COMPARISON OF BACKFILL METHODS IN UNDERGROUND MINING

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ABSTRACT

The strength of side rock is important for mining operations and safety of employees. Main parameters affecting the backfill strength are use of binder, type/ratio of binder, type of filling material used, the size of filler, conditions of placing filler and opening structure. This study includes a brief information about backfill methods in underground mining operations. Underground backfill methods are analyzed for this purpose. In underground mining; rock, hydraulic and paste backfill are used for reasons of economy, ease of application and environmental harmony. Within the scope of this study, the differences and similarities of backfill methods have been revealed.

Keywords: backfill, underground, mining methods, filling types

INTRODUCTION

Backfill is defined as the process of storing cemented or uncemented waste rock, ore waste or aggregate to ensure the safety of both surface and underground openings, which are opened with the aim of production or transportation. Cemented and uncemented rock, hydraulic and paste backfill methods (Archibald vd., 2003; Amaratunga and Hein, 1997; Benzaazoua vd., 2002; Külekçi, 2013).

There are numerous methods and applications in different variations used in the underground mining productions in the world to adapt these methods to different underground reserves. About 60% of the world's mines are produced by underground production.

It is important to control and dispose of tailing and/or waste material resulting from underground mining. The effect of stability and safety of hazardous wastes are very important on water and soil quality. Additionally, very high pressures encountered in deep underground mines require different support systems to produce the ore in an economical way and to carry out a safe underground operation. For this reason, backfill process applied in underground mining is of great importance in terms of safety in underground operations, prevention of subsidence on surface and storage of hazardous and waste material produced by mining operations. Because of these reasons, the storage of underground mining waste materials in underground storage rooms has gained importance in the world in recent years.

FILLING TYPES AND PROPERTIES

Backfill is a filling process of underground openings for providing support and/or storage for wastes by using a suitable filling material. Rock, hydraulic and paste backfill methods are widely used in underground mining areas (Amaratunga & Hein 1997, Benzaazoua et al. 2002, Yılmaz 2003).

Rock Backfill

It is a kind of backfill to openings, consisting of side rocks and various sized aggregates produced after underground mining operation as a waste material. In the application of rock backfill, providing cemented aggregate from quarries and/or cement factories increases the cost considerably. Therefore, it is much more economical to backfill rock waste to underground openings. Additionally, at the same cement ratio, the strength gain is considerably higher than other backfill methods (Özdoğan, 2009).

Rock backfill method has different applications depending on the binder content, transportation and placement type. According to binder content, depending on the purpose of use of backfill in underground (if or not working under backfill stope, machine working over backfill, how long to remain stable, etc.) it is described as used with binder or not. Whether the backfill is cemented or uncemented is related to expected compressive strength (Figure 1). In the mining process, rock backfill is made to fill openings only for filling or support, so compressive strength range is very large in the cemented rock backfill. The 28-day strength is generally expected to be between 1 to 11 MPa. Accordingly, the rate of cement used in rock backfill varies between 4% and 8% by weight. The amount of cement to be used may vary depending on the desired strength and economical reasons. In the mining sector, since the economical reasons became more prominent in the last years, amount of cement was reduced and pozzolan materials such as fly ash, blast furnace slag to cement as additive or replacement were also tested in rock backfill (Özdoğan, 2009).

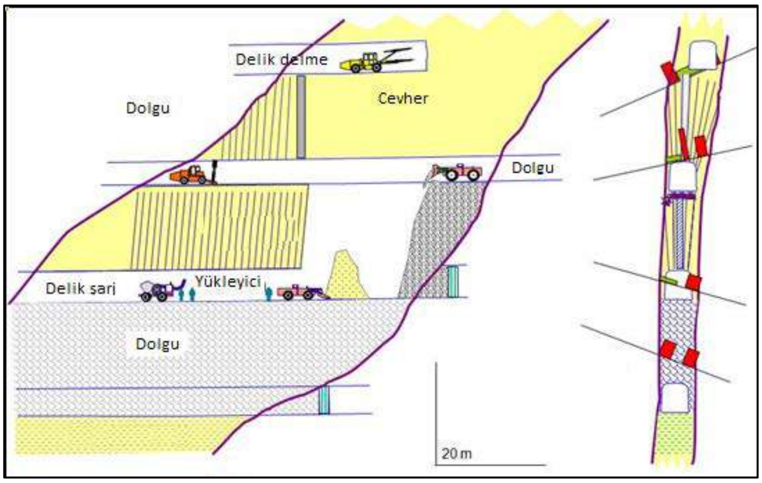

Figure 1. Rock backfill method (URL-1).

Hydraulic Backfill

It is based on the principle of transferring backfill material with water, filling of opening, separation of excess water from solid filling material and hardening processes. In the hydraulic backfill method, particle size distribution is important in terms of the transfer of backfill material (coarse grain size and amount) and separation of water after filling (fine material) and generally classified waste material are used. When the hydraulic backfill is placed in underground openings, excess water is removed by drainage. This is achieved by a drainage system consisting of porous pipes placed inside of filled material. The stability of the barricade installed in the hydraulic deposit is important in preventing failures that may be caused by the risk of liquefaction or poor drainage.

It is the most widely used filling method in the mining sector since the 1940s. The hydraulic backfill is defined as the filling of cavities resulting from mining operations by transferring the appropriate size of the material with water to the ground by pipeline extending from surface, the separation of excess water from solid backfill material and the hardening cycle. The waste to be used as backfill material must have certain properties (Potvin, 2005) (Figure 2).

The mixture should be between 60% and 70%, depending on the diameter of transport system, the volume of the coarse grains that can rise above the flow rate, the largest particle size and the volume of fine grains that can be filtered from the water (Thomas et al., 1981). It is requested that the material used in the hydraulic filler mixture is less than 10% by weight less than 10 μm material because it is not required to hold the water due to free drainage system in the hydraulic filler and it is requested that the water contained should be removed as soon as possible (Abdul-Hussain, 2011).

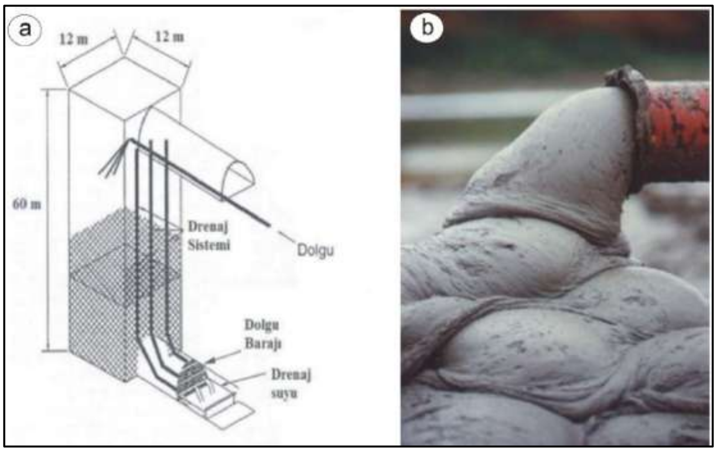

Figure 2. Hydraulic backfill method, a) backfill application procedure, b) physical image (URL-2).

Paste Backfill

Paste backfill consists of dewatered plant wastes, water and binder mixture (generally cement). To obtain backfill strength, 3-9% binder by weight is added to paste material. Portland cement is usually used as a binder and the binder constitutes about 50-75% percentage of operating cost of backfill process [4]. It is indicated that calcium-rich binders such as Portland cement cannot protect the long-term stability of fillings prepared especially from sulfur-rich wastes and solutions are searched to prevent that. It is stated that the most effective method to solve this problem, which is called as acid and sulphate attack in concrete industry, is the use of mineral additive materials (marble and brick dust, metakaolen, diatomite, blast furnace slag etc.) with pozzolanic character. Given the fact that cement costs constitute a significant part of the filling operation costs, the use of pozzolanic additives in the backfill will play an active role in solving the acid and sulfate attack and at the same time considerably reduce cement consumption and plant operation costs. Although the use of marble and brick waste as a pozzolan is very widespread, there is not any study in the literature regarding the use of marble and brick waste in paste backfill. The use of marble and brick wastes with abundant amounts of pozzolanic in our country at certain ratios instead of Portland cement produced from sulphure rich wastes will positively affect the stability of backfill as well as the problems of storage of surface waste (marble and brick).

Rock Backfill Application

Rock backfill is used for caving systems resulting from drills between levels and blasting. The most important unit is injection. Generally, for 1 m^3 injection, 720 kg of water and 900 kg of cement, 2880 kg of water for 4 m^3 of injection and 3600 kg of cement are used. Injection tank can get maximum 16 m^3. Trucks are used in backfill material transportation. The injection is combined with waste to soften it and provide an effective backfill material. The duration of the truck is variable depending on the floors, and it can be 4-5 minutes for near floors and 20-25 minutes for far floors.

The rock backfill is divided into two separative method according to the way of transport to the underground by means of borehole drilling and transportation by trucks. According to the criteria such as the volume of the opening to be filled and the distance to the surface, the mixture prepared on the surface is transported appropriately (Figure 3). In the borehole drilling method, the process is to send dry material to the underground openings to be filled with pre-opened boreholes. The points to be considered in this application are the amount of material to be transported per hour, the grain size distribution of the material, the drilling diameter and the largest grain size being in the material. The second process of transport is the transportation of the dry or wet fill with underground trucks. It is the most preferred method because it is easy to control and easy to use (Darling, 2011).

The rock backfill process is terminated by transportation and final placement. If the installation is placed from top to bottom with trucks or borehole at a certain distance, it is expected to be self-settling with the effect of filling weight and gravity.

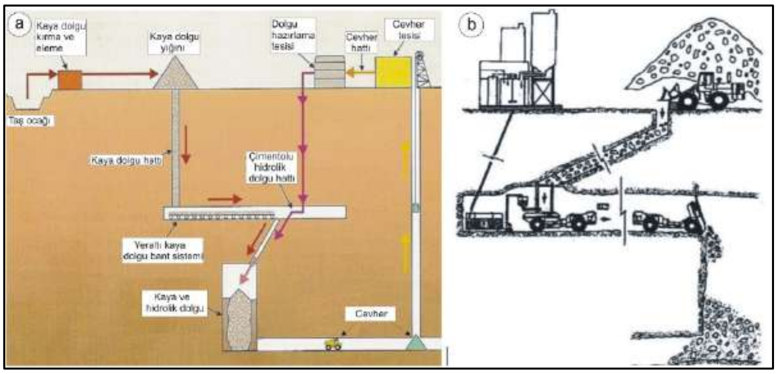

Figure 3. a) Rock backfill made by aggregate provided by quarry b) Application of cemented rock backfill with the help of gravity (Erçıkdı, 2009; Hustrulid W., 2001).

If the gravity cannot be used or ineffective, in this case, rock backfill material is placed horizontally and can be filled into openings with various mining machines such as remote controlled loaders (Darling, 2011) (Figure 4).

Rock backfill method;

- Crushed aggregates obtained from underground and generally up to 40 mm size reduce waste storage and waste storage costs with the use of pickling or side rock.
- By reducing the storage on the surface, waste damage to the environment is reduced.
- The preparation, transportation and haulage processes are very simple and feasible and therefore it does not include costs such as the cost of building barricades and the cost of dewatering.
- Underground filling provides a safe working environment.
- By increasing the cement ratio, the strength can be achieved relatively at the desired level.
- Due to the rising of the filling material obtained from underground or open pit mining, it can increase the backfill tonnage three times and volume by two times, increase the strength and decrease the binding (cement) consumption by less than 2%. Decreasing the amount of binder will reduce the cost (Külekçi, 2018).

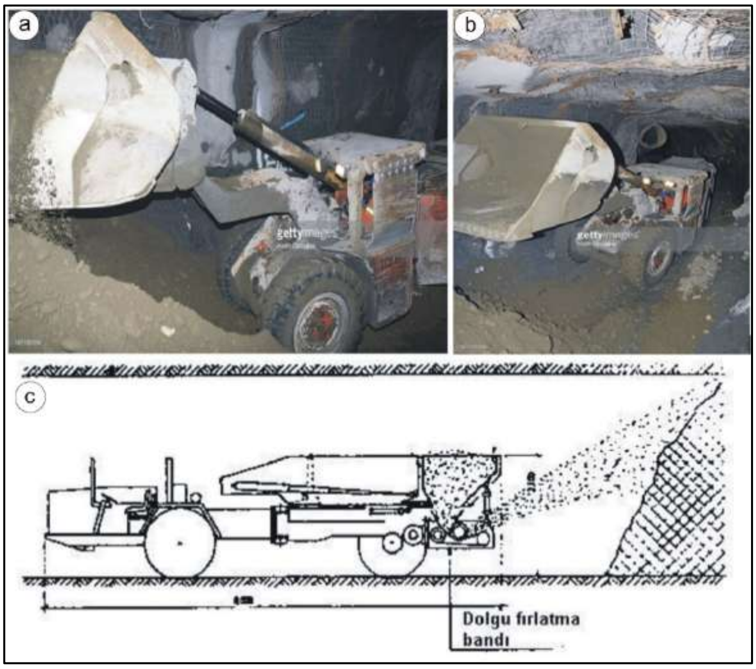

Figure 4. Rock backfill in horizontal a, b) bucket assistance and c) backfill with throwing band (URL- 3, Hustrulid W., 2001, Külekçi, 2018).

Paste Backfill Application

Paste backfill method is a granular structure mixed with water enough to fill the openings between the grains forming the mixture to ensure the fluidity of the material. The colloidal electric particle charge, which combines solid particles and water molecules in the paste backfill systems, ensures that water is retained between the particles of the granular material (Kesimal et al., 2002) (Figure 5).

The paste backfill is generally prepared at paste backfill plant. This plant is designed at a rate of approximately 82% by weight and a capacity of producing 45 m^3 of paste per hour. Plant waste containing 45-75% by weight of solid waste is sent to paste backfill plant with a 4" diameter pipe. The wastes are first thickened in a 16m diameter thickener and transported to the storage tank. The homogenized wastes in the storage tank are dewatered using two vacuum disk filters. The solids content of the resulting filter cake is 84-86% by weight. Then, the filter cake is mixed in the condenser tank with water and the binder in the mixer and mixed homogeneously and the prepared mixture is transported to the underground openings by using 5 "diameter pipes and Putzmeister pump. The binding content of the mixture varies depending on the location and function of the backfill in underground. The fluidity of the prepared backfill mixtures is generally between 7"- 8" slump.

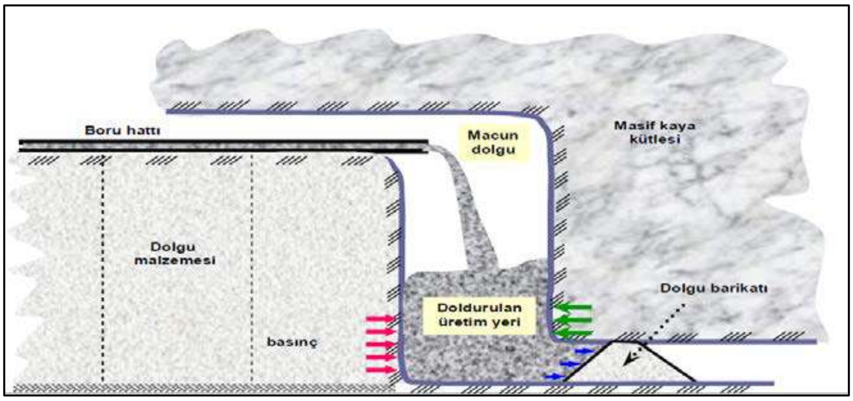

Figure 5. Paste backfill method applied in underground mines (Erçıkdı, 2009).

COMPARISON OF BACKFILL METHODS

Placement of the backfill in the ore-produced areas is usually accomplished by adding some binder and mixing water to the mixture. As filler material, generally used rock fragments and broken aggregates are obtained from ore processing wastes, sand and stone quarries. In underground; rock backfill, hydraulic backfill and paste backfill (increasingly prevalent in recent years) methods have been used generally (Amaratunga & Hein 1997, Benzaazoua et al. 2002, Yılmaz 2003). These underground fillings have many similar and different properties. Some of these properties are given in Table 1.

Tablo 1. Backfill types and their properties [5]

Properties	Rock Backfill	Hydraulic Backfill	Paste Backfill
Waste ratio	100 %	60-75 %	75-85%
Binder	Cemented or not-cemented	Cemented or not-cemented	Only cemented
Water/Cement ratio	Low W/C ratio High binder strength	High W/C ratio Low binder strength	Low W/C ratio High binder strength
Barricade	Not required	Expensive	Cheap
Transport	Transportation shaft Mobile equipment	Drillhole and pipeline	Drillhole and pipeline
Grain size	> 20cm	>20 µm (>90%)	>20 µm (>15%)
Placing speed	100-400 ton/hr.	100-200 ton/hr.	50-200 ton/hr.
Investment cost	High	Low	High
Operational cost	High	Medium	Low
Advantages	High strength Easy material supply No water problem	Easy material supply Graded waste used Widely used	Low cement usage All waste usage Easy application
Disadvantages	High transport cost Structure of cavities Plant waste not used	Drainage of excessive water High cement usage / low strength	High-tech required (pumping and dewatering process)

RESULTS

Filling the openings formed after the extraction of valuable ore in underground is called as filling or backfill process. The main purpose of backfilling is to fill openings and/or reach valuable ore in the next stage. Backfill methods is selected by considering the function of filled openings (toe, footwall, hanging wall, support, etc.) and the duration of permanence. The advantages and disadvantages of backfill methods are given in table 1. According to the conditions of mining, the purpose and economics of filling, the material should be applied by selecting the most appropriate method.

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