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Experience with Geotextile Tubes in Mining Tailings Storage: Gran Colombia Gold Segovia

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ABSTRACT

The Gran Colombia Gold Segovia company, Colombia branch (GCGS), has a mining operation between the municipalities of Remedios and Segovia, Department of Antioquia - Colombia. The extraction material is processed at the María Dama Plant and the tailings are pumped to the El Chocho deposit.

The original tailings deposit project contemplates two reservoirs generated by 2 earth dams, called: Upper and lower tailings storage. Phases 1A, 1B and 1C were defined in the upper tailings storage. Phase 1B is used at 100% capacity with pulp tailings, phase 1A in operation and phase 1C under construction. Technifying the sludge disposal process in phase 1A, 91 geotextile tubes (TG) were used, which are filled with tailings, adding flocculants to improve the separation of solids and subsequent water filtration.

The GT were placed in the 1A containment dam in a structured manner, following the design and the corresponding technical specifications. In the specified procedure, 2 previously analyzed situations will be seen -more unwanted- however, there was an action plan in case of occurrence. The first one related to the size of the geotextile opening vs. minimum particle size. Occasionally, the pumped tailings from the treatment plant proceed with the smallest size to the opening of the geotextile. The second scenario was presented during the filling operation of a GT, which was ripped longitudinally despite its high resistance to stress and breakage. The existing barrier in the downstream zone contained the tailings.

The use of GT allowed to expand the storage capacity of the tailings by replacing the loan material from the phase 1A dam with mining tailings. The current GT (1A) dam will be integrated into the downstream tailings, from the storage of filter-pressed mining tailings, ensuring the stability of the 1A dam , in the time.

INTRODUCTION

Gran Colombia Gold Segovia (GCGS)'s main contribution of gold ore comes from the El Silencio, Providencia and Sandra K underground mines and, in a second contribution, the operation of small mining units within the GCGS property.

The tailings deposition is part of the final mining process, constituting material with no economic value for the company. The good management and exploitation of the tailings dams ensures the continuity of production and the benefit of the mineral.

In the mining sector, application cases with GT technology are known, such as the recovery of precious metals, maintenance of leaching ponds, construction of dams, berms or perimeters for the management of tailings, among others. GCGS used this technology initially to enhance a dam in phase 1B, and later to replace a homogeneous earth dam with a GT dam in phase 1A, being integral structures of the El Chocho tailings project.

Some considerations for applying this technology include waterproofing the soil to avoid seepage, preparing the base with homogeneous gravel, proper handling of contact / non-contact water and resistance to seismic conditions. The design established for the construction of Dam 1A supports the hydrostatic thrust of the pressed filter tailings and rainwater, guaranteeing the stability of the structure.

The GT in the upper storage are structures that will be confined by pressed filter tailings after the completion of phase 1C of the project.

METHODOLOGY

The municipality of Segovia is founded on the Jurassic batholith of Segovia, consisting mainly of Diorites, especially quartz Diorite, and locally basic rocks and Hornbondic gabros. The stratigraphic-lithological profile of the dam area, defined in previous studies, is defined by sandy clay in the first meter and clay sandy soil (14.08 % fine, 3.24 % gravel and 83.30 % sandy). The parameters for the anti-seismic design, according to the Colombian regulation NSR-2010, are attributed to the municipality of Segovia as an intermediate seismic risk. Considering the type of soil existing in the project area, the resistant anti-seismic design parameters are 0.15 for the effective peak horizontal acceleration coefficient (Aa) and 0.20 for the coefficient representing the effective peak horizontal speed (Av).

The water table found in the project area is 2.30 meters on average, however, some soundings in the area did not record values. With the use of finite elements, the flow network was drawn and the expected filtration of 90.61 x 10-9 m / day was determined.

The original project includes two reservoirs generated by two earth dams, called: Upper and lower tailings storage. Both reservoirs contemplated a storage capacity of 1.5 million m3. However, due to terrain governance characteristics, the area within the Upper Storage was optimized.

Phases 1A, 1B and 1C were defined in the upper tailings storage. Phase 1B is currently at 100% full capacity, and phases 1A and 1C are under construction. Technifying the tailings disposal process (use of TG and filter press) in phase 1B 60 GT were used to enhance a dam and in phase 1A 91 GT were used for the construction of intermediate dam 1 A.

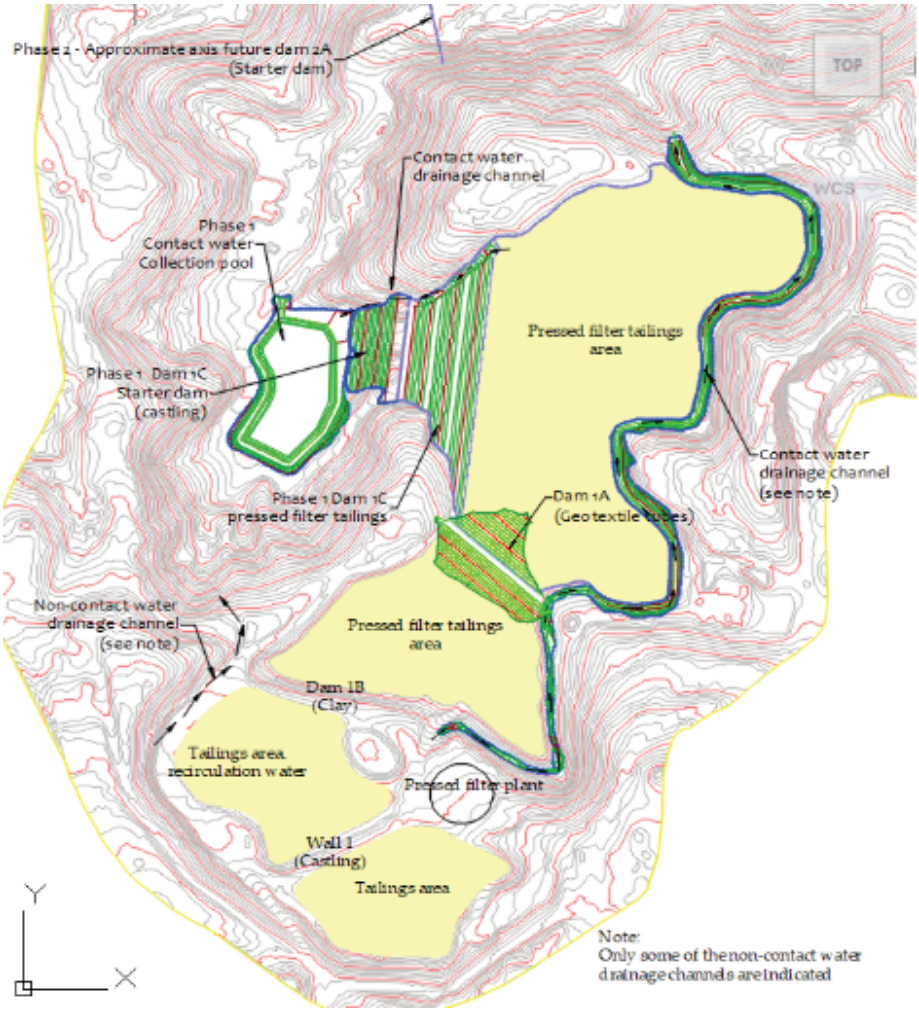

Figure 1 Bottom up phases overview: dam 1B, 1 A, 1C and 2A

The construction of the tailings deposit containment structures and material deposition is carried out from phase 1B in the upper storage to phase 2 of the lower storage, corresponding to the levels 750 masl and 635 masl.

The tailings are pumped from the María Dama process plant (MDPP) to the project with a density of 1.1 ton / m3, undergoes a conditioning process in a thickener tank and anionic-type flocculant is added where it reaches densities of up to reach 1.6 to 1.65 ton / m3.

Once the density is reached, within the project the Chocho through a manifold made up of gate-type valves, the tailings can be taken to the press filter plant or directly to the GT with 3 - inch hoses, as the case may be.

Based on the topography of the area and considering the technification process (filter press and GT) in phase 1, the volumetric capacity for the different sub-phases of the project was determined, observing a 166 % increase in total capacity, compared to the 1.5 million m3 of the initial project.

Table 1 Final storage capacity of the El Chocho project

Stages of the project	Start deposition	End of deposition	Duration (days)	Capacity (m3)
Phase 1B containment (pumping)	2018/04/13	2019/05/01	383	240,000
Phase 1A containment (geo tubes)	2019/05/01	2019/11/10	194	140,000
Phase 1C containment (filter pressed)	2019/11/10	2022/07/09	972	810,000
Total phase 1				1,190,000
Bottom storage (filter pressed)	2022/07/09	2025/08/07	1124	1,300,000
Total phase 2				1,300,000
Total project storage				**2,490,000**

Geotextile tube technology (GT)

The GT used in the El Chocho project are large tubular bags formed by high-resistance, permeable polypropylene woven geotextile membranes, joined by seams, which are filled with tailings, in a fluid state, by pumping . A flocculant is added to the fluid mass that is pumped into the geotubes to thicken or densify it, in order to minimize the output of its finer particles through the membrane. Excess water drains by gravity through said membrane, retaining within the geotube most of the solid component of the flocculated tailings, consolidated, in our case 7 days after filling, the internal density of the material reached 2 ton / m3 and the internal humidity between 12 and 8 %. The entrance of the tailings to the geotextile tubes is made through the sewn inlets and located along the upper central axis of the tube, which allows filling efficiently. They have tapes (handles) that facilitate the manipulation of the tube.

The filling of the geotextile tubes is carried out consecutively, leaving an overlap of 1.5 meters of support with each other in the longitudinal direction. Solids retention is 99 % giving way to water through the pores of the geotextile.

The stability of the Geotube Dam was analyzed by the manufacturer, using a program developed by that company, obtaining as a result a satisfactory sliding safety factor.

The polypropylene membrane used in geotubes has a tensile strength of 70 kN / m ≈ 7,000 kg / m ≈ 7 Ton / m.

As an example: a geotube 60 m long and 2.13 m high, once the tailings that fill it are dehydrated, would weigh approximately 1,000 tons.

In addition to the friction that develops in the contact of the rough membranes, there is also a lock between them, due to the deformation of the upper geotube, which partially penetrates the space between the lower two.

A barrier was built at the foot downstream of the dam, in order to retain the solids resulting from the filling operation. In this way, no discharges are delivered to the Peñitas stream downstream of the project. The water from the GT is collected through a network of sub-drains which is channeled to return to the MDPP, being an environmentally sustainable process of the water resource.

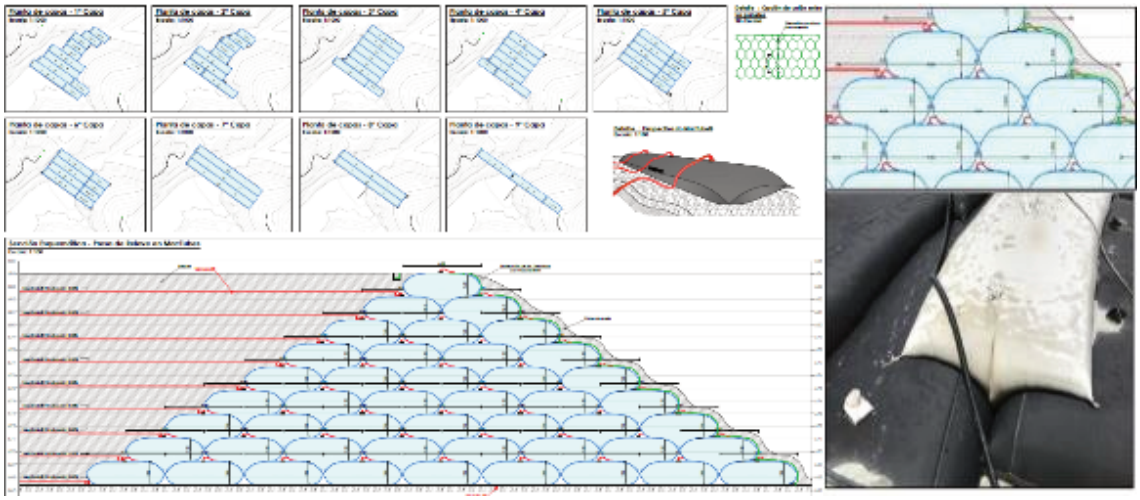

Figure 2 Cross section of the TG dam, phase 1A

In the filling operation and with the rainfall in the area (more than 2,500 mm / year), it is appreciated that the GTs maintain their shape and internal consolidation, once fully filled.

Table 2 Characteristics of the geotextile tubes used

Location of geotextile tubes	Number of tubes	Length (meters)	Perimeter (meters)	Height (meters)	Fill time (hours)	Total time (hours)
Dam. Phase 1A	25	15	13	1.8	3	75
	31	31	13	1.8	6	186
	5	60	13	1.8	12	60
	30	20	12	1.3	3	90
Total phase 1A	91					411
Berm. phase 1B	60	20	12	1.3	3	180
Total phase 1B	60					180
Total phase 1	151					591

Unwanted scenarios

During the filling of the TG and the construction of the structures, two unwanted scenarios were presented in the operation, which were previously contemplated.

Scenario 1. Size of the particle passing through the geotextile

The opening of the geotextile is 0.425 millimeters and the retention must be 99 % of the solid whose particle size is 100 % through mesh No. 325 (0.04 mm). During the filling of the first GT, the filtered water contained tailings particles in suspension, the drainage barrier (rock wall wrapped in geotextile) built at the downstream foot contained the sediment and the water was led to the treatment plant through a network of pipes. In the case evaluation, the geotextile was retaining 80 % of the suspended solids. Faced with this scenario, the PBMD engineers adapted the ratio of the flocculant applied to the tailings in the thickener tank. By changing the concentration and installing a coil in the filling line, the retention of 99 % of the tailings was obtained and clean water was delivered.

Scenario 2. Breakdown of the geotextile

The placement and filling of the GT must follow the procedure recommended by the providers, this consists of extending the GT horizontally and distributing the flow evenly through the nozzles, in order to balance the internal pressures. During the construction of the dam in phase 1A, 4 geotextile tubes were torn due to failures during the filling operation, situations attributed to the handling of the handles, placement of the geotextiles, overfilling and poor distribution of the tailings. The effective perimeter defined for each geotextile tube must be respected to guarantee the integrity and stability of the structure. Under this scenario, the solution was to remove all the tailings and damaged surfaces, replacing it with another TG, optimizing the filling technique, slowing down the flow, and continuing the placement of the GT, according to the design.

ANALYSIS AND DISCUSSION OF RESULTS

The optimization of the storage capacity in the El Chocho tailings deposit was obtained with the alternate use of GT and filter-pressed tailings. The volume of loan material that would initially be used in Dam 1A was replaced by compacted tailings within the GT. Placing the GTs on the waste rock in phase 1B was effective in raising the tailings level and draining the water through the rock dam.

The main failure mechanisms defined for mining tailings dams include slope slide and seismic action.

Dam 1A stability analysis is not performed according to traditional homogeneous dam practices, where the study is based on the application of slip circles. GT are independent elements that work by gravity and friction, arranged in horizontal alignments and interlocked with each other. Filter pressed, deposited and compacted tailings in phase 1A reduce the development of overpressures in the structure. Considering that the level of the tailings rises and the vessel will not be emptied, the probability of slipping on the internal face of the structure decreases as a consequence of a possible change and decrease in unit weight. The empty spaces between GT were filled with filter-pressed tailings and manually compacted. The construction procedure used reduces the chances of siphoning in the foundation, avoiding deformation and slipping of the GT. Dam 1A will not be used as a service route for vehicles or machinery, a condition that allows its integrity to be maintained.

The stability design of the dam is subject to the patent of the supplier, who indicated the design, layout of the GT, filtration system, installation procedure and general recommendations.

Assessing the qualitative behavior of the saturation line in any dam and the state of compaction of dam 1A by the use of GT, where the internal passage of water is minimized, precautions were taken in the foundation through a system of French type herringbone drainage, to channel possible leaks at the foot of the dam, increase stability and prevent landslides.

Establishing similarity of a GT dam with a typical dam and the level of tailings with the level of sediments, the hydrological factors related to the floods do not apply, however, a free edge of 0.50 meters was established that allows the damping of the waters of rain in the event of extreme events, a slope of 1% of the tailings towards the internal rainwater channel and surface type spillway for water evacuation was defined.

According to NSR - 10 Col, the project is located in an intermediate seismic zone, previous studies do not indicate failures or undesirable elements for the foundation. During the earthmoving and waterproofing stage of the vessel, no cracks or unfavorable conditions were observed in the foundation.

The El Chocho tailings project has high quality standards in its procedures and materials used, thus complying with environmental, structural, hydraulic and operational aspects.

CONCLUSIONS

The optimization of the tailings storage capacity in the El Chocho project was achieved with the use of TG and the use of the filter press.

The use of GT reduced the construction time of the containment structures, allowed the continuity of the filling, even in rainy seasons, and ruled out any stop of MDPP due to lack of capacity in the tailings deposit. Its slopes are not affected by rain or wind erosion. The use of TG does not cause dust emissions.

The use of the TGs minimized the affectation of the soil, flora and fauna resources. The filtered water was immediately available in the process, being recirculated to the MDPP and marking a sustainable

management of the water resource. By using pipes to transport the tailings from the plant, fine particles in the air or pollution were eliminated by the previous transport in trucks.

Construction time for Dam 1A was relatively shorter with the organized arrangement of the GTs vs. the construction of a loose materials dam. Construction did not require the use of machinery, and weather conditions did not generate delays in construction, which represents a decrease in costs.

The final closure structure, lower storage phase (1C), will be a stone structure. Achieving a significant reduction in the materials for the dam of loose materials from the original design. In this way, the current GT (1A) dam will be integrated into the downstream tailings, from the storage of filter-pressed mining tailings, ensuring the stability of the 1A dam, in the time.

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