside these materials, also trend is to use some other binders. Generally, these binders include but are not limited to sulphate resistant cements, and/or as a partial replacement for Portland cement by artificial pozzolans, natural pozzolans, calcium sulphate substances and sodium silicates. Beside the cost reduction, application of these binders is to ensure long-term stability and effective control over environmental contaminants

(Tariq and Yanful, 2013). Natural pozzolans, such as volcanic tuff and pumice, and artificial pozzolans, like pulverized fly ash from thermal power plants and slag from metallurgical processes (ferrous slag and non-ferrous slag) are usually used as binders (Tariq and Yanful, 2013; Sheshpari, 2015).

Beside binders, in the aim of the enhances of process activations some hydration activators can be added, like cement kiln dust, calcium sulphate or gypsum, waste gypsum, etc. (Tariq and Yanful, 2013; Sheshpari, 2015).

Laboratory investigations and applications in practice are shown that the utilization of pozzolanic additives as binders performs a variety of functions that can improve the properties of hardened cemented paste backfill, i.e. refinement of cemented paste tailings pore structure and densification of interfacial transition zone surrounding tailings grains (Tariq and Yanful, 2013).

But according to literature reviews, it is obvious that the cemented paste backfill needs laboratory investigation for application in practice.

Study performed by Benzaazoua et al. (2002) particularly highlighted the complexity of paste backfill materials for which the compressive strength acquisition depends on three main components (tailings, binder and mixing-water characteristics). Benzazzoua et al. (2002) find that there is no typical recipe for all paste backfill mixtures and, also, that each type of tailing and each type of mixing water requires laboratory optimization for choice of binder. It can be concluded from the same authors that the chemical properties of the three main components of paste backfill play an important role in its compressive strength acquisition and must be considered when designing and operating a paste backfill plant.

In general, it has been found that, although mine fill types have become progressively more engineered products, the selection of fill components is usually site-specific, and the mix formulations used and cement additions made are still based on experience and various empirical techniques (Archibald et al, 2009). Tipically, most paste fill plants with large capacities prepare the required paste recipes on the surface because of their complexity and the control that is required (Ilgner, 2006).

4 BACKFILL METHOD - PRACTICE IN SERBIA

In Serbia, the backfill method in underground mining is not practically applied. Based on the available data, only laboratory tests were performed. For example, a possibility of filling the chambers in the ore body Bor River of the Bor Copper Mines with backfilling consisted of flotation tailings, small amount of cement and water, was tested from Đurđevac Ignjatović et al. (2015) and Djurdjevac Ignjatovic et al. (2016). It can be concluded that the paste backfill, made with uncyloned tailings, has far better characteristics than the paste backfill with cyclone tailings.

In the second part (Part II) of this paper it will be shown the different materials (tailings, fly ashes from thermal power plants and heating plants, ferrous and nonferrous slag, cement etc.) that can be used to apply for the backfill method in Serbia. According to the available data, the particular characteristics of some of these materials (chemical, mechanical, physical, physico-chemical etc.) also will be shown.

5 CONCLUSION

The mines in Serbia have a good possibility of applying the backfill method in underground mining. More specifically, underground coal mines as well as lead, zinc and copper underground mines have sufficient tailings to apply this method. In addition, the three cement plants in Serbia have a good geographical position for distribution of cement to the mines. Thermal power plants and heating plants, as well as two smelters, can also provide materials that could be used as a binder. It is very important to consider the use of these materials, especially in view of the fact that some mines will close and some will increase their capacity. It is certain that this area is the basis for future research, which would determine the best opportunities and conditions of application of the aforementioned materials for paste backfill forming.

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