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Dewatering of Ultra-Fine Slurry using Composite Dewatering Bags

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Abstract

This paper details the development and implementation of composite geotextile dewatering bags used to dewater an ultra-fine calcium carbonate and sodium carbonate slurry. Dewatering of wastewater streams traditionally requires the use of complex and costly mechanical dewatering equipment for onsite desludging. The need for mechanical dewatering equipment arises from the presence of ultra-fine slurries generated as a waste stream during the treatment process by the water treatment industry.

Dewatering bags, manufactured from woven polypropylene geotextiles are incorporated in the dewatering process to extend the life cycle of wastewater treatment ponds once reaching their capacity. However, in the case of a wastewater slurry consisting of ultra-fines, addition of synthetic polymers is required to increase the effective particle size in the sludge in order for the traditional woven geotextile dewatering bags to effectively dewater.

A partnership between a local dewatering bags manufacturer together with a local staple fibre nonwovens manufacturer have developed a composite dewatering bag using a staple fibre polypropylene non-woven and a woven geotextile. The newly developed composite geotextile dewatering bags are able to cost-effectively dewater ultra-fine slurries and address the need for a flexible and cost-effective alternative to mechanical dewatering equipment while addressing the short falls of the standard woven geotextile dewatering bags with regards to ultra-fines.

Keywords: *Dewatering, Non-woven, woven, Ultra-fine slurry, staple fiber*

1 Introduction

A water treatment company based in South Africa currently operates and maintains a 22ML/D potable water treatment plant. The plant approached the dewatering bags specialist seeking a cost-effective alternative dewatering solution after it experienced several failures with the current mechanical centrifuge in use. The potable water is used to supply the surrounding mining community. The plant consists of an ion exchange softening process which requires the regeneration of the resin once it is loaded with water hardness causing components. The regeneration process is carried out by making up the fresh brine to be fed back into the system. The combination of chemicals used during the formation of the brine produces a slurry that needs to be dewatered. The dewatering process enables the filtrate to be used for the regeneration of the resin, whilst the solids to be extracted are disposed as waste. Economic restraints around the trial project made it unfeasible to utilize a standard woven tube solution with the addition of a polymer flocculants.

Porous filter fabrics are commonly used around the world for filtration. This process of filtration can be defined as the separation of separation of the suspended particles from a dispersing medium (Kalaivani, 2016). Types of filter fabrics typically used are either categorised as woven or non-woven. For this paper we are only considering a combination of a woven and needle-punched nonwoven fabric. The aforementioned composite was proposed as a possible solution to an ongoing challenge faced by a number of industries to effectively dewater ultra-fine slurries. This paper will look into the development and implementation of a composite dewatering bag to dewater an ultra-fine calcium carbonate ($CaCO_3$) and Sodium Carbonate (Na_2CO_3) slurry waste stream from a water treatment facility without the addition of polymer.

1.1 Conventional Mechanical dewatering

Conventionally the use of belt filter presses and centrifuges are types of typical mechanical dewatering techniques that are used to remove excess water from sludge's and produce a low-moisture content "cake". The dewatering of slurries from industrial waste streams provides a reduction in the mass and volume of sludge to be stored and transported, removes free liquids and prevents them from landing up in landfills. The disadvantages of mechanical dewatering techniques require large capital outlay initially and daily maintenance programs to ensure continued operation, high energy requirements and critical operator attention to ensure functionality (Henderson, 1999).

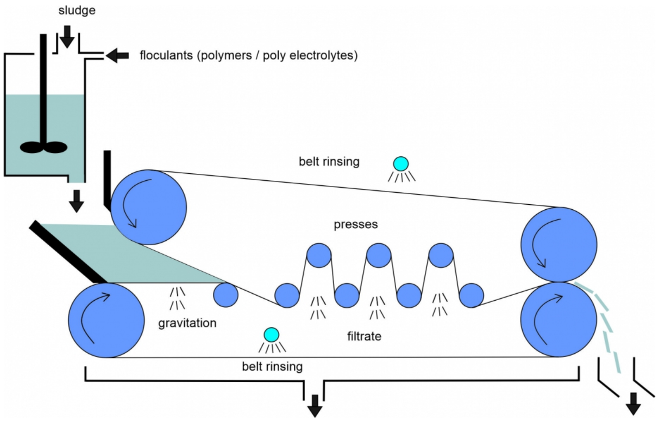

Figure 1: Belt Filter Press system

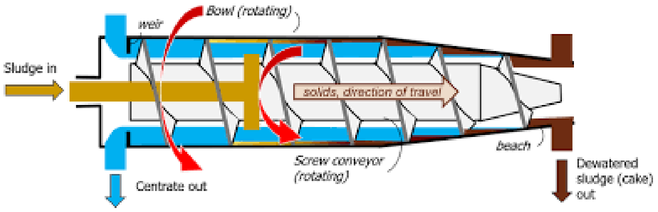

Figure 2: Centrifuge or Screw Press

1.2 Dewatering using Geotextile tubes and Polymer Additives

Dewatering applications for geotextile bags in the form of tubes have been used to contain and dewater sludge's from riverine environments for decades (Fowler, 1997). In the dewatering process, geotextile dewatering bags or tubes are used to thicken and dewater fine grained sediments or slurries. This is a developing field and has experienced limited applications in the industrial mining and municipal waste sectors in South Africa. However, technological advancements in the use of, and application of polymer flocculants and coagulants to waste sludge's have facilitated the use of geotextile tubes to expediently dewater sludge's that would typically require traditional mechanical dewatering techniques. The polymers are added to the feed stream with the use of a dosing system before entering into the geotextile tube or bags. Typically, any slurry with a particle size distribution that contains less than 30% of solids below 10 µm requires the addition of a polymer to ensure sufficient solids retention by the standard woven geotextile.

2 Selection of the Filter media

Filtration is defined as "The mechanical or physical method used for the seperation of solids from fluids by interposing a medium through which only the fluid can pass" (Sakpal P.P, 2013). It is important to note that filtration differs from sieving, whereby particles too large to pass through a defined pore size are retained. Filtration utilizes a multi-dimensional lattice to retain particles that are unable to navigate a pathway through an entanglement of fibres.

There are three main types of wet filtration:

- Surface filtration: All particles larger than the pores in the filter are captured on the filter media surface. Filter media that rely solely on this mechanism for filtration require careful consideration on the pore distribution and the permeability properties. This filtration mechanism is a property of both needle-punched nonwovens and woven geotextile filters.

- Depth filtration: Particles smaller than the pore size of the filter media become entrapped within the fiber structure. This is a characteristic of needle punched nonwoven filter media due to their thickness.

- Cake filtration: A filter cake or residue is formed by a buildup of substances retained on a filter media surface. This filter cake increases filter media efficiency over time, however once the cake becomes too thick efficiency decreases as excessive blinding begins to occur.

Zebratube embarked on the development of the of the new composite geotextile that would be able to retain the ultra-fine solids contained in the feed slurry without the addition of a polymer. The benefit of using a lined geotextile bag would enable the water processing plant to bypass the use of centrifuge which had experienced several failures leading to the search for a cost effective alternative solution. The dewatering bags specialist approached a nonwovens company in South Africa have an extensive range of fluid filtration media with the proposed solution to combine their high-flow woven geotextile with a non-woven filter fabric to dewater the ultra-fine slurry consisting of the Sodium Carbonate and Calcium Carbonate. It was proposed the use of its needle punched staple fiber bag filtration media range.

2.1 Needle-punched Nonwoven Component

Needle-punched staple fibre nonwoven fabrics are commonly utilized in the liquid filtration industry as prefilters to remove particulates from a variety of industries including chemical processing. Advantages of Needle-punched include longer flow path due to bulky nature of the fabric, higher permeanility controlled pores per unit area due to random distribution of the short staple fibres resulting in higher filtration efficiency (Kothari, 2007). Needle-punched non-wovens like those produced by a local South African manufacturer are seen as three-dimensional filtration media, they have length, width and depth. The needle-punched nonwovens are good at trapping suspended solids on both the surface and withing the nonwoven itself. The pores may be greater than the particles to be retained and yet the produces a very high efficiency of separtion due to the ultra-fine particles becoming entrapped in the non-woven (Sakpal, 2013).

Table 1 below, shows the characteristics of the staple fibre nonwoven used for this project trial as the primary filter layer on the inner side of the composite dewatering bag.

Table 1: Nonwoven Geotextile Characteristics

Fibertex Bagtex350 Nonwoven Geotextile		
Tensile Strength MD	≥ 675 N	EN ISO 9073-3
Tensile Strength CD	≥ 675 N	EN ISO 9073-3
Mass per unit area	350 g/m^2	EN ISO 9073-1
Thickness	2.2 - 3.0 mm	EN ISO 5084
Air Permeability	≤ 27 m^3/m^2/min	ASTM D0737

2.2 Woven Filter Fabric Component

Woven filter fabrics are known for low elongation properties which counteracts the high elongation of the nonwoven. This combination becomes advantageous when used in large tubes or bags required for the processing large quantities of slurry. Typically, dewatering bags are pumped to capacity and then allowed undergo a period whereby excess liquid in the bag is allowed to drain out before the bag is once again pumped to capacity. This cyclic pumping is then repeated until the dewatering bag is completely full with retained solids. Woven filter fabrics are noted as two-dimensional filter media due to the fact that only surface filtration occurs (Kothari, 2007).

Table 2 below depicts the chareteristics of the low-flow woven geotextile used as the outer layer of the composite dewatering bag. The primary use of the woven geotextile is to prevent any excessive elongation that may occur in the nonwoven inner liner.

Table 2: Low-Flow Woven Geotextile Characteristics

Low Flow Woven Geotextile		
Tensile Strength (Warp/Weft)	54 / 42 KN/m	SANS 1915:2003
Elongation (Warp/Weft)	12% - 35% / 8% - 25%	SANS 1915:2003
Permeability (100mm head)	25 L/s/m^2	SANS 10221-2007
Characteristic Opening Size	207 µm	EN ISO 12956

3 Trial Preparation

3.1 Particle Size Distribution

A sample of the material was collected and taken for a Particle Size Distribution (PSD) analysis. The particle size distribution is given in Figure 1 below. For this case 90% of the feed slurry recorded a particle size smaller than 39.9 µm and 10% with a particle size smaller than 5, 61µm.

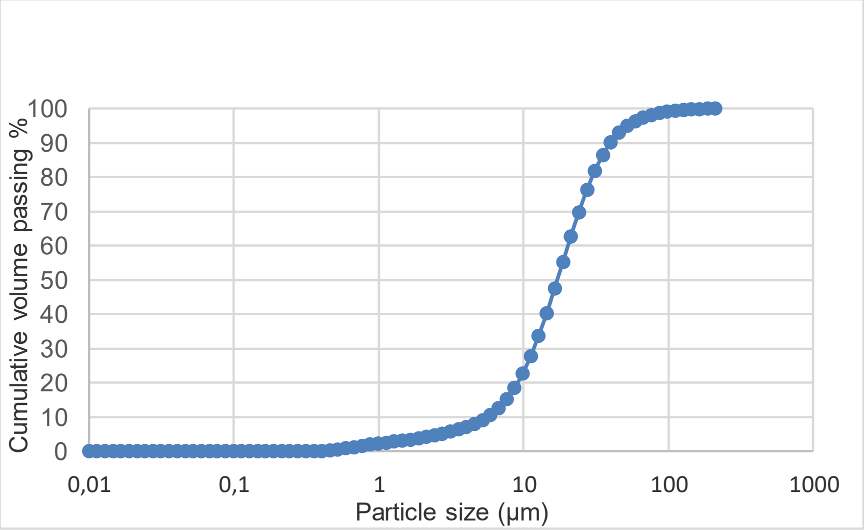

Figure 3: Particle size distribution of the feed slurry

The Particle size distribution analysis shown in Figure 3 recorded that 90% of the feed slurry to contain solids with a particle size smaller than 39.9 µm and 10 % of the sample recorded a particle size smaller than 5.61 µm. Thus confirming that the use of a standard woven geotextiles without the addition of a polymer to agglomerate the solids to ensure sufficient solids retention would not have been an effective solution.

3.2 Requirements for Trial

The trial required the use of an open top dewatering tube to monitor the filling process and take accurate measurements. The bag was mounted in a flow bin frame with a drip tray to ensure percolation through the bottom of the bag and to ensure that the bag does not topple over during the study.

The trial utilized the following:

- 1m x 1m x 1m Open top composite dewatering bag. Seen in Figure 4 below.
- Flowbin frame, with modified bottom plate for percolation and positioned in a drip tray.
- Sample collection containers: 500ml and 1000ml
- Stopwatch

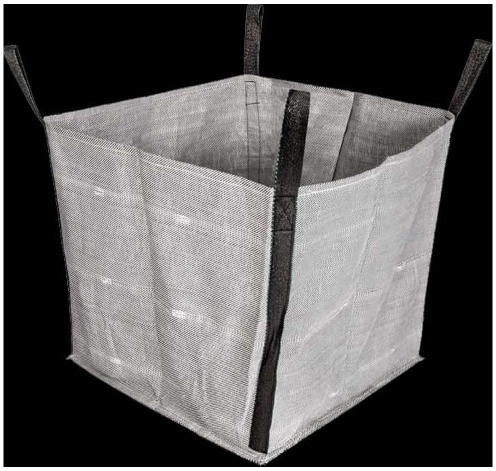

Figure 4: 1m x 1m x 1m Zebratube dewatering bag for trial with lifting inserts

4 Method

Dewatering using the composite bags required that the slurry be fed to the bag by pumping. Once the slurry is inside the bags the solid particulates are allowed to settle, this allows for a filter cake to form on the surface of the nonwoven filter fabric. The formation of the filter cake enhances the filtration efficiency further, thus, allowing clear filtrate to percolate through the filter fabric.

The composite geotextile's dewatering efficiency was tested by conducting on-site trials utilizing the composite dewatering bags in a 1 ton square bag configuration. The bags were allowed to drain under standard atmospheric conditions under gravity. The feed slurry to the 1 ton composite bags was fed at a flowrate of 15m^3/h and contained 2% solids by mass and recorded a density of 1,04 t/m^3.

The total suspended solids concentration of the filtrate was tested for and determined during the filling procedure. On completion of the filling procedure, the contained material in the composite bags were allowed to passively drain. Thereafter the dewatered material was tested for moisture content.

On completion of the test preparation and setup detailed in section 3 above, the following steps were followed:

- The slurry was fed into the composite dewatering bag at a feed rate 15m^3/h with the use of a slurry pump.
- A 500ml feed sample was taken.
- The time taken to fill the bag was recorder.
- A 500ml filtrate passing through the composite dewatering bag was sampled intervals to determine the total suspended solids concentration in the filtrate.
- Two samples of the dewatered material retained in the composite dewatering bag were tested for moisture content at 15 hours and 72 hours respectively.

5 Results

Figure 4 below demonstrates the development of the filter cake on the geotextile filter surface and the effect it had on the dewatering efficiency of the composite dewatering bag. During the filling process it took 4 minutes for the 1m x1m x1m composite dewatering bag to completely fill. Figure 5 illustrates the suspended solids of the filtrate over time. Filtrate quality during filling was recorded as 34 mg/L after 4 minutes, with the suspended solids in the filtrate reducing to 4 mg/L after 10 minutes (during passive drainage).

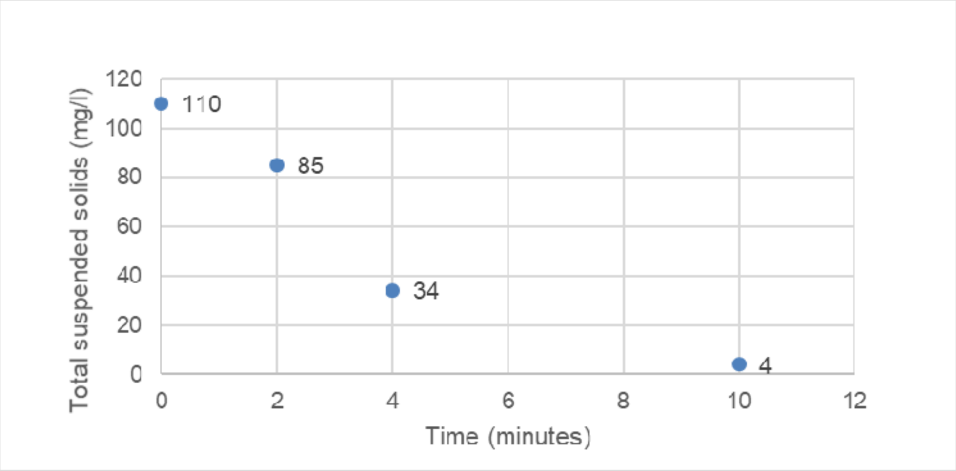

Figure 5: Filtrate Suspended Solids over time during the filling period

The two samples of the dewatered material contained in the composite dewatering bags were tested for moisture content. The first sample had a standing period of only 15 hours and recorded a moisture content of 60%. A second sample was taken after 72 hours with a moisture content of 57% recorded, as shown in Table 3 below.

Table 3: Moisture content analysis results

Sample ID	***Standing time***	***Moisture content analysis %***
Sample 1	15 hours	60%
Sample 2	72 hours	57%

6 Conclusion

The results detailed in the aforementioned section depicts the ability of the composite dewatering bag to effectively dewater an ultra-fine slurry from a 2% solids concentration in the feed slurry to 4mg/L after 10 minutes under passive drainage conditions. The filtration efficiency is considered more than acceptable and allows for the filtrate to be utilised for the resin regeneration at the water treatment plant. The centrifuge currently installed at the water treatment plant produced dewatered solids with a moisture content ranging from 50-60%. This compares favourably with the retained dewatered solids in the composite bag shown in Table 3 with a range of 57-60% moisture content recorded after 72 hours. It should be noted that for this trial the dewatering sample bags were kept indoors and had not been taken out to be dried by atmospheric conditions.

The benefit of the composite dewatering bag solution as opposed to the mechanical centrifuge were that the dewatering bags require no specialised technical expertise to operate or maintain. The use of the composite dewatering bag solution allowed for continuous operation when using multiple bags simultaneously, thus avoiding downtime caused by the frequent breakdowns experienced with the centrifuge. The newly developed composite dewatering bags did not require the addition of any polymers, thus further reducing the need for more mechanical dosing equipment and further reducing the operational costs of the system.

The newly developed composite dewatering bags were purposefully designed and developed by Zebratube for this particular project, however, can be used for a wide range of applications and industries namely:

- Water Treatment Plants
- Agricultural sector
- High value mineral refineries
- Sewage disposal and effluent treatment plants

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