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Innovative Coastal Resilience: Design and Application of Hydraulic Geotextile Tubes as Sustainable Breakwater Cores in La Union

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Abstract. The constant assault of waves contributes to the loss of valuable coastal land of La Union, necessitating innovative and sustainable methods to protect the shoreline. In the pursuit of sustainable solutions, innovative technologies such as hydraulic geotextile tubes have emerged as promising contenders for enhancing shoreline protection. This study explores the design and application of hydraulic geotextile tubes as breakwater cores along the La Union shoreline. Due to their permeability and flexibility, hydraulic geotextile tubes offer a viable substitute for conventional breakwater materials. The research aims to provide valuable insights into sustainable coastal management by determining how these tubes can be designed to resist wave forces, ensure stability against hydrodynamic pressures, identify various installation methods, and evaluate their advantages and disadvantages in preventing shoreline erosion and potentially reclaiming sand. The study's findings could inform strategies that balance shoreline protection with environmental preservation. It highlights the interaction between creative engineering solutions and environmental stewardship in addressing evolving coastal challenges.

Keywords: Breakwater core; Coastal erosion; Hydraulic geotextile tube; Shoreline protection

1. Introduction

The shoreline in the Philippines, is known for its fine sandy beaches and vibrant community living in close proximity to the sea. Like many coastal regions worldwide, it faces significant environmental challenges, including shoreline erosion and the need for effective protection against the relentless impact of waves. Erosion issues in coastal areas, exacerbated by human activities, threaten habitats, impact local economies, and contribute to the loss of real estate. The destruction of dunes intensifies these problems, with potential consequences for

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living creatures. The vulnerability of sea dikes to seismic waves adds urgency to the need for coastal protection. Many nations, private organizations, and local governments are actively working on preventive measures such as beach nourishment and the construction of geotextile containment structures (Shin et al., 2018).

The Geotextile Tube stands out as a novel technology for constructing breakwater structures to combat shoreline erosion. This flexible, large-scale structure, typically filled with sand, forms a resilient core that effectively mitigates wave impact and shoreline erosion. Its ability to reclaim sand adds to its sustainable appeal, crucial for reinforcing coastal resilience amidst dynamic environmental challenges. Ongoing advancements in materials and construction methods continue to refine hydraulic geotextile tubes, enhancing their versatility and effectiveness in global engineering projects. Studies, such as those by Smith et al. (2020), underscore their success in stabilizing beaches and reducing erosion, particularly relevant to coastal conditions akin to those in the Philippines. Effective breakwaters, as highlighted by research from Zhang and Liu (2019), play a pivotal role in attenuating wave energy and safeguarding shorelines from abrasion. The choice of core material for these structures varies based on engineering needs and environmental considerations, emphasizing their critical role in coastal defense strategies.

2. Methodology

This research study is a descriptive-qualitative research. This type of research aims to describe characteristics of the study, exploring the design criteria and application methods. Qualitative research emphasizes exploring meanings, experiences, and perspectives of individuals or groups. In this study, case studies, literature reviews, and field study were chosen as research instruments. Descriptive-qualitative researches generally collect the research data through these.

2.1. Sampling Procedure

Random sampling was used to all participants from La Union. As cited in Encyclopedia (2008), random sampling refers to a variety of selection techniques in which sample members are selected by chance, but with a known probability of selection. According to The Economic Times (2020) it is a part of the sampling technique in which each sample has an equal probability of being chosen.

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2.2. Respondents

The sources of the data gathering includes academic literatures, technical reports, documentations, manufacturer's specifications and online resources. For qualitative scenario, participants will be engineers and local residents of La Union.

2.2.1 Research Site

The field study took place in La Union Province, specifically in the towns of Agoo, Sto. Tomas, and Bauang. These areas were chosen because they already have some breakwater constructed, and there are ongoing construction projects that were observed during the study.

3. Results and Discussion

3.1. Current Barriers vs. Geotextile Tube as Breakwaters

The current barriers that mostly exist along the La Union shoreline consist of traditional methods such as grouted riprap, gabions, and seawalls. Most of these barriers are privately constructed by beachfront owners and often consist of makeshift wall barriers designed to protect their properties from high tides and waves. These privately constructed barriers vary in quality and effectiveness, depending on the resources and expertise of the property owners.

When deciding between more modern options like geotextile tube breakwaters and more established techniques like gabions and riprap for coastal areas like La Union, there are a number of important considerations to consider. It is commonly known that gabions and riprap may absorb wave energy and stabilize shorelines. However, they can change natural environments and frequently need constant upkeep. Furthermore, with time, waves and erosion have the potential to harm certain riprap installations. On the other hand, the advantages of geotextile tube breakwaters, which use fabric tubes packed with gravel or sand, include their flexibility and ability to adjust to shifting coastal conditions. Its structure dissipates wave energy as it passes through the porous material. They can be customized to meet the individual requirements of a project, reduce the negative effects on the environment during installation and operation, and have proven successful in reclaiming sand and enhancing wave protection, especially in places where the shoreline is sparse or non-existent.

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The choice between these approaches is impacted by factors such as wave attenuation effectiveness, environmental impact, upfront expenditures, and the need for continuous maintenance, all of which are specific to the objectives and distinctive features of each coastal protection project.

3.2. *Design Calculation Criteria*

Against Wave Attack	**Against Current Attack**
H_t = Filled Height of Geotube B_t = Filled Width of Geotube B_t = Base Contact Width of Geotube U_{cr} = critical water flow velocity (m/s) (Δ_t) = relative density of the geotextile tube D_k = Effective thickness of the geotextile tube B_t = width of geotextile tube L_t = length of the geotextile tube g = acceleration due to gravity (g=9.81 m/s)	Ucr = critical water flow velocity (m/s) (Δt) = relative density of the geotextile tube Dk = Effective thickness of the geotextile tube Bt = width of geotextile tube Lt = length of the geotextile tube g = acceleration due to gravity (g=9.81 m/s)
Parallel to direction of wave attack $\frac{\mathrm{H_s}}{(\Delta t)(Dk)} \leq 1.0$	Parallel to direction of current attack $\frac{\mathrm{Ucr}}{\sqrt{(g)(\Delta)(Dk)}} \leq 1.2$
Perpendicular to direction of wave attack $\frac{\mathrm{H_s}}{(\Delta t)(Dk)} \leq 1.0$	Perpendicular to direction of current attack $\frac{\mathrm{Ucr}}{\sqrt{(g)(\Delta)(Dk)}} \leq 1.2$

Table No. 1 *Design Calculation Criteria*

3.2.1. Stability Check

Equilibrium of forces in X and Y directions	Equilibrium of moments (around point A)
$\sum F_x = 0$ (sliding) $\sum F_y = 0$ (soil bearing capacity)	$\sum M_A = 0$ (overturning)

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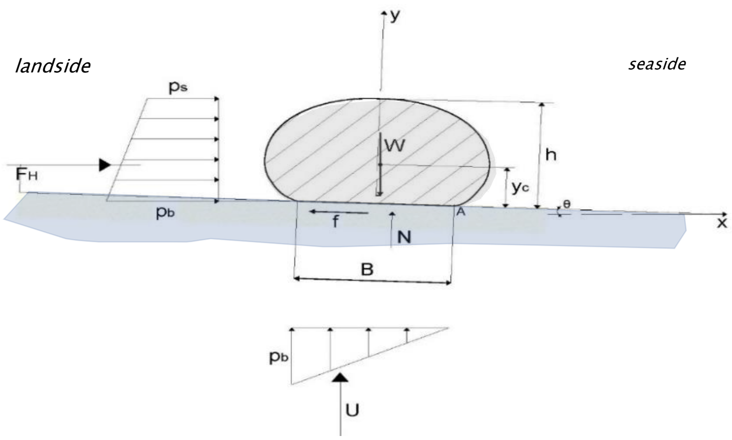	h = geotextile tube height W = geotextile tube weight y_c = distance of the geotextile tube gravity centre from the beach level Θ = beach slope F_H = horizontal acting force (water) U = uplift force (hydrostatic force) B = geotextile tube base width N = foundation reaction f = friction force A = rotation centre

Table No: 2 *Stability Check Calculation Scheme – Typical Forces*

3.3. Installation of Geotextile Tubes

There are 2 types of installation of geotubes.

1. ***Pump Method:*** A pump and a pipe system are used to transfer the material from its source directly into the geotube at a continuous rate.


Figure No. 1 *Pump Method*

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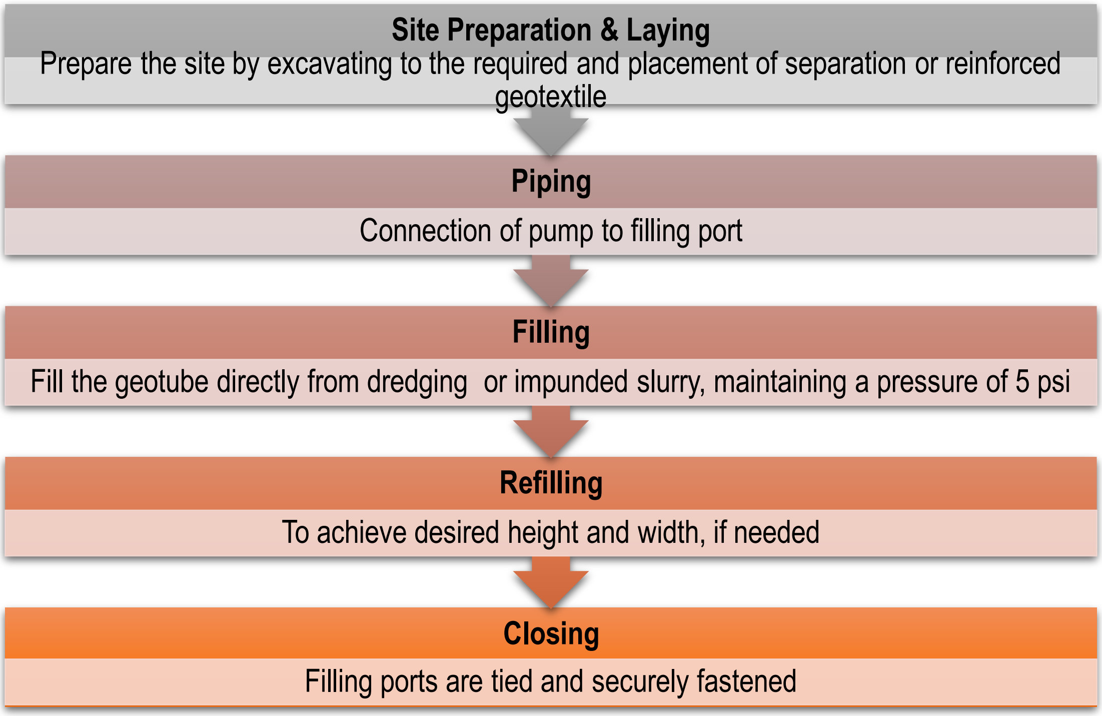

Chart No. 1 *Pump Method Application Process*

2. ***Hopper Method:*** A stable frame or support structure is required to hold the material in place and a customized funnel is used to facilitate a controlled and efficient filling process.

Figure No. 2 *Hopper Method*

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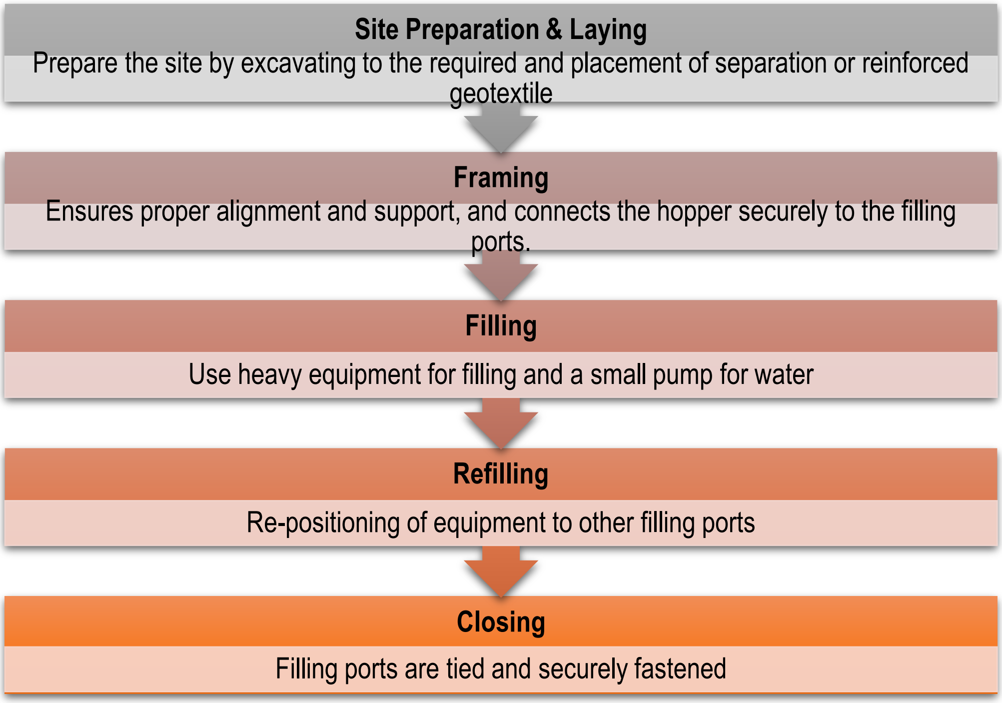

Chart No. 2 *Hopper Method Installation Method*

3.4. Advantages and Disadvantages of Different Installation Method

	Advantages	**Disadvantages**
Pump Method	• Quickly moves materials into place, saving time. • Effective even in underwater environments. • Ideal for dewatering wastewater: Particularly suited for draining and managing water in sewage systems.	• Relies on a system of pipes for operation. • Monitoring pump pressure prevents bursts. • Pumping must be constant until reaching the desired height.
Hopper Method	• Allows precise management of filling operations by hand. • Lower risk of bursting due to absence of high pressure. • Except for water supply, minimal need for additional pipe systems during filling.	• Requires more time for setup and readiness. • Requires bigger openings for material placement. • Unsuitable for submerged conditions • Not recommended for dewatering

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Table No. 3 *Advantages and Disadvantages of Pump Method and Hopper Method*

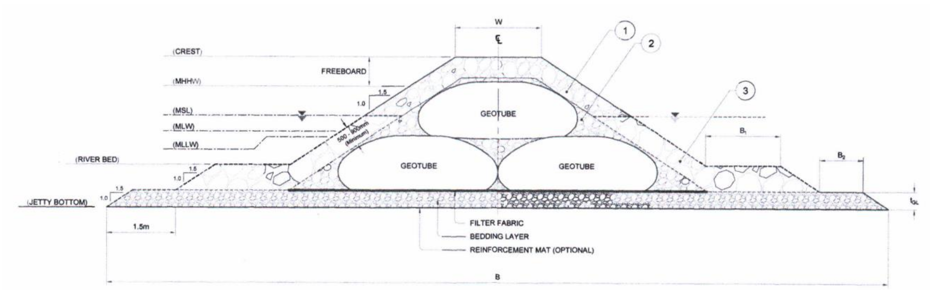

Figure No. 3 *Typical section with geotextile tube core*
Source: DPWH-BOD, Water and Projects Division

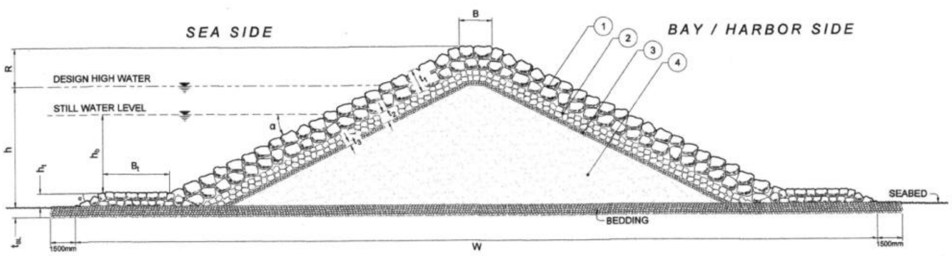

Figure No. 4 *Typical section of rubble mound breakwater*
Source: DPWH-BOD, Water and Projects Division

4. Conclusions

The study concludes that a number of variables affect how geotextile tubes intended as breakwater cores are designed. To increase these tubes' efficacy in safeguarding coasts, it's critical to optimize their diameter to length ratio. This improvement stabilizes shorelines against erosion by enabling the tubes to endure stresses from waves and currents. Geotextile tubes are more advantageous than conventional engineering solutions since they are made from porous material, flexible and simple to install. Every strategy offers unique benefits and drawbacks that are impacted by things like project size, material handling requirements, and site conditions. While the hopper method approach uses gravity for simplicity but may not work well in rough terrain and submerged condition, the pump method gives exact material placement and versatility with different materials.

Geotextile tubes offer an adaptable and environmentally friendly method of protecting the coast that reduces erosion while maintaining the natural dynamics and habitats of the beach. In comparison, traditional stiff constructions may be less flexible in response to shifting environmental circumstances. After some of the existing shoreline protections were destroyed, groins proved beneficial not only in restoring but also in reclaiming sand. Groins function by interrupting the longshore transport of sand, causing it to accumulate on the updrift side of the structure. This accumulation effectively widens the beach and provides additional protection to the shoreline against erosion. While groins can be effective in localized beach restoration and stabilization, their impact on adjacent areas and long-term effectiveness depend on factors such as the design, placement, and ongoing sediment dynamics of the coastline.

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