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Fluid Fine Tailings in Stacked Geobags
Concepts & Lessons learned

Fluid Fine Tailings (FFT) in Stacked Geobags Concept & Lessons learned

Outline

- ✓ Overview
- ✓ Inherent properties
- ✓ Recipe
- ✓ Zeta potential
- ✓ Process
- ✓ Physical stability
- ✓ Chemical stability
- ✓ Conclusions

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FFT in Stacked Geobags – Overview

Deposit capable of facilitating reclamation

- Accelerate consolidation and improve stability of closure landforms

Inline chemical treatment (recipe) of the FFT

- Assist solids/water separation and ensure fines agglomeration during pipeline transport prior to the deposition in the geobags

Treated FFT dewatering in geobags / rate of dewatering

- Recipe
- Inline mixing process
- Short drainage path
- Internal pressure and gravity head during filling
- Filtration properties of the geofabric
- Evaporation
- Freeze-thaw
- Increased total stress due to loading

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FFT in Stacked Geobags – Inherent properties

Mineralogy (A)

- Predominantly fine quartz followed by clay minerals (kaolinite and illite)

pH, solids content (slurry density), bulk density, specific gravity and plasticity

- The pH is 8, solids content is ± 20%, bulk density is 1.15 t/m3, specific gravity is 2.5 and plasticity is low

Quartz (B) & Kaolinite (C) versus pH

- Quartz (Van Lierde, 1980) and kaolinite (Masliyah, 2004) at pH > 2 remains in suspension by action of the electrostatic repulsive forces

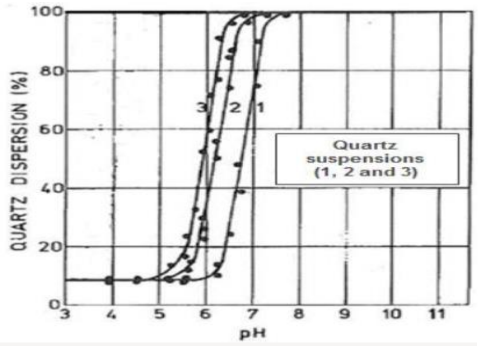
Particle size distribution (PSD)

- Typical FFT PSD is 97% finer than 75 micron and 37% finer than 2 micron, consistent with the mineralogy results

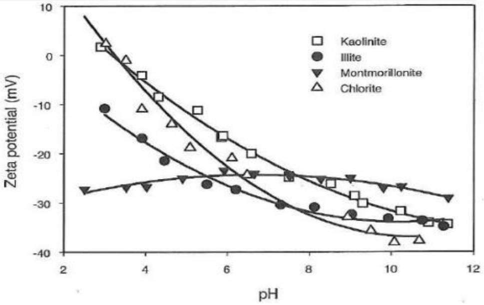
(A)

Mineral	Quantity (%)
Quartz	55.5
Kaolinite	23.2
Illite	11.6
Microcline	3.2
Clinochlore	0.8
Siderite	1.0
Pyrite	0.2
Anatase	0.7
Rutile	0.7
Albite	1.3
Dolomite	0.9
Calcite	0.9

(B)



(C)



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FFT in Stacked Geobags – Recipe

Chemical treatment

- Objective: maximize fines capture, enhance dewatering and accelerate consolidation

FFT is predominantly quartz and kaolinite particles

- FFT at pH 8 presents a highly negative surface charge (- 40 mV) that leads to a dispersive state by action of electrostatic repulsive forces (A)

Coagulation with high valence cations (Al3+)

- Quartz and kaolinite repulsion forces are reduced with high valence cations, resulting in coagulation of the particles (B)

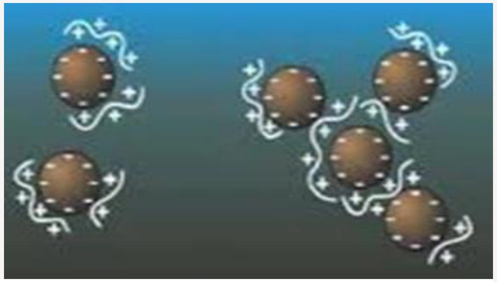
Flocculation with anionic flocculant

- Efficient fines agglomeration and dewatering of the coagulated quartz and kaolinite particles are achieved with anionic polymer addition (C)

(A)

+

(B)



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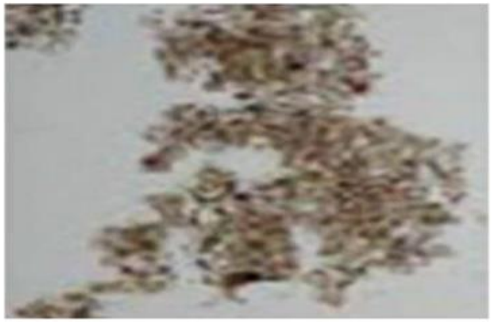

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FFT in Stacked Geobags – Zeta Potential

Zeta potential

- FFT zeta potential is - 40 mV at pore water pH 8

(A) Quartz particles (adapted from Masliyah, 2004)

- Point zero charge at pH >10 with increased concentration of CaCl2+ cations, resulting in coagulation of the particles

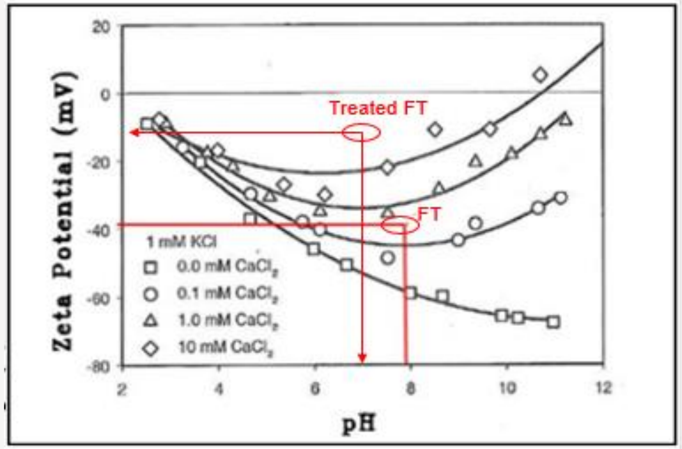
(B) Kaolinite particles (adapted from Peng and Di, 1994)

- Point zero charge at pH 3 with increased concentration of CaCl2+ cations

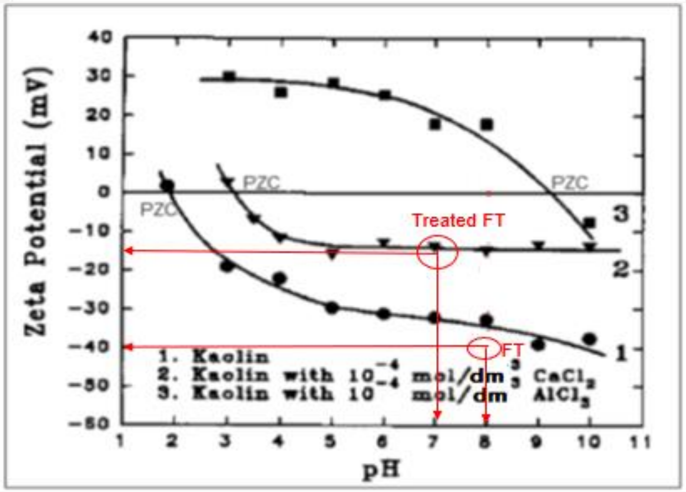
Treated FFT with coagulation + flocculation

- Coagulant (Al3+) + flocculant (anionic) = efficient flocculation of quartz and Kaolinite particles = treated FFT zeta potential = - 14 mV at pore water pH 7

(A)



(B)



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FFT in Stacked Geobags – Process

Chemical treatment (recipe)

- FFT is chemically treated inline by coagulation and flocculation addition

Filling the geobags - commercial size 40 m circumference x 100 m length

- Specific strength and hydraulic parameters of the geofabric limiting the intake pressure and the filling height (max 3 m)

Dewatering and Water recovery recycled to the ops process

- Dewatering due to recipe, short drainage path, internal pressure and gravity head, self-weight consolidation and loading

Treated FFT physical properties

- Agglomerated Silty-clays, normally consolidated
- Medium plasticity; 60% solids content by mass (initially); specific gravity 2.36; 98.6% fines capture; and SFR 0.14

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FFT in Stacked Geobags – Physical stability (PS)

Under loading conditions of 2 layers of geobags

- Undrained shear strength and pore water pressures were monitored for one year to evaluate consolidation and strength gain behaviors

Excess pore pressure dissipation

- Bbar parameters show that the treated FT remains contractive and dissipating excess pore water pressure
- Consolidation = dissipation of excess pore water pressure

Undrained shear strength

- Undrained shear strength increases with time, responding very well to the relative rapidly loading
- The second layer was stacked right after the completion of the first layer (still at 2 kPa strength)

Excess pore pressure dissipation

Parameter	Bag filled (initial)	After 1 year	Seasonal cycle completed
Static pore water pressure U_0 (kPa)	19.62	10.79	
Excess pore water pressure Δu (kPa)	9.86	2.35	
Bbar (kPa)	*0.50*	*0.24*	*Excess pore pressure dissipation*

Average undrained shear strength (Su) of the stacked geobags.

Parameter	Bag filling completion	After 1 year	Comments
Peak	2.0 kPa	15.0 kPa	Field and lab testing
Peak remolded	0.3 kPa	2.8 kPa	

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FFT in Stacked Geobags – Physical stability (PS)

Tensile work strength of the geofabric

- Parameter based on lab analysis cross machine direction (CMD) provided by the manufacturer – for commercial size GT500 = 220 kN/m

Ultimate strength

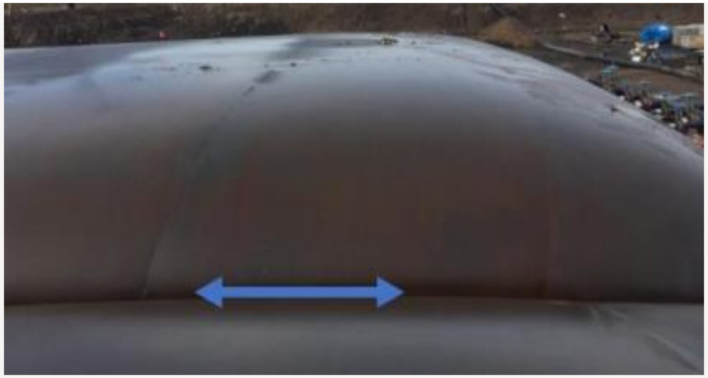
- T (ult.) = T (work) x FS (id x ss x cd x bd x creep), where:
- T (work) = 220 kN; id (installation damage) = 1.3; ss (seam strength) = 2; cd (chemical degradation) = 1.0; bd (biological degradation) = 1.0 and creep = 1.0

Verification of the geofabric Factor of Safety

- FS (circumferential direction) = T (work tensile strength) ÷ (T ult.) and therefore, FS = 220 ÷ [24.93 (1.3 x 2.0 x 1.0 x 1.0 x 1.06)] = 3.2

Geobag properties

Input		Output
Geobag height	2.90 m	Max. circumferential tensile force = 24.93 (kN/m)
Geobag circumference	44 m	Max. average axial tensile force = 23.00 (kN/m)
Density of the fill material	1.2 t/m^3	Geobag base contact width = 20.66 m
Seam type	Circumferential	Cross section area = 55.21 m^2
Fill port type	Rigid mech.	Volume/length = 55.21 m^3/m
Fabric type	GT 500	(%) max. fill capacity = 36%
		Pressure at the base = 34.256 kPa
		Circumferential direction FS = 3.2
		Axial direction FS = 3.0
		Fill port rupture FS = 3.2



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FFT in Stacked Geobags – Chemical stability (CS)

Chemical stability of the treated FFT – The 1st Step

- Understand geochemical processes x mineral alteration and their relation to dam stability
- Sulfur speciation on the solid fraction of the FFT would give sulfur in the form of sulfates to allow sulfur in the form of sulfides to be deduced

Mineral composition influences oxidation process

- Mineralogical and geochemical interactions are essential aspects to understand the parameters controlling acid mine drainage formation and develop effective prevention methods

Neutralization process

- Carbonate speciation is pH dependent
- Dissolution of calcite increases the amount of carbonate in solution which increases the neutralization potential of the solution
- Therefore, the neutralization potential of the treated FFT could be evaluated by the amount of carbonate in solution

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FFT in Stacked Geobags – Conclusions

1. Geosynthetics technology is a well-established innovative solution available for geotechnical engineering projects that involves their use to combine mechanical and hydraulic properties in a controlled manner.

2. Geobag is a successful technology that can be implemented to improve tailings management and stability of closure landforms if the FFT is treated effectively before the geobag is filled.

3. The success of FFT disposal in geobags requires a chemical treatment that combines coagulation and flocculation that is referred to herein as the “recipe”.

4. The recipe objective is to maximize fines capture, enhance dewatering, accelerate consolidation, and maintain the integrity of the agglomerated fines to ensure that segregation does not occur.

5. The geobags act as a filter pressure system, with most of the water recovery occurring while the bags are being filled. Fines capture ranges between 97 and 99% (i.e., 51% silts and 47% clays).

6. The treated FFT in geobags shows a considerable gain in strength over a 10 days period, increasing from 2 to ≥5 kPa.

7. The recipe, short drainage path, internal pressure and gravity head, self-weight consolidation and loading are key contributors for the enhanced dewatering and accelerated consolidation of the FFT in geobags. Evaporation and freeze-thaw were also identified as contributors for dewatering with time.

8. Filling of the geobags is controlled by the specific strength and hydraulic parameters of the geofabric that limit the intake pressure and the filling height.

9. Tensile work strength with low elongation provided by the geofabric is a key reinforcing parameter of the geobags deposit, allowing for stacking at low undrained shear strength (2 kPa).

10. This technology also allows for the formation of thick, geotechnically stable, layered deposits by simply stacking the geobags.

Our values are the essence of our company's identity. They represent how we act, speak and behave together, and how we engage with our clients and stakeholders.

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We put safety at the heart of everything we do, to safeguard people, assets and the environment.

INTEGRITY

We do the right thing, no matter what, and are accountable for our actions.

COLLABORATION

We work together and embrace each other's unique contribution to deliver amazing results for all.

INNOVATION

We redefine engineering by thinking boldly, proudly and differently.

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