A mekong delta experience: Protecting the riverbanks with geotextile sand containers

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ABSTRACT: The Mekong Delta is located in the Southwestern Vietnam where the Mekong River approaches and empties into the sea. A network of distributaries branches off from the main river forming the river delta. This area is Vietnam's most productive region in agriculture and aquaculture sustaining approximately 17 million inhabitants who rely on these activities. Erosion on the distributaries causes failures to the riverbanks which threaten the life and activities in the region. A need to rectify the problem arises and the authorities are actively seeking for remedial solutions. A remedial solution was proposed using geotextile sand filled containers. The soft engineering solution attracted the authority's interest and a trial section was constructed. The section consists of a 50 m long riverbank facing the erosion problem. A civilian access road situated directly besides the section makes it critical for immediate remedial work. The location of this section at the curve of the river makes it a suitable choice to test out the workability of sand container solutions towards critical local conditions. Further details of this trial project are elaborated in this paper.

Keywords: *Geotextile Sand Container, Erosion Protection, Mekong Delta*

1 INTRODUCTION

The Mekong Delta, one of the largest deltas in the world lies to the west of Ho Chi Minh City stretching to the Southern tip of Vietnam. The delta that encompasses a large portion of Southwestern Vietnam consists mainly of flat plains in a low-lying terrain. A network of distributaries branches off from the Mekong Delta and provides the main economic contribution of the region from agricultural and fishery activities. A large percentage of locals in this region depend heavily on these distributaries with their house constructed in close vicinity to the river as a mean for income and transportation.

Soil in this region consists mainly of alluvium deposited over thousands of years as the river changed its course due to the flatness of the low-lying terrain. The delta is affected by tidal fluctuation. The river delta depends on sustained sediments supplies in order to maintain the shoreline position and to balance subsidence (Anthony et al, 2015). In recent years, there has been a rapid increase in erosion problems in the delta contributed mainly from human activities, such as dam construction, river-bed mining, etc. and also from weather changes (Erban, Gorelick & Zebker, 2014). Along with subsidence accelerated by groundwater extraction from the populous delta, the growth of erosion problems at this immense rate poses threats to the livelihood and safety of the locals which are dependent on the delta for their survival (Ghimire, Ferreira & Dorfman, 2015).

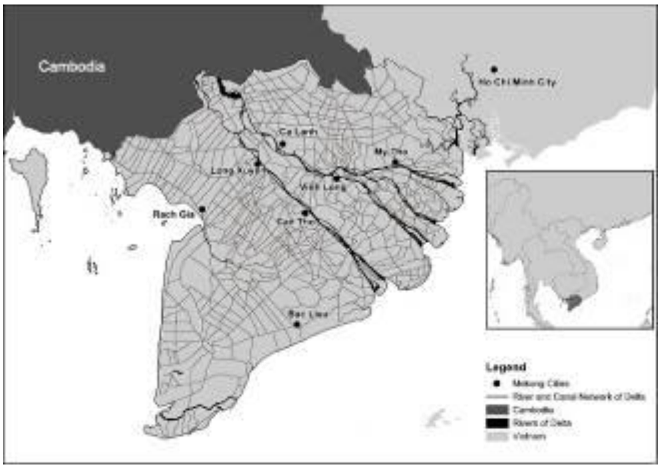

Figure 1. Map of the Mekong Delta and distributaries. (Benedikter, 2014)

Erosion control could help in addressing and improve the problem caused by erosion. Erosion control can be defined in order to curb or restrain the gradual or sudden transport of soils (Theisen, 1992). There are various types of engineered systems that could help to rectify the problem ranging from a hard solution, such as concrete solution, rip-rap or gabion to soft approaches, such as geosynthetic solutions. The paper focuses particularly on the use of a soft engineering approach with nonwoven geotextile sand containers as riverbank erosion protection with a 'brick like' stacking.

Whenever the local government faces problems with severe erosions that could threaten the local community, conventional solutions with concrete structures or timber piles have been used. As an alternative solution the use of geotextile sand filled containers have been proposed which will be described in the following. With a proper design and application, this solution provides advantages compared to the conventional method.

2 EROSION PROCESS

Erosion occurs whenever the hydrodynamic shear stress is higher than the sediment or granulation critical shear stress. The high near bed or near slope velocity can be caused by currents, waves or vessels. Additional erosion can result from wave uprush and wave down rush on slopes.

Erosion effects or scour formations are difficult to predict, therefore a properly designed erosion protection is required.

3 EROSION PROTECTION

3.1 *Geotextiles as filter and geotextile sand containers as filter and ballast*

Geosynthetics are often used in revetments along the canal slopes and reservoir slopes, along flowing waters in streams or rivers as described in various guidelines. Heavy filter geotextiles are specified and installed due to their unique qualities and their ability to prevent erosion below revetments or rip-raps. The rip-raps provide sufficient ballast and have to be designed in consideration of the given project-specific hydraulic conditions (flow velocity, waves, slipstream of a bow thruster, etc.). The filter geotextile prevents erosion of the subsoil by holding the soil back (mechanical filter stability) and allowing the water to flow through without any water pressure built up in front of the geotextile (hydraulic filter stability).

Revetment system - Typical scour protection system (defined from top to bottom):

- Ballast: rip-raps
- Filter: geotextile filter
- Subsoil: needs to be protected against erosion/scouring

Robust filter geotextiles have to be selected to prevent potential damages resulting from covering operations. When installing filter geotextiles under water, geotextiles often float on the water, because the density of polypropylene is lower than the density of water. For the underwater installation of nonwoven filter geotextiles system solutions are required. A ballast layer is necessary in order to install the filter geotextile below the water level and to stabilize the geotextile in case of hydraulic loads. Here for example sandmats or fascine mattresses can be used.

Sandmats are made from two filter nonwovens encapsulating sand as ballast between the sheets in order to reach a mass per unit area of up to 6100 g/m² for underwater installation. Sandmats are delivered in rolls and can be installed in horizontal and inclined areas. During the installation process they provide a sufficient position stability up to a determined maximum flow velocity which is dependent on the ballast of the product. Finally a ballast layer (e.g. rip-raps or armour stones) has to be positioned on top.

In case of e.g. a poor availability of rip-raps or armour stones or e.g. a high flow velocity, wave motion or a high water depth, the possibility is given that additional/alternative measures for the installation of the filter geotextile are required. In case that a poor availability of rip-raps is given, more and more often geotextile sand filled containers are installed as filter layer and flexible erosion protection measure. Geotextile sand filled containers replace the ballast and the filter layer in one element in case of a double layered installation. Geotextile sand filled containers can e.g. be installed horizontally on the river bed or in inclined areas in a staggered arrangement like bricks.

4 NONWOVEN GEOTEXTILE SAND FILLED CONTAINERS

Geotextile sand filled containers can be produced in different shapes. The following paper will concentrate on the use of geotextile containers in a bag-like shape, which have to be filled on-site with locally available sand fill material. After filling the single geotextile containers, they have to be closed with a sewing technique. Figure 2 shows a geotextile sand filled container.

A unit of geotextile sand container is formed with a geotextile as a filter layer while the ballast, here the sand fill material is encapsulated within the unit as shown in Figure 2. The size of a geotextile sand container can be readily customized and fit into different scenarios depending on the local hydraulic and ground conditions. In general, geotextile sand containers with a fill volume of 1 m³ are widely used. The container is manufactured of nonwoven geotextiles. One side remains open for site filling.
Minimum requirements for the geotextile sand containers can be documented:

- Robustness of nonwoven geotextiles to withstand mechanical stress during installation (e.g.: abrasion and puncture resistance).
- Soil retention capacity and filter stability of the geotextile container to retain the sand fill material.
- Sufficient protection against mechanical damage and UV-radiation (e.g. with the use of a cover soil layer or sacrificial geotextile layers (e.g. composite geotextiles))
- Seam strength of approximately 80% of the geotextile strength is recommended.

Figure 2. Illustration of a geotextile sand filled container

Needle-punched nonwoven geotextile sand containers are best suited for hydraulic applications as they have a high flexibility and better friction properties compared to a woven type sand container. A woven geotextile performs like a sieve and not like a grain filter with a 3-D pore spectrum. Moreover, the weft and warp yarns are not fixed at the crossing points, making it susceptible to shifting which would enlarge the pore opening that potentially could lead to a loss of fill materials. (Heibaum, 1994)

5 MEKONG DELTA

5.1 *Problems*

There are 12 provinces located in the Mekong Delta, and Hau Giang province is one of them. With an area of 160,245 hectare, the mean of transportation for local paddy industry includes two main waterways which are the Xa No and Quan Lo Phung Hiep canal. Due to the delta formation, a lot of the locals are using the interlacing system of distributaries as their main transportation for daily usage. Maintaining these waterways is crucial to keep the economy of the province running with increasing transport infrastructure constructed contributing to the socio-economic development of the province.

When the usage of the waterways is increasing throughout the years, areas where there is less maintenance and focus, it is inevitable that erosion or scour problems will occur due to the periodic tidal effect as well as ships induced waves harming the adjacent structures and dwellers. There are a lot of cases where the access to houses is cut off because of riverbank failures affecting the access roads that were built along the waterways. This increases the risk of accidents when locals are forced to use these unstable access without maintenance or reparation. According to the Vietnam Institute of Meteorology, Hydrology and Climate Change, the region has 406 eroded sections with a total length of 891 km. It was mentioned that by the year 2100, 38% of the Mekong Delta's land surface maybe submerged. Figure 3 shows a typical failed section of an access road along the waterway in the Hau Giang Province.

The reduction in sedimentation due to hydropower dam constructions in the upstream essentially hinders the seasonal flow variability (Le et al, 2007) and indirectly reduces the sedimentation of soil particles. Without a constant supply of sedimentation, the erosion process is accelerated.

5.2 *Solutions*

The municipality in the Mekong Delta generally uses two types of solution when the waterways need reparation caused by erosion or section failure. Due to long term negligence towards erosion, the eroded sections progressively deepen to the point where slope failures occur as shown in Figure 3. When the situation is less severe, the eroded sections are supported by timber piles at the toe of the slope and the eroded soil is filled back. This solution only addresses the stability issue of the section and does not provide any erosion control. The remediated section is still prone to failures in the future when erosion starts, and the cycle of failures will continue.

Figure 3: Failed section of roads in the Mekong Delta

Where erosion or section failure is more severe, a combination of concrete retaining structures is favored. For example, concrete-sheet-pile methods are utilized to solve the stability problem as well as to act as a protection structure towards the waterways. This solution is effective when the design of the concrete sheet piles are done correctly and all components contributing to the system are installed as per designed. The drawbacks of this system are always the high costs associated to it. The hard solution also does not align itself to the focus of a more environmentally friendly solution. Failures could happen in the system due to pore pressure accumulation and high repair costs.

As an alternative to the conventional solution the use of the soft engineering solution with geotextile sand filled containers was proposed as a trial section in the Hau Giang Province. The geotextile sand container solution involves less investment to the project and shortens the project construction duration. With regard to the high flexibility of geotextile sand containers, they adopt very well to changing boundary conditions (e.g. settlements, deformations, etc.). This solution is also able to accommodate vegetation on the surface which enables the system to blend into the surrounding.

6 HAU GIANG TRIAL

6.1 *Proposal*

Proposal for a trial site to test out the functionality of the system was presented in 2015. The main purpose of the trial is to show the practicality of the system being conform to various site conditions with the correct design approach. The first steps for the trial would be to choose a location which has experienced erosion problems and is located in an area where the ground and hydraulic conditions represented are on the critical side. By having a more critical site condition, the trial would be able to cover a wider spectrum of ground and hydraulic conditions.

The Cai Doi canal located in Nga Sau town, Chau Thanh District, which is used for navigational purpose, was finally chosen as trial location. Figure 4 shows the location of the navigation canal. The location was chosen, because it is located at a bend, where water is constantly eroding the riverbank and where some collapses in the soil are visible. The navigational canal is also affected by the tidal level and the water level difference can be as high as 3.0m.

The local authority required an immediate solution to fix the access road near to the failed section. They decided to build the riverbank erosion protection system with the use of geotextile sand containers as trial section. A trial period of one year to monitor the functionality of the system was discussed and agreed on.

6.2 *Design*

The hydraulic condition on site is defined with a ship induced wave height, H_s of 0.4m to 0.6m while the maximum peak period is 1.5s. The maximum flow velocity of the navigational canal is 2m/s. This area is affected by the semidiurnal tidal cycle where two high and two low tides of approximately equal sizes are expected every day. The highest water level is located at +2.85 mRL while the lowest water level is +0.50 mRL. The lowest ground level of the canal is located at -2.00 mRL and the crest level is +2.85 mRL. As part of the planning, the customer has set the height of the foundation at the toe of the system to +0.00 mRL, which is located below the water transmission zone. The total slope height that needs remedial works is approximately 2.85m and the slope length is 50m.

An initial check for the compatibility of the proposed sand container size against the flow rate is performed by Bauberatung Geokunststoffe. Using a 1.0 m^3 sand container, with respect to the volume and relative density (Pilarczyk, 2001), the system is able to resist the water flow rate on site. A maximum slope angle of 45^o is planned for the system. The geotextile used for the sand container has an average mass per unit area of 600 g/m^2. This material is approved as filter geotextile by the German Federal Hydraulic Engineering and Research Institute (BAW) for use in navigable waterways. Additionally, a thorough check on the hydraulic conditions was performed by independent consultants verifying the stability of the proposed sand containers subjected to waves and longitudinal water currents.

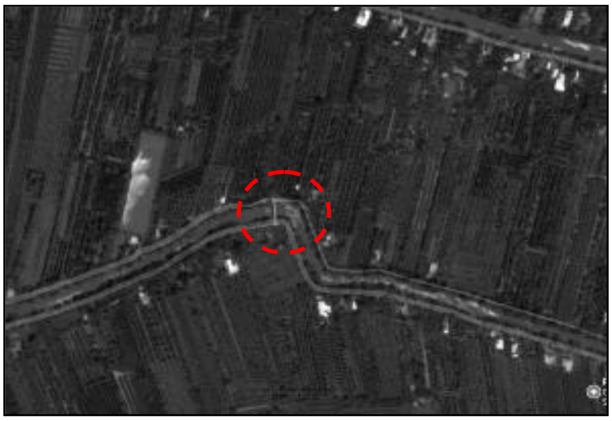

Figure 4: Trial location and eroded area

In consideration of the single-layer design with geotextile sand filled containers in front of the slope, a nonwoven filter geotextile layer is specified behind the geotextile sand containers which act as filter layer. The filter geotextile prevents subsoil erosion through the gaps between the sand containers. This filter geotextile layer can be omitted if the design uses two layers of geotextile sand containers where the containers can be arranged in a staggered position. This arrangement could avoid formation of gaps that exposes the retained soil directly to hydraulic influences. A thing to note of, the filter geotextile must also be tested filter stable against turbulent flow conditions and has to be robust enough to avoid damages from the surrounding, for example, puncturing of geotextile and abrasion.

The ground stability must be checked against settlement and rotational failure due to the weak soft soil presence on site. Internal and global stability were checked using limit equilibrium analysis while the settlement was checked using finite element analysis. To ensure the stability of the whole system, additional 16 numbers of timber piles per square meter were recommended at the base of the system which reduces the pressure exerted by the sand containers to the foundation soil. The cross section of the full system is represented in Figure 5.

6.3 *Trial and current condition*

The construction of the section commenced on early May 2016 and was finished end of May 2016. Access to the site is limited to a small 2.5m wide road where excavators are only able to mobilize into the site via barge. The filling of the sand containers was done in another site besides the jetty and they were shipped to the job site which is located approximately 2.5km away from the site. Closure of the sand containers can be done on site with a simple hand held sewing machine. The site was first cleared from any objects that could potentially damage the filter geotextile and geotextile sand containers. The geotextile filter was then laid and fixed on top to prevent washing away from the water flow.

Due to the high water level during high tide, the installation can only be done twice a day on low tide in the morning and at night. Sufficient lighting was prepared providing better visibility to ensure the safety of the workers working on site. Timber piles were first driven into the subsoil. The filter geotextile was then install starting from the top towards the toe of the slope. The geotextile sand containers are then transported with straps using excavator and stacked in staggered position with the no-seam side facing outward to protect the seam areas. Care must be taken to avoid any damages towards the sand containers during installation. Any punctured holes are repaired immediately according to the manufacturer's recommendation. This system only involved simple machineries and manpower.

After completion, the system shall go through a monitoring period of one year. During this period, periodical monitoring with site visits and surveys are carried out. During an official visit with the local authority of Hau Giang Province by the end of 2016, the system was deemed satisfice and the early approval was confirmed. Figure 6 shows pictures of the geotextile sand container system during construction and after completion.

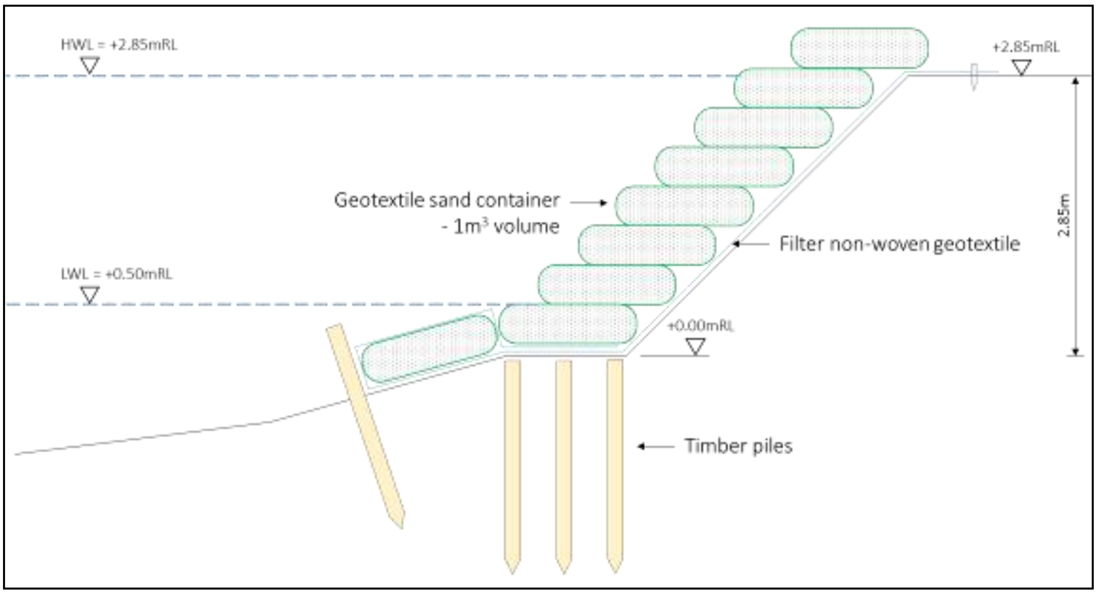

Figure 5: Cross section of geotextile sand container system

As final cover layer, a layer of mud has been used to protect the geotextile sand filled containers against mechanical damages and UV-radiation. Here maintenance work is required, in case that this cover layer is washed away.

Figure 6: Situation during construction and after completion

7 CONCLUSION

In the past 60 years, the use of geotextile sand containers is constantly growing throughout the world. There are various design codes available for designing such system and ongoing researches studying the functionality of the system enhance the knowledge and understanding. A well-designed system coupled with good construction quality could ensure the service life. Currently, we understand the system provides advantages compared to conventional system in term of construction cost and time, ability to use local fill materials and flexibility of the system conforming to local conditions.

This system is well suited for riverbank erosion protection as well as coastal protection in case that additional countermeasure towards UV attacks will be carried out. With the erosion problems we face in the Mekong Delta, along the coastline of Vietnam and also countries in the South East Asia region, the use of geotextile sand filled containers could be one of the solutions solving the long standing erosion problem in the region.

Ultimately, to ensure the functionality of the geotextile sand filled containers, the geotextile containers need to be:

- Made of robust nonwoven geotextiles to withstand mechanical stress during installation (e.g.: abrasion and puncture resistance).
- Provide sufficient filter efficiency, to retain the sand fill material. Sufficient protection against mechanical damage and UV-radiation (e.g. with the use of a cover soil layer or sacrificial geotextile layers (e.g. composite geotextiles))
- As seam strength approximately 80% of the geotextile strength is recommended.

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