Feasibility studies for phosphate fine tailings disposal in geotextile tubes

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ABSTRACT: Currently, the containment of tailings mining has been one of the greatest challenges of modern geotechnical. The volumes involved, the environmental constraints and the reduction of areas available have shown the necessity for the development of alternative methodologies for the disposal of these materials, replacing the traditional model of dams. This paper presents the concept of the geotextile tubes for the dewatering a typical phosphate fine tailings and explains the process used in the phosphate mining company from Brazil, including the preliminary tests, small scale geotextile tube and final implementation of the conceptual design is the dewatering system.

1 INTRODUCTION

In Brazil, carbonatitic phosphate exploitation is limited to a few mines that occur along the margins of the Paraná Sedimentary Basin in SE Brazil. In these mines, apatite ores have been extracted from the carbonatites and typical P_2O_5 content of the deposits commonly reaches 30% or higher for apatite for secondary ore deposits and usually < 15% or up to 4% for apatite primary ore deposits. In general, a deposit that predominantly contains primary apatite tends to show lower phosphate average grade and a less significant variation of the CaO/P_2O_5 ratio, typically ≤ 1.3.

In the chemical plant, the apatite concentrate is converted to phosphoric acid via the sulfuric acid process route. Then, phosphoric acid is used to manufacture mainly fertilizers and animal feed. In the case of treatment processes of phosphate rocks, with lower P_2O_5 contents, three different types of tailings are always generated: tailings from a magnetic separation process, flotation tailings and fine tailings from comminution, classification and flotation processes (`slimes').

Initially the apatite ore undergoes removal of magnetite using wet magnetic drums, generating a residue rich in magnetite and ilmenite. After magnetic separation, a set of cyclones is used to deslime (i.e., remove the fines from the ore slip), and finally, the flotation is applied to separate apatite from the remaining minerals. The flotation tailings typically contain less than 1.5% of P_2O_5.

Diverse applications of these resulting tailings were subsequently developed, as they are economically useful for the cement industry (both carbonate and magnetite concentrates). The carbonate tailings with high magnesium are utilized as soil additive. Part of the fragmented (blasted) residues is further crushed and sold as construction aggregate.

Phosphate slimes from chemical ore plant are constituted of very fine tailings (100% particles below #200) and have low solid content (normally below 10%), high plasticity (typical values are w_L = 80% and I_P = 40%) and reduced permeability (hydraulic conductivity coefficients in the order of 10^{-9} cm/s) and its disposal presents a great problem.

These residues are discharged into large settling ponds (Figure 1) where the extremely fine suspended solids remain in the water for relatively long periods of time before settling to the bottom of the ponds or dams. The process is too slow and transforms large areas into unsightly and dangerous lagoons. This fact, in addition to the potential applications of these residues as industrial sub-products, has formed a favorable scenario to submit them to dewatering techniques.

In the dewatering method context, woven geotextiles permit a great variability of applications in the form of hydraulically filled tubes. This conception differs from other dewatering methods because the pulp material is surrounded and encapsulated by the filtration system. In some applications, the use of flocculating agents for improving or increasing the dewatering process of contaminated residues is required. In function of the specific nature and high water content of fine tailings, the mechanisms of filtration of the geotextile tubes, therefore, demand special approaches in the laboratory and field.

Figure 1. Phosphate tailings lagoon: general view.

The technology of geotextile tubes and bags have been used as a geocontainment system since the 60's in marine applications, however it started to work as a dewatering process for sludge and contaminated sediments in the 1995, when lime and aluminum sulfate wastes from the Eagle Lake and Culkin Water Districts, Vicksburg, Miss., disposal lagoons were placed in two geotextile bags and one tube (donated by TC Nicolon Corp.) and closely monitored for filtration and consolidation testing. Since then many studies are being done about geotextile tubes technology and its benefits for many kinds of waste dewatering all over the world (Fowler et al 2002, Castro 2005, Lawson 2006, Martins 2006).

This paper explains the process used in one Brazilian phosphate mining company, located in the State of São Paulo. It will include the preliminary tests and a small scale geotextile tube to simulate in small scale the filling process and dewatering with the objective of given the characteristics of excessively fine tailings sampled, evaluating the best dose of flocculating to be used.

Moreover, presented briefly article project conceptual developed for the company to installation of a system of disposal of wastes fine for servicing the scale of production of the company, approximately 1,000 m3/h of pulp content of 8% total solid particle size and composition presented 90% below 325 mesh.

2 TESTS TO EVALUATE DEWATERING AND FILTRATION EFFICIENCY FOR GEOTEXTILE TUBES DESIGN

2.1 *Introduction*

The main targets of preliminary tests, it can be in the laboratory or a field procedure, are visualize the dewatering methodology, verify if it is necessary a dewatering accelerant, evaluate the efficiency of the selected polymer or any other flocculant, analyze the clarity of the effluent and indicate achievable percent solids, what will be an in put in design methods. Nowadays, is specify two types of tests for evaluate dewatering and filtration efficiency, they are the cone test and a small scale geotextile tubes, laboratory and in situ tests, respectively and reported by Castro et al.(2009).

2.2 *Sampling*

Representative samples of phosphate slimes from ore treatment process (90% particle sizes below 325 mesh), mining complex located in the State of Sao Paulo, that is currently producing apatite from one of the world's lowest phosphate average grade deposit, were collected directly from the discharge point, homogenized with overlying site-water and placed in glass jars.

2.3 *Laboratory procedure – Cone test*

In laboratory tests, different polymers and other chemical conditioning agents were used for the effective separation of fine-grained solids from water (Figure 2). These additives were evaluated based on the water release rate, water clarity, flocculent appearance, and water volume after passing through a geotextile filter.

Figure 2. Phosphate tailings retained in the cone test.

For this case, it were defined a 10 ppm of flocculent, and the behavior before and after the test is visible and are shown in Figure 3.

Figure 3. Phosphate tailings passed, before and after the cone test.

2.4 *In situ procedure – Small scale geotextile tube*

In the field, a small scale geotextile tube according to Castro et al. (2009) and GRI GT15 (Figure 4) were performed based on the recommended previous chemical analyses to evaluate filtrate quality and time to attain desired cake solids within the tube container.

Figure 4. Small scale geotextile tube.

Analyzing the material that was retained in the small geotextile tube, is possible observe that the dry tailing presents the chemical characteristics shown in the Table 1.

Table 1. Phosphate tailings chemical characteristics.

Description	Quantities
P_2O_{5Total}	3,73%
MgO	4,25%
SiO_2	1,31%
Fe_2O_3	1,53%
CaO	49,59%
SO_3	0,84%
K_2O	0,57%
SrO	0,58%
TiO_2	0,05%
Al_2O_3	0,32%

From this, it was observed two important points, the concentration of P_2O_5 and the concentration of MgO are very close of the initial values of mine deposit, around 5% and 4%, respectively.

In the small scale unit, it was also evaluated the total solids of the material during a time period.

Figures 5 and 6 show the results small scale geotextile tube. The maximum total solids after 10 days is around 74% starting from initial total solids of approximately 12%. The water content ranged form 31% to 25, 3% in this period.

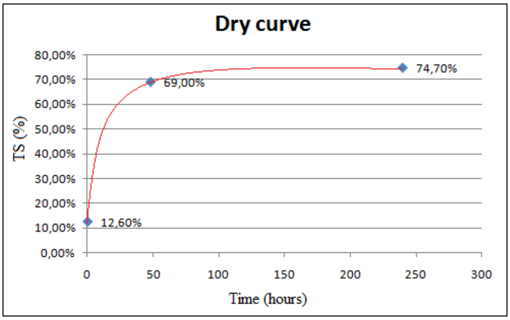

Figure 5. Dry curve total solids versus time.

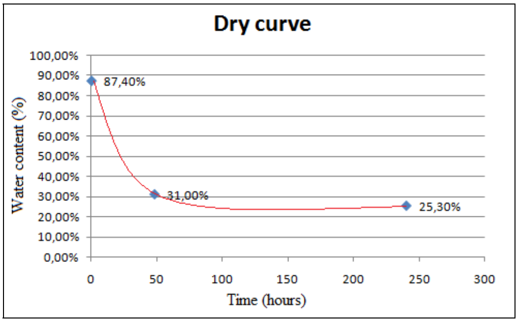

Figure 6. Dry curve water content versus time.

3 THE DESIGN SIMULATION

The design with geotextile tubes they had been employed the results of laboratory and in situ tests, a flow rate of 250 m^3/h, one year of work and a total volume of tailing with 1,056 kg/m^3 specific gravity, around 2 000 000,00 cm^3.

The current design, the preliminary requirements are based on geotextile tubes that had a circumference of 36.5 m, a height of 1.5 m and lengths of 47m, 56m and 65m, for a stacked three-geotube configuration.

Alternative conceptions using geotubes have been proposed for the raising embankments design in upstream method tailings dams in Brazil. This is the most economic construction method for dam raises. The projects imply some kind of co-disposition process, involving granular tailings and fine tailings encapsulated in geotextile tubes. This technique is particularly interesting in tailings disposal systems provided by hydro-cyclones (more efficient way to separate the larger tailings sand sized particles from the finer sized slurry sands, silts and clays by the use of centrifugal force) or in phosphate plants that generate residues composed of larger sand particles and finer slurry materials, separately (Martins 2006, Gomes 2007).

The upstream method relies on the strength and drainage of the perimeter slimes deposited and settled tailings beach material for raised dyke construction. In addition, the coarser tailings beach materials are deposited around the perimeter of the impoundment to provide better strength, drainage and containment for the finer low strength tailings. An alternative model consists of incorporating geotextile tubes with slimes as structural elements of the dam upstream slope (Figure 7).

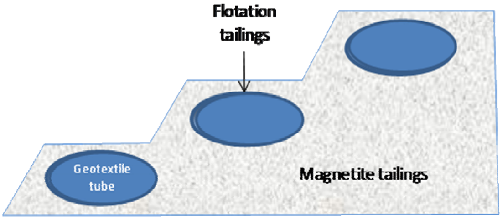

Figure 7. Geotextile tubes as structural elements in upstream method phosphate tailings dams (Gomes 2007).

The most important factor in upstream method dam stability is an adequate tailings beach drainage, which requires the ability to deposit settled tailings above the impoundment water pool level. Therefore the lowest risk for the upstream method dams is to have the water pool located as far away from the dam as possible after discharge operations. For improving dam stability, granular tailings deposit stacked up against the upstream slope dam have been an adopted solution. Another alternative will be to insert geotextile tubes into the stacked deposit, in orderly arrangements involved by granular tailings, forming structures called 'geoberms' (Figure 8).

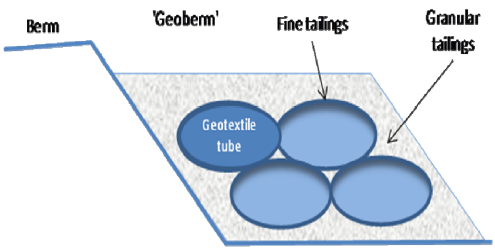

Figure 8. Geotextiles tubes as structural elements in 'geoberms' (Gomes 2007).

4 CONCLUSION

The tests realized the excellent behavior of interface geotextiles-tailings, especially when these are flocculation. One of the objectives of the work, given the characteristics of excessively fine tailings sampled, was to evaluate the best dose of flocculating to be used. The quantity defined ideal polymer and shown the technical feasibility of dewatering of wastes in geotextile tubes.

The results of the work attest the technical viability of the provision of fine tailings phosphate geotextile tubes, both experimental as at industrial level. Waiting from the results, new experimental may be made to enlarge the knowledge on the disposal of tailings mining in geotextiles tubes.

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