Use of geotubes in Colombia, South America

J.FOWLER, Geotec Associates, jfowler@vicksburg.com, Vicksburg, MS, USA
C.ORTIZ, Msc, Geofort Limited, Bogotá, Colombia
N.RUIZ, TC Nicolon, Bogotá, Colombia
E.MARTINEZ, Dragados Hidraulicos, Bogotá, Colombia

ABSTRACT:

This paper describes two case histories of geotube projects constructed in Colombia, South America. The first case history involves one of the first locations in South America where geotubes were used for construction of confined disposal area islands used for containment and dewatering of fine-grained maintenance dredged materials. This project is located on the San Antonio Inlet, Buenaventura Colombia. This dredged material containment area was the first of two circular shaped islands planned in this riverine and tidal environment. This new and innovative construction methodology involved hydraulically filling geotubes with a sandy fill material. Geotubes are simply an assemblage of geotextile fabric panels sewn to form long tubes for containment of dredged material. The geotubes were positioned end to end to provide a perimeter dike for dredged material containment in tidal variations of 4 m twice a day. After the first island was completed, it served as a dredged material containment facility until it was filled. After it has stabilized, it will be planted in Mangrove trees and other native vegetation and will be used exclusively for environmental purposes.

The second case history describes the use of concrete filled geotubes that were used to block a 10 m diameter bypass construction tunnel that was inadvertently left open during construction and filling of Chivor reservoir, Santa Maria, Colombia. During periodic maintenance and inspection of the generator turbine blades, it was discovered that undue wear and impact damage to the metal turbine blades was occurring. Reservoir sediments had accumulated to a depth that exceeded the height of the tunnel. The tunnel was located in the bottom of the reservoir. An erosion channel had formed at the mouth of the tunnel opening indicating that fine-grained lake sediments had been entering the tunnel for quite some time. Continued surficial rock sliding of sediment had contributed to the amount of material entering the tunnel and impacting the turbine. The tunnel was successfully closed with twenty-five concrete filled geotubes placed in front of the tunnel opening. The geotubes closed the opening and prevented the further loss of sediment and damage to the turbine blades.

1 FIRST CASE HISTORY BUENAVENTURA, COLOMBIA

1.1 *Introduction*

One of the first geotube applications in Colombia, South America was for the construction of a confined disposal area island used for containment and dewatering of fine-grained maintenance dredged materials (Fowler et al., 1994). This project is located on the San Antonio River, Buenaventura Colombia. The dredged material containment area is the first of two circular shaped islands planned in this riverine and tidal environment. This new and innovative construction methodology involved hydraulically filling geotubes with a sandy fill material. Geotubes are simply an assemblage of woven high strength geotextile fabric panels sewn to form long tubes for containment of dredged material. The geotubes were positioned end to end to provide a perimeter dike for dredged material containment in tidal variations of 4 meters twice a day. One island has been completed and filled with dredged material. After the dredged material stabilizes, the circular shaped island will be planted in Mangrove trees and other native vegetation and used exclusively for environmental purposes. At this writing, the second island is in the planning stage.

1.2 *Background*

The dredged material containment project is located about 80 kilometers inland from the Pacific Coast adjacent to a 15-meter deep navigation channel that serves the Port of Sociedad, Buenaventura, Colombia, an international port for deep draft ships. A new port, Port of Solo, is planned across the river from Port of Sociedad to serve the expanding trade in this region. Port Solo will also be constructed utilizing the geotube concept for containment and confinement of dredged material for rapid and economical construction of a very stable, upland area for ship container cranes and storage facilities. A 3000-meter roadway leading out to the 15-hectare port facility will also be constructed using parallel geotubes with fill placed between the geotubes to form the roadbed. Foundation sand will be dredged from the river and placed in the proposed port and roadway.

New port developments have caused a need for new work channel deepening, maintenance dredging and additional disposal areas. Existing dredged material disposal areas have either been filled to capacity or have deteriorated because of inadequate maintenance and design. An attempt to construct a disposal area using cement and rock filled gabions adjacent to the city of Buenaventura on the San Antonio River has been abandoned because of environmental and foundation conditions. Another disposal area located across the river in an area planned for the Port of Solo was constructed using small sand bags, but it has been completely filled with maintenance dredged materials and is no longer in service.

Political concerns have caused the use of Colombian Navy personnel to secure the construction areas during day light hours. The use of the Navy's deep draft boats were limited when the tides were very low or at night allowing local Guerrilla forces to harass the construction workers. Kidnapping of the Port Engineer and Port owner's nephew occurred a couple of months prior to construction of the disposal area.

1.3 *Environmental Concerns*

Permission to construct dredge material containment facilities for fine grained dredged materials in Colombia had become very difficult because of environmental constraints by local and state governments. The navigation channels leading into this area were constantly being dredged and disposal alternatives were limited. The existing upland disposal areas had been depleted. Transport 80 kilometers to the Pacific Ocean for disposal was not considered to be economically feasible when compared to disposal islands constructed with geotubes. Several alternatives such as construction of upland disposal sites and dumping in the river adjacent to the navigation channel were met with environmental concerns and were not allowed. An upland dredged material disposal area was not an option because of potential damage to Mangrove trees, poor foundation conditions and limited space. Construction of dikes on poor foundation materials, in open water with 4-meter high tides twice a day was not considered to be technically feasible without the use of geotubes.

1.4 *Design*

The 1100-meter circumference of the circular shaped island design was oriented to minimize obstruction to river currents. The circular shaped dredged material disposal areas were designed using 20-meter circumference, 3.0-meter high geotubes fabricated with a TC Nicolon GT500 woven polypropylene geotextile fabric. This fabric has an Area Opening Size of 0.425 mm and a wide width tensile strength in the machine and cross direction of 70.0 and 96.3 kN/M respectively. Seam strengths were about 50 to 60 percents of these values. At a height of 3.0 meters, the geotubes contained about 22 cubic meters per linear meter of dredged material.

The first disposal area was about 1100 meters in circumference and 350 meters in diameter. It was estimated to contain about 300,000 cubic meters of maintenance material. The second disposal area was designed to be 1600 meters in circumference and 500 meters in diameter. This disposal area should contain an estimated 600,000 cubic meters of maintenance material. At this writing, the second disposal area has not been constructed.

1.5 *Construction*

The construction plan for the first disposal area was to hydraulically fill eleven 100-meter long geotubes with sandy dredged material from the navigation channel to form the perimeter dike for the circular shaped disposal areas. The geotubes positioned along the proposed alignment were temporarily anchored during filling with 4-meter long poles that were attached to nylon straps pre-sewn along each edge of the geotubes. The contractor made every attempt to locate the more sandy materials for filling the geotubes. Initial filling attempts resulted in too many light weight fine materials in the far end of the 100-meter long geotube and tidal fluctuations cause the first geotube to get slightly off the proposed alignment. To minimize this effect the geotubes were filled in increments of 25 meters with sand with the un-filled portion resting on a small barge until the next 25 meters of geotube was needed. During the filling of the geotubes, a certain portion of the fine-grained dredged material was allowed to flow into the disposal area to maximize sand fill in the geotube (Figure 1). The contractor located the dredge within the disposal area during filling of the geotubes to maximize storage capacity.

Figure 1. View of geotube being filled.

There was only one act of vandalism when a three square meter section of geotextile fabric was cut out of the top of one the earlier filled geotubes. Apparently the vandals found no use for the geotextile fabric. The geotube was repaired by simply hand sewing a panel of fabric into this location. There was also only one act of thief and shooting that took place when a small boat was taken one afternoon. The boat was recovered the next day when it came drifting back downstream nearby the construction site.

The contractor finally worked out a scheme for joining the geotubes to form a watertight joint (Figure 2). This was accomplished by pulling enough slack up onto the existing geotube prior to filling from the opposite end. As the filling operation approached the existing geotube it would form fit around the filled geotube.

Figure 2. Example of watertight joint with two joining geotubes.

Placement of the last geotube to close the island perimeter was very difficult. Four-meter high tides, twice daily, caused water to pond in the disposal area. Deep scour holes developed at the edge of the geotubes along the opening. The opening was close by filling a 25-meter long Geotube positioned across the opening (Figure 3).

Figure 3. Aerial view of geotube island after construction.

1.6 *Summary and Conclusions Case History One*

Construction of the geotube perimeter containment dike for the first circular shaped dredged material containment facility was successfully completed in June of 2000 and is currently being used as a dredged material disposal area. Construction of the second circular shaped disposal area has not begun as of this date. The use of geotubes to form the perimeter dike for the dredged material containment facility has proven to be constructionally practical and technically and economically feasible. Construction of the disposal area perimeter dike would not have been successful without the use of geotubes.

2 SECOND CASE HISTORY, CHIVOR RESERVOIR, SANTA MARIA, COLOMBIA

2.1 *Introduction*

This case history describes the use of concrete filled geotubes that were used to block a 10 m diameter bypass construction tunnel that was inadvertently left opening during construction and filling of Chivor reservoir**.** Chivor Dam is the third highest earth and rock dam constructed in the world with a height of 220 m and a crest length of 800 m. The dam was designed by INGETEC S.A consultants and constructed by IMPREGILO contractors between 1977 and 1980. The reservoir contains an area of approximately 10,000 hectors. The dam is located near Santa Maria, which is about 200 km northeast of Bogotá, Colombia. The reservoir supplies water to a 1000-mega watt hydroelectric power generating plant that contains eight 5 m diameter turbines. The power plant is located 30 km downstream and has a head of 1000 m. A Chilean contractor operates and maintains the reservoir and electric power plant with the Colombian government. The power plant provides over 1/10 of the electric power for Colombia. The reservoir also provides water for agriculture and municipal use for several communities located nearby.

2.2 *Background*

During periodic maintenance and inspection of the generator turbine blades, in September 1998, it was discovered that undue wear and impact damage to the metal turbine blades was occurring. This damage was caused by the impact and abrasion from reservoir bottom sediments entering a 10 m diameter bypass construction tunnel that was inadvertently left open after construction and filling of the reservoir. The bypass tunnel was located in the very bottom of the reservoir and served to bypass surface water during construction of the earth and rock filled structure. Since construction in 1980, reservoir sediments have accumulated to a depth that exceeds the height of the tunnel. An erosion channel had formed at the mouth of the tunnel opening indicating that fine-grained lake sediments had been entering the tunnel for quite some time. In addition to the normal accumulation of lake sediments, recent rockslides in 1998 occurred on the east abutment above and near the tunnel. Surficial sliding of sediments continues to occur along these scarped faces and the possibility of large cobble size particles entering the tunnel and causing complete destruction of the turbines was eminent (Figure 4). The tunnel had to be closed immediately without causing an increase of sediments to enter the tunnel during closure.

Figure 4. Rock and surficial sediment slides were potential danger to turbines.

2.3 *Closure Alternatives*

Several tunnel closure alternatives were presented and evaluated by consulting firms. One of these alternatives was to place prefabricated concrete hexapods until the tunnel opening was closed. Some of the concerns with this method were that the velocity might increase during closure causing larger size particles to enter the tunnel and impact the turbine blades. Another method proposed was to pre-construct a large, steel reinforced, concrete structure that would act like a large manhole cover. The problem with this concept was that it was too large and heavy for small barge mounted cranes to handle over water. The other problem was that there was no clear understanding or mapping of the subsurface contours in front of the tunnel opening for construction of the concrete cover. Several other alternatives were considered, but the selected method was the use of concrete filled geotubes that were lowered in front of the tunnel opening. This method was chosen because it provided the least amount of disturbance to bottom sediments.

2.4 *Geotube Design.*

The geotextile fabric tubes are commonly referred to as geotubes or geobags. They are sewn to form a tube or bag with openings for filling it with a variety of materials such as dredged material, sludges, sand, silts, clays or concrete. The geotubes for this project consisted of a TC Nicolon GC1000 woven polypropylene geotextile fabric. This fabric has an Area Opening Size of 0.425 mm and a wide width tensile strength of 200 kN/m in both the machine and cross directions. Seam strengths were about 50 to 60 percent of these values. Each geotube was 5 m in circumference and 5 m long with two fill ports. At a height of 0.5 m the geotubes contained about 10 cubic meters of concrete.

2.5 *Geotube Placement*

Geotube placement was accomplished with the use of a specially designed steel pontoon barge that was outfitted with four sets of electric winches and side boom cranes that were attached to a steel cradle positioned under the barge. The barge was 20 m long and 10 m wide and the two pontoon sections were welded together to form an opening at the mid point for filling the geotubes. The cradle was submerged under and positioned in the center and perpendicular to the longitudinal axis of the barge. The cradle contained the geotube during filling with concrete and during placement in front of the tunnel (Figure 5).

Figure 5. Filling of geotube in cradle.

Five-inch slump concrete was pumped 200 m from the shoreline to the placement barge with a positive displacement concrete pump. The high-pressure steel pipe used to transport the concrete from the shoreline to barge and geotube was supported from the shoreline on a 2 m wide raft of logs and bamboo that were tied together with rope (Figure 6).

Figure 6. Raft of logs and bamboo supporting steel pipe transporting concrete.

The depth of water under the barge at the tunnel location was 100 m. The cradle was lowered to a depth of 90 m and tilted to allow the geotube to roll out of the cradle falling the last 10 m in front of the tunnel opening. Horizontal positioning of the placement location was accomplish through the use of a Global Positioning System (GPS), and triangalization was accomplished using laser survey equipment located on shore and on the barge. Twenty-five geotubes were successfully placed in front of the tunnel opening, closing the opening and preventing the loss of sediment. The project began in mid April 1999 and was completed in mid May 1999.

2.6 *Summary and Conclusions Case History Two*

Placement and construction of the concrete filled geotube tunnel closure was very successful and the construction method and equipment was very innovative and practical. The percent solids passing through the turbine blades have decreased significantly since the tunnel was closed. The use of concrete filled geotubes to close the tunnel proved to be technically and economical feasible compared to other alternative methods that were proposed. The concrete filled geotubes provided a very successful and permanent tunnel closure.

REFERENCES

Fowler, J., Sprague, C.J., & Toups, D. 1994. *Dredged Material-Filled Geotextile Containers, Environmental Effects of Dredging Technical Notes*. U. S. Army Engineer, Waterways Experiment Station, Vicksburg, MS.