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Research Article

Geosynthetic Materials Used in a Waste Storage Facility and Laying Rules

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ABSTRACT

Mining activities generate a large amount of waste, depending on the amount of production. Wastes have the potential to cause much damage to the environment, according to their characteristics. Mining wastes consist of topsoil, stripping, waste rock, and beneficiation wastes. The waste materials generated due to the beneficiation of low-grade ores constitute a significant portion of the ore produced in quantity. Tailings dams are constructed to prevent environmental impacts and store waste. Thus, both environmental effects are eliminated, and storage space is provided for waste material. Good technical planning and design should be made during the construction phase of waste dams. Thus, it will be possible to prevent environmental impacts caused by waste. This study discusses the construction stages of a tailings dam where metallic mine wastes are stored.

1. Introduction

The saleable product of the ore enriched after mineral processing is called concentrate, while the worthless products are defined as waste and stored in the tailings dam. Ore beneficiation plants are designed based on the properties of the ore, and there are many methods in the literature for beneficiation. There are many stages in the production and beneficiation phase (Figure 1).

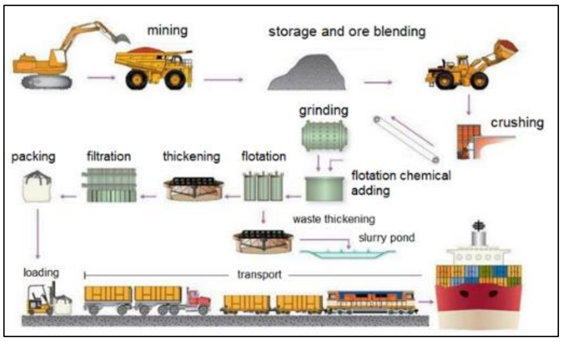

Figure 1. Metallic ore extraction and processing [1].

One of the methods commonly used in the beneficiation of metallic ores is the flotation method. After beneficiation, two types of materials are produced: concentrate and tailings. Mine tailings are usually made as slurry, a mixture of fine mineral particles and water, with the help of mills. Especially the wastes stored in the water in the tailings pond can be sources of dangerous toxic chemicals such as heavy metals, sulfur, and radioactive content (Figure 2). Vick (1990) stated that the waste generated due to the rapidly increasing mining activities worldwide should first be disposed of, but if this is not possible, the waste should be stored [2]. Arol (2019) mentioned land reclamation or rehabilitation works carried out to prevent permanent damage to nature caused by environmental degradation due to mining wastes and mining activities [3].

Due to their environmental impact, removing these wastes is necessary both for human health and the continuity of the ecosystem. These wastes are kept in mine tailings dams called surface storage areas. Tailings dams are structures used to ensure that solid and liquid materials such as water, various heavy liquids, chemicals, etc., which emerge in the process following the ore preparation processes in mining activities, are stored in a particular area in a controlled manner to prevent their effects on the environment.

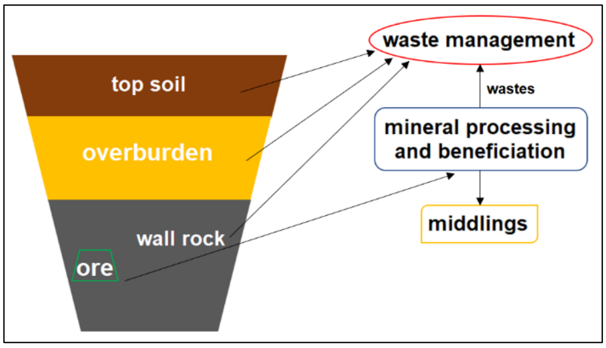

Figure 2. Mining waste management.

Depending on the natural landform and engineering characteristics, there are various tailings dam types, including regular ring, valley, and pit types [2]. Ring-shaped tailings dams can be constructed closer to the beneficiation plant without being dependent on topography [4]. Valley-type tailings dams are built to utilize the advantages of natural topography. Pit-type tailings dams are used for waste storage in open pit areas with depleted reserves.

Construction and control of tailings dams is very important. In this context, many tests and analyses should be performed and before any storage activities are started, the ADT should be designed with actual dimensions, and the necessary calculations and tests should be made and constructed in full capacity dimensions by the regulations [5]. Tailings dams and ADTs are standard and economical designs, but they are structures that can result in significant environmental disasters if necessary precautions are not taken [6]. In his study, Yılmaz (2008) gave information about the issues to be considered in the site selection of storage facilities. The author stated that geographical conditions and geological, hydrogeological, and geotechnical features are effective in site selection [7]. Jantzer and Knutsson (2007) stated that seepage and internal erosion control are important for very long-term stability control and that maximum hydraulic slope is an indispensable parameter for dam life and stability [8]. Zhenzhong et al. (2009) conducted a safety analysis of an iron mine tailings dam regarding seepage control. The authors investigated dam safety by performing a 3D dam analysis [9]. In their study on the use of waste materials in mining, Külekçi and Yılmaz (2018) stated that the strength of recycled waste aggregate increased at the end of the 28-day curing period and can be used as filling material in underground [10]. In his study, Külekçi (2021) determined that recycled aggregates are reactive for alkaline silica reaction. According to the author, marble and lead-zinc mining plant wastes added as substitutes to recycled aggregates reduce the expansion effect of ASR in cement paste [11].

1.1. Waste Dam Construction Methods

It is possible to speak of two basic types of surface storage: retention dams and rising embankments, of which there are many types. The difference between these two is that the initial construction of retention dams is done after reaching the final height [2]. Rising embankment dams are constructed at a height that meets the need to store ore beneficiation tailings and process water. With the base impermeability layer designed to eliminate the environmental impacts that may arise from waste storage facilities, groundwater pollution can be prevented (Figure 3).

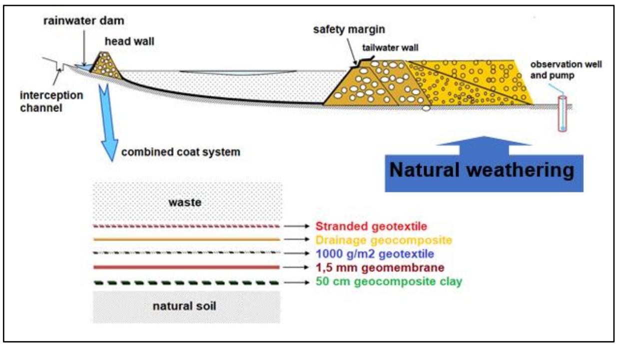

Figure 3. Waste pond cross-section [12].

1.2. Creation of Base Impermeability

When designing the tailings dam, an appropriate design should be made to prevent environmental impacts caused by waste material. According to the Regulation on Mining Wastes, clay group minerals with a thickness of at least 50 cm and a permeability of at most 9–10 m/sec, compacted in at least two layers and moistened under appropriate conditions, should be laid in the construction of the impermeability layer formed on the floor and side surfaces of the facilities where hazardous mining wastes will be stored (Table 1). This layer is reinforced using a high-density polyethylene (HDPE) geomembrane. A suitable natural material, or geotextile, is laid on it to protect the geomembrane. If it is technically challenging to reduce the slope on the side walls due to topographic conditions and if it is possible to ensure stability on steep slopes, a geosynthetic clay layer is applied together with HDPE geomembrane instead of clay [13].

Table 1. Landfill base imperviousness system characteristics by classes [14].

Landfill Facility	Natural Geological Impermeability Clay Permeability and Thickness	Artificial Impermeability
Class I	$K \leq 1x10^{-9}$ m/sec; thickness ≥ 5 m	0.5 m (minimum)
Class II	$K \leq 1x10^{-9}$ m/sec; thickness ≥ 1 m	0.5 m (minimum)
Class III	$K \leq 1x10^{-7}$ m/sec; thickness ≥ 1 m	0.5 m (minimum)

If the geological impermeability layer cannot provide the necessary conditions naturally, a geomembrane creates and reinforces an artificial layer. The total thickness of the impermeable mineral material and synthetic impermeability layer should be at least 0.5 meters. Protective cover materials should protect the artificial impermeability layer [14].

1.3. Geocomposite Drainage Layer

Geocomposites generally consist of a flexible polymer drainage core, lined on one or both sides with a filtering geotextile, designed for water drainage within an embankment structure. The polymeric core within the geocomposite material provides a free conduction path for water and liquid flow. Geocomposites, which have high flow capacity at low slopes and under pressure, significantly eliminate the need for mineral fills for environmental protection. The functions of geocomposites can be listed as pressure distribution, protection of insulation in underground structures, transport of water to collectors, prevention of clogging of collectors or drainage pipes with fine soil or fill particles, removal of excess water from the ground, improvement of weak soils with high water content. The geocomposite drainage layer consists of a geonet providing drainage and protection and a non-woven triangular geotextile providing filtering. Unwoven geotextile should be made of 100% pure polypropylene, and the geonet layer should be made of high-density polyethylene (HDPE) raw material and comply with CE and ISO 9001 standards.

Two types of geosynthetic materials used in the waste storage facility are specified separately with their properties. The first type of geocomposite will be used in the upper drainage and requires UV resistance.

Figure 4. Bottom drainage geocomposite [15].

The second type is used in the bottom drainage and does not require UV resistance. Geocomposite material production should be made of non-recyclable materials. The most crucial feature of geocomposites is retaining the solid part of the waste in the solid-liquid mixture under high pressure and ensuring that the liquid part's permeability reaches high values (Figure 7, 8).

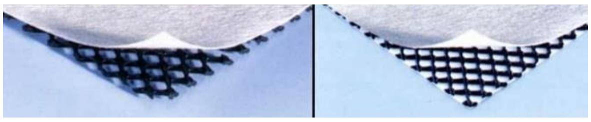

Figure 5. Upper drainage geocomposite [16].

1.4. Geosynthetic clay cover (GCL)

Geosynthetic clay cover is an impermeable material laid before geomembrane coating. It contains an artificial clay material called montmorillonite. Since the montmorillonite in the GCL swells when water is taken, the environment must be water-free for laying. The thickness of the GCL to be used should be 5 mm, the weight should be 3400 g/m^2, and the geosynthetic clay liner should be 5.5 meters in width and 50 meters in length (Figure 6).

Figure 6. Geosynthetic clay cover [17].

1.5. Geomembrane Coating

For the body impermeability of the waste storage facility, a 2 mm smooth high-density polyethylene (HDPE) geomembrane should be used on the base, and a 2 mm rough HDPE geomembrane should be used on the slopes. Geomembrane properties should be provided according to standard test methods, and geomembranes that do not meet the quality criteria should not be used (Figure 7).

Figure 7. Geomembrane coating [18].

1.6. Anchor Trench

Anchor trenches around the site are 100-130 cm deep to prevent the geomembrane from shifting due to the stored waste load. The anchor trench serves as compaction for the ADT that has been laid (Figure 8).

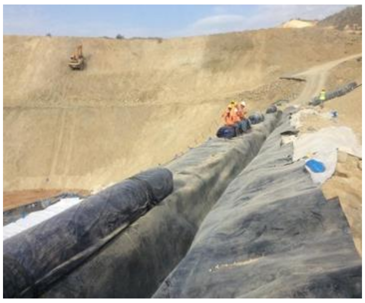

Figure 8. Anchor trench [19].

2. Field Tests

Field test welds are made to verify the suitability of welding conditions and equipment. Test weld length should be 3 meters for double seam fusion welding and 1 meter for extrusion welding. 2.5-meter-wide test specimens are cut from each end of the test weld and tested with a tensiometer for shear and peel tests. The sample taken for trial welds must meet the minimum requirements of shear strength ≥ 90% and peel strength ≥ 60%.

2.1. Shear Test

The shear test tensile force is applied to the joint plane. This force is intended to separate the weld. This test separates the weld using the top plate on one side of the specimen and the bottom plate on the other. These tests indicate the behavior of the weld under field conditions. In this test, the geomembranes in the upper and lower layers are pulled in opposite directions, and the process continues until rupture occurs. If the rupture occurs outside the weld, the weld is approved (Figure 9).

Figure 9. a) Preparation of geomembrane samples before testing, b) Shear test application [20].

2.2. Integrity Test

The material used in the electronic test application is T-shaped and 1 m long iron and the part touches the surface with a diameter of 8 mm. The material used in the electronic test application consists of a T-shaped and 1 m long iron and a part touching the surface with a diameter of 8 mm. In addition, the electromagnetic system carried by the tester is connected to the outer ground with the help of cables is connected. A voltage of 12 volts is obtained with the cable connected to the external ground, and it is determined whether there are any holes while traveling on the geomembrane. This test aims to resolve the possible problem caused by holes, tears, or any material for any reason in the laid geomembrane. If a potential problem is detected due to this test, the problem area is determined. A vacuum test is performed on this area, and the presence of the problem is tried to be determined by a vacuum test. Still, even if the problem is not detected as a result of this test, the problematic area is patched by extrusion (Figure 10) [16].

Figure 10. a) Integrity test application at the base, b) Integrity test application at slope [20].

2.3. Vacuum Test

It is performed to determine whether the extrusion weld is sealed by applying negative pressure inside the vacuum fan. It is performed to determine whether the extrusion weld is sealed by applying negative pressure inside the vacuum fan. All repairs made by extrusion and patching of damages (caused by unwanted or unforeseen reasons) detected in the areas where geomembrane laying is completed in the field should be checked for leak tightness with this test (Figure 11).

Figure 11. a) Vacuum box [20], b) Vacuum test application.

2.4. Air Pressure Test

Air pressure test test shows that the air duct between the seams of the geomembrane is carried out to control its tightness by subjecting it to pressure for a while. For this test, an air pump with a manometer, a manometer-mounted air needle with a safety needle, an approved calibrated air-pushing device/compressor, and a stopwatch are used (Figure 12). The pressure values accepted for the test are given in Table 2.

Figure 12. Air test application.

Table 2. Pressure values for air pressure test [14].

Geomembrane Thickness (mm)	Lowest Pressure (psi)	Highest Pressure (psi)	Allowable Pressure Loss (psi)
1,0	24	30	4
1,5	27	35	3
2,0	30	35	2
2,5	30	35	2

3. Conclusions

The waste generated from mining activities will have inevitable environmental impacts if no measures are taken. Prevention of environmental impacts will be possible with appropriate project design and technically adequate planning at the design stage. In the design phase, materials designed by the standards should be used in the waste storage facilities constructed to collect mining wastes and minimize their environmental impacts. In the facilities, the strength and durability of the laid material should be determined by shear, integrity, air pressure, and vacuum tests. It will be possible to eliminate environmental impacts that may occur during and after the mining phase, with work carried out by regulations and standards.

Ethics committee approval and conflict of interest statement

"There is no need to obtain permission from the ethics committee for the article prepared"

"There is no conflict of interest with any person/institution in the article prepared"

Authors' Contributions

-Study conception and design: Dilmaç and Kürtünlüoğlu.

-Drafting of manuscript: Dilmaç

-Critical revision: Dilmaç

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