Bioengineering approach for shoreline protection using geosynthetics: A Malaysian experience

L. K. Lim
TenCate Geosynthetics Asia Sdn Bhd, Malaysia

S. H. Chew
National University of Singapore, Singapore

S. H. Wee
Tradimas (Sarawak) Sdn Bhd, Malaysia

Lucas U. C. Lau
Jurutera Minsar Consult Sdn Bhd, Malaysia

ABSTRACT: This paper describes the use of bioengineering approach for the design and construction of shoreline erosion protection at an oil and gas jetty in Sarawak, Malaysia. Bioengineering approach was chosen by the client over conventional armour rocks as it is the most economical solution, minimal disturbance to existing loading and unloading activities and safety as the jetty handle flammable cargos and does not permit use of heavy equipment. The reclamation works can be divided into two stages. The first stage involved construction of a geotextile tube containment dyke platform above the mean sea level which was created by placement of a 1.8m inflated height geotextile tube infilled with sand subjected to a maximum tidal variation of 6.0m. This tube is made of coarse grain geotextile sheet and is installed over a thick layer of soft underlying soil. Stage two involved sand reclamation beside and above the geotextile tube dyke to a maximum height of 4m at a slope inclination of 1V: 2H. To maintain the slope inclination of the sand filling slope from wave erosion, a layer of coarse grain sand filled mattress inflated to an inflated height of 0.18m, and geotextile bags was installed over the sand- filled slope. To prevent global sliding and lateral movement of the structure during construction, a layer of high strength geotextile basal reinforcement was installed on the soft underlying soil prior to the geotextile dyke placement and sand filling. An important highlight of this paper is the installation of the geotextile dyke in a limited headroom space as the tube alignment need to pass through between piers under the existing bridge deck. A total quantity of 340m length of geotextile tube dyke, 6000m^2 of sand filled mattress, 500 pcs of geotextile bags and 5000m^2 of high strength geotextile was successfully installed.

Keywords: Geotextile tube, geotextile bag, sand filled mattress, reinforcement

1 INTRODUCTION

Tanjung Manis is a town by the Rajang River which has been identified as one of the main growth nodes of the Sarawak Corridor of Renewable Energy (SCORE) and is specifically ear-marked as the Industrial Port City. The OGC (Oil, Gas & Chemical) Terminal is situated approximately 2.5km upstream of the Tanjung Manis Township which is located next to the Tanjung Manis Port. The scope of river protection work at OGC was part of the overall scopes of the Refurbishment and Improvement of the Existing Tanjung Manis Port. These ports along Rajang River has a maximum tidal difference of 6m. Two options were evaluated by the consultant and client for the shoreline protection: Option 1 is a conventional armour rock revetment system, and option 2 of geosynthetics system using a combination of geotextile tubes, sand filled mattress, geotextile bags and scour apron (Fig. 1 and Fig. 2). After extensive evaluation on the design and cost by the client and consultant, option 2 of geosynthetics system approach was chosen as it offers the most cost effective option and also allows blending with the surrounding vegetation.

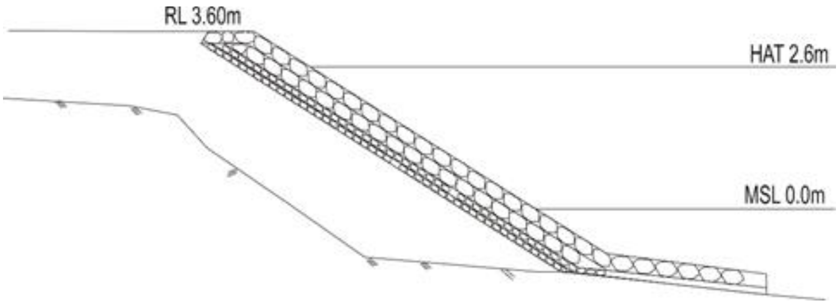

Figure 1. Conventional armour rocks protection system

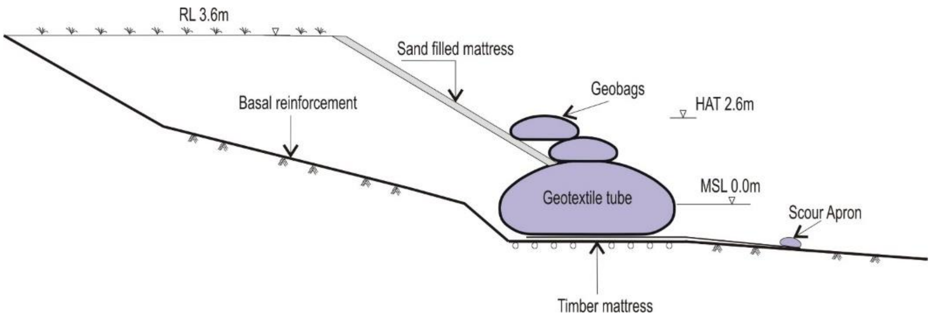

Figure 2. Geosynthetics system using tubes, sand filled mattress, bags and scour apron

1.1 *Site investigations*

Site investigations work was carried out to ascertain the ground conditions of the proposed site whereby the geosynthetics system will be constructed. Five (5) nos. of boreholes were carried out with undisturbed samples collection and Standard Penetration Test (SPT) tests conducted at an interval of about 3 m. Undisturbed samples were retrieved from the boreholes for undrained shear strength in laboratory testing. The subsoil profile for the proposed site is shown in Figure 3.

The first layer consists of approximately 10m to 15m of soft Clay with the SPT- N values ranging from 2 to 5 blows. This layer is then underlain by 2m to 4m of stiff grey with SPT- N values range from 9 blows to 14 blows. Thereafter, the subsoil is dominated by 10m of stiff to hard grey silt SPT- N = 50 blows before reaching the bed rock level.

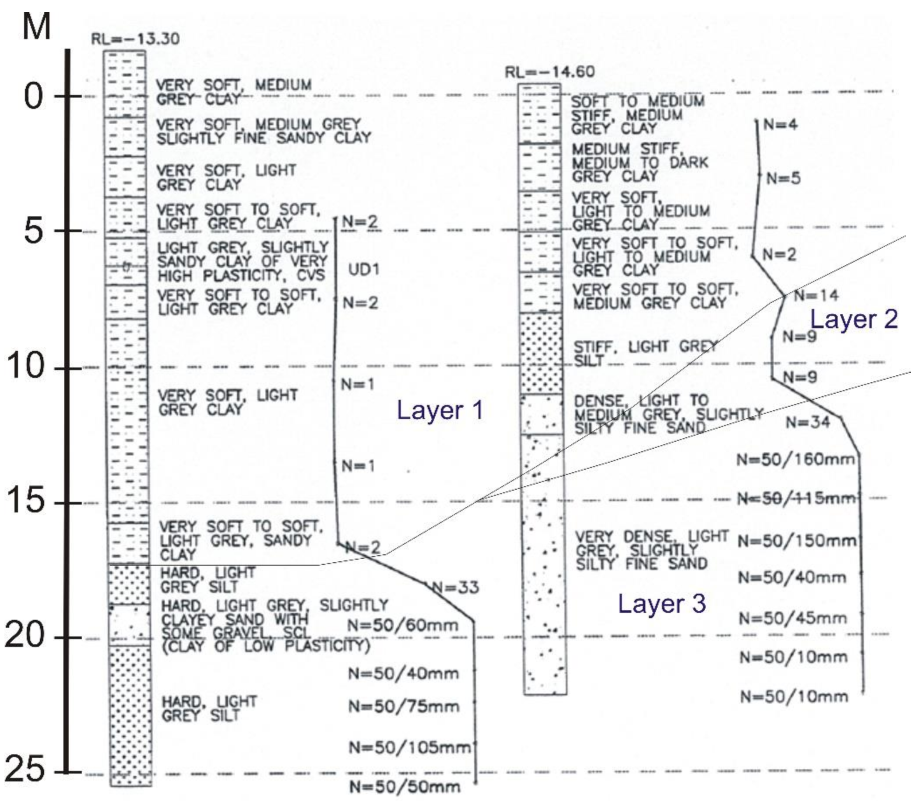

Figure 3. Subsoil profile

2 GEOTEXTILE TUBE TECHNOLOGY

Geotextile tube is defined as “a large tube greater than 2.3m in circumference, fabricated from high strength, woven geotextile, in lengths greater than 6.1m”, according to GRI Test Method GT11: Standard Practice for “Installation of Geotextile Tubes used as Coastal and Riverine Structures”. Geotextile tubes used in coastal and riverine applications are most commonly filled hydraulically with slurry of sand, although other fill materials have been used.

Geotextile tube is typically supplied with closure seams at both ends of the tube. Also associated are “filling ports” or “inlet ports”, which are geotextile sleeves sewn into the top of the geotextile tube into which the pump discharge pipe is inserted (Fig. 4). Initially, the “filling ports” at the two extreme ends of the geotextile tube were utilized for filling while those in between are temporary closed. “Filling Port” at one end is for pumping in of sand slurry, while the “filling port” at other end is for water pressure relief and discharge. In this way, the slurry will flow from one end to the other end of the tube and gradually depositing sand along the way as pressure drops. After filling the geotextile tube the “filling ports” sleeves are closed and attached to the geotextile tube in a manner sufficient to prevent movement of the sleeve by wave action.

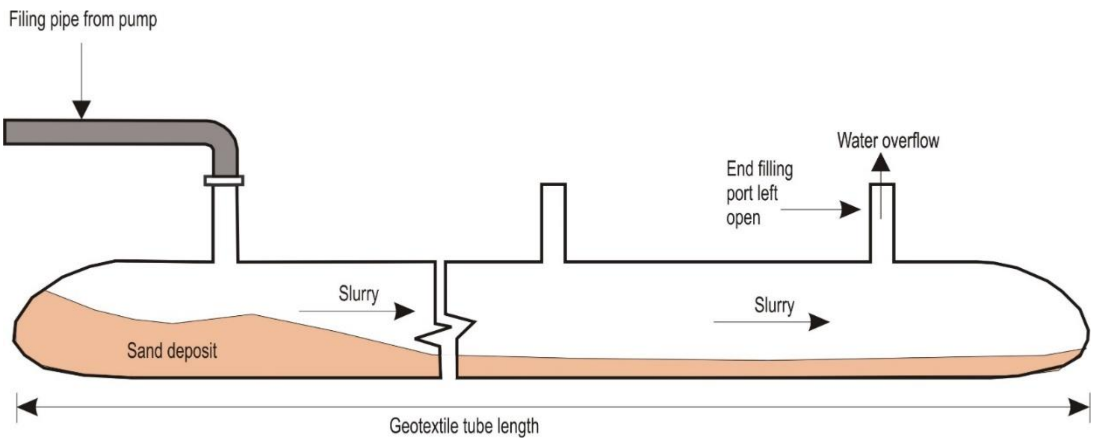

Figure 4. Schematic of filling of geotextile tube with sand slurry

3 DESIGN AND STABILITY ANALYSIS

3.1 *Geotextile tube design methodology*

- Internal stability
  - The geotextile used to fabricate the tube, including seams and closure, need to withstand the tensile stresses that may be encountered during the filling operation, and the placement of geotextile tubes.
  - The geotextile should prevent excessive loss of fines but be sufficient permeable to prevent excessive buildup of pressure during installation.
- External stability
  - The geotextile tube should be hydraulically stable against waves and currents.
  - The geotextile tube should be geotechnically stable against sliding, overturning, bearing and global slip failures (Fig. 5).
- Survivability and Durability
  - The geotextile tube should endure the hush environment of the whole installation process.
  - The geotextile tube should endure and perform the engineering functions over the lifespan of the design.

Conditions that influence the properties of the geotextile over time should be considered. The polymer used for manufacture of geotextile should be durable in biological, chemical environment and ultra violet light resistance. In the design analyses, a global factor of safety of 3.5 -5 was applied for creep, construction damage, environmental damage, seam efficiency, etc. The geotextile tensile stresses of the tube during hydraulic filling were analyse using Geotube® Simulator software program; which is a computer program developed by Tencate Geosynthetics North America. The required ultimate circumferential and axial tensile strength of the tube were determined to be 53.8 kN/m and 41.7 kN/m respectively. Hence, the geotextile tubes supplied were fabricated using a composite woven polypropylene geotextile with tensile strength of 55 kN/m in both warp and weft directions and seam strength of 45 kN/m. The geotextile composite tube has the unique properties of entrapping sand due to its three-dimensional properties and thus has higher UV, vandalism and abrasion resistance required for the project (Figure 6).

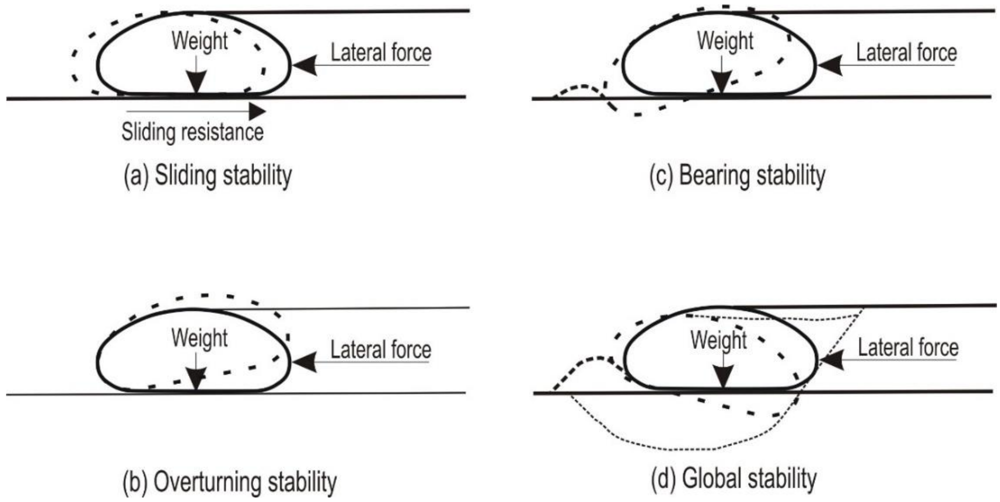

Figure 5. Geotechnical stability check

Figure 6. Composite geotextile tube fabric

3.2 *High strength basal reinforcement, sand filled mattress and geotextile bags design*

The external stability analysis was carried out by Slope/W software (by GeoSlope International, Calgary, Canada) using Morgenstern-Price method. Morgenstern-Price Method was used as it used the Moment and Force equilibrium in the computation of the Factor of Safety compared to Bishop Method which used only the Force Equilibrium in the Factor of Safety computation (GeoStudio, 2012). From the external stability requirement to achieve a F.S. > 1.5, a layer of high strength basal reinforcement geotextile with ultimate tensile strength of 600 kN/m was required at the base of the geotextile tube. The sand filled mattress and geotextile bags was designed according to CUR – 217 Design Guide and checked against current, tensile rupture and soil piping (Bezuijen, 2013). The sand filled mattress was designed to a filled thickness of 180mm while the geotextile bag was designed to a filled thickness of 300mm.The fabric used for the sand filled mattress and geotextile bags fabrication are made from composite coarse grain that allows soil entrapment, high UV resistance and vandalism resistance.

4 CONSTRUCTION METHODOLOGY

4.1 *Scour apron*

A layer of timber mattress was constructed using *bakau* at a grid formation of 0.7m x 0.7m and installed over the soft marine clay. The timber mattress allows construction trafficability and also increase the bearing capacity of the soft underlying marine clay. A scour apron of 5m width are then installed over the timber mattress with the position of the pilot tube at a distance of 5m from the centre line of the timber mattress. The scour apron and timber mattress are pegged in position using bamboo pegs to ensure that it stays in position during high tide. The pilot tube of the scour apron is then infilled with sand slurry to designed inflated height of 0.4m (Fig. 7).

Figure 7. Installation of scour apron and infilling of pilot tube in operation

4.2 *High strength basal reinforcement*

The high strength basal reinforcement was seamed at site and prepared with anchorage length varies from 6m to 18m, pre-cut to the profile of the eroded bank. The pre-cut reinforcement fabric was then installed over the scour apron during the low tide and pegged into position using bamboo pegs at one meter spacing to prevent movement during sand back filling operation (Figure 8).

Figure 8. Installation of high strength basal reinforcement over the scour apron.

4.3 *Geotextile tube*

The installation of the geotextile tube had to be properly planned and scheduled to the influence of daily tidal fluctuations. The geotextile tube installation was carried out during the low tide and secured to the timber mattress.

A mixing pit of dimension 5m x 5m x 2 m depth was excavated into the existing ground where sea water and sand are mixed to form a sand slurry (Fig. 9). The pumping of sand slurry into the geotextile tube is carried out during low tide by inserting the discharge pipe into “filling ports” at one end of the tube while the other end “filling ports” is left open for water pressure relief. All other intermediate ports are closed. This filling operation is repeated until the whole tube attained the final filling height of 1.8m (Fig. 10).

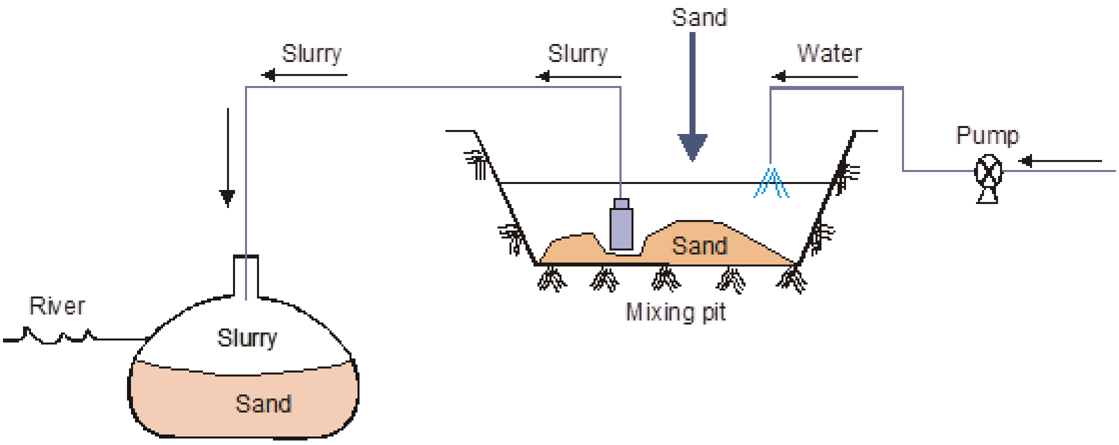

Figure 9. Schematic of mixing pit and pumping set up unit.

Figure 10. Geotextile tube installation and pumping operation.

4.4 *Sand filled mattress and geotextile bags*

Special composite sand filled mattresses with coarse fibre surface were installed on the slopping ground above the crest of the geotextile tubes. The coarse fibre surface is design to trap and hold the topsoil in place and allow the growth of vegetation on top. The sand filled mattresses were anchored into trench at the crest. Two rows of geotextile bags were used to ballast the toe of the sand filled mattresses, so that the sand filled mattresses will not be lifted by the currents. These rows of geotextile bags are placed right above the crest of the geotextile tubes.

Figure 11. Sand filled mattress installation and filling operation

Figure 12. Completed geotextile bag installation

5 CONSTRUCTION ISSUES

5.1 *Geotextile tube under the bridge deck*

Part of the geotextile tube bund has to pass underneath an existing jetty which was support by piled desk system over a layer of very soft clay. Thus, any lateral subsoil movements, or pressure exerted on the piles may displace the jetty. The selected geotextile tube's inflated width has to be smaller than the spacing between the edges of the piles and the geotextile tube has to be placed precisely that, when inflated, both sides of the geotextile tube will not touch the piles. Filling of the geotextile tube was carefully controlled with close monitoring of the movement of the underlying soft clay to prevent excessive lateral squeeze.

Figure 13. Installation of geotextile tube under the jetty deck.

6 CONCLUSION

Geosynthetics solution using a combination of geotextile tubes, sand filled mattress, geotextile bags, high strength basal reinforcement and scour apron were successfully designed and installed for the construction of a shoreline erosion protection at an oil and gas jetty. The installation of the geotextile tube was carried out in accordance with GRI Test Method GT11: Standard Practice for “Installation of Geotextile Tubes used as Coastal and Riverine Structures”. The geotextile tube was fill with sand slurry.

The geotextile tubes were properly design taking into consideration of the internal stability, external stability, survivability and durability of the tube. The fabric used for the geotextile tube should prevent excessive loss of fines but be sufficient permeable to prevent excessive build-up of pressure during installation. Geotechnically, it must be stable against sliding, overturning, bearing and global slip failure. Also, the tube should endure and perform the engineering functions over the installation process and the whole lifespan of the design whereby the geotextile should be durable in biological, chemical environment and ultra violet light resistance.

The high strength basal reinforcement, sand filled mattress and geotextile bags were part of the complete solution to this coastal erosion prevention solution, in additional to the geotextile tubes. All have to be designed taking into account the strength and the environmental considerations.

The installation sequence of the above components has to be properly planned and scheduled based on the tidal condition on site. Suitable pegging and anchoring were done to prevent the lateral movement of the riverbank soft soil during the installation process. One specific construction challenge is to install the geotextile tube beneath the jetty desk which is supported by rows of piles: that is, the geotextile tube should not exert any additional stress or movement onto the piles. This was achieved by careful installation control with monitoring of soil movement during the installation process.

REFERENCES

Lim, L.K. & Lee. L. 2009. Soft engineering system using geosynthetic for riverbank reclamation works: A Malaysian experience. International symposium on Geotechnical engineering, Ground improvement and Geosynthetics, Thailand.

Yee, T.W., Zingerink, E & Choi, J.C. 2007. Geotextile tube application for Incheon Bridge project, Korea. Proceedings of the CEDA Dredging Days 2007 Conference, Rotterdam, Netherlands

Yee, T.W. 2015. Dredging works and geotextile tube applications for construction of the longest sea crossing bridge in Vietnam. Proceeding of Western Dredging Association and Texas A&M University Center for Dredging Studies, Dredging Summit and Expo 2015, Texas, USA.

GeoStudio 2012, May 2014 Release version 8.13.1.9253 for slope stability analysis.

A. Bezuijen & E.W. Vastenburg. 2013. Geosystems Design Rules and Applications.