Implementation of Artificial Mangrove Roots FADS in Preventing Abrasion

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Abstract

FADS (Flotilla Abrasion Defense System) is coastal protection system designed to imitate mangrove roots, which serve to protect beaches and help retain sediment. As we know, it takes a long time for natural mangrove roots to grow strong and large. An innovation has been developed to create artificial mangrove roots, providing immediate access to the protective benefits of mangrove roots. FADS are made from environmentally friendly materials that are durable for up to 12 years. Testing and implementation have been carried out on sandy and muddy beaches in Thailand, and the results show that FADS perform effectively.

Keywords

Artificial, coastal protection, sediment trap, sandy beach, muddy beach

Introduction

Beaches are naturally protected by ecosystems such as mangroves, coral reefs, and dunes, which act as barriers against erosion and absorb the impact of waves and storms (French, 2002; USACE, 2002). These natural protections help maintain the stability of the beach and support local wildlife. However, beaches can be damaged due to various factors such as rising sea levels, coastal erosion, storms, and human activities like construction and pollution. Over time, these elements can lead to significant damage, reducing the beach's ability to protect against further degradation.

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To protect beaches, artificial protection methods are often used, including seawalls, groins, breakwaters, and beach nourishment (adding sand to the shore) (USACE, 2002).

Mangroves act as a natural barrier against coastal abrasion. Their complex root systems help stabilize the soil, absorb wave energy, and prevent erosion (Winterwerp et al., 2020). Mangrove forests reduce the intensity of waves and storm surges, acting as a shield to the shoreline. They also absorb energy from water that can cause abrasion on land. However, many studies have indicated that natural mangroves cannot survive in unsuitable conditions, particularly in areas severely impacted by coastal erosion, sea level rise, land subsidence, and other environmental threats (Anthony et al., 2015; Bidorn et al., 2021; Charoenlerkthawin et al., 2024; Charoenlerkthawin et al., 2023; Takagi, 2019; Winterwerp et al., 2020; Yin et al., 2018). The degradation of mangrove forests not only exacerbates shoreline erosion but also disrupts ecosystems, leading to broader environmental issues (Macreadie et al., 2021; Pranchai et al., 2019).

For this reason, the Flotilla Abrasion Defense System (FADS) innovation incorporates Artificial Mangrove Roots (Thanawatth, 2020, 2021) to stabilize shorelines and rehabilitate coastal ecosystems in eroded areas. Innovations FADS (Flotilla Abrasion Defense System) can also be used to mimic the function of natural mangrove roots, offering additional protection from erosion and helping to retain sediment. These artificial solutions, when carefully implemented, can support the natural resilience of the coastline and help preserve its integrity.

An Abrasion Defense System refers to a strategy or infrastructure designed to protect coastlines, shorelines, or other vulnerable areas from the harmful effects of abrasion, which is the wearing down or erosion of land caused by water, wind, or other natural forces. In coastal and marine environments, abrasion typically occurs due to the action of waves, tidal currents, and storm surges, which gradually erode soil, rocks, and coastal structures. Artificial Mangrove Roots are synthetic structures designed to mimic the natural root systems of mangrove trees, often used in coastal protection projects, ecological restoration, or for research purposes. These artificial roots aim to replicate the benefits that natural mangrove roots provide, such as shoreline stabilization, erosion control, and habitat creation for marine life.

Artificial mangrove roots have been implemented in Thailand and developed at Chulalongkorn University. In collaboration with Udayana University, the technology is being adapted for development in Bali. FADs have great potential to be developed in Bali because the island of Bali is surrounded by coastlines and mangrove areas. Pujianiki et al., 2021 and 2024 have conducted research on coastal damage in Bali using remote sensing. Their study utilizes advanced technology to monitor and assess changes in the coastline, providing valuable data on areas affected by erosion, sediment loss, or other environmental challenges. By applying remote sensing techniques, they have been able to track the extent of damage over time, which helps inform better management and protection strategies for Bali's beaches and coastal ecosystems. These structures can provide additional coastal protection and support the preservation of Bali's important ecosystem, making them a valuable solution for the region.

FADS consists of poles and roots made from high-density polyethylene (HDPE), designed to resemble the roots of a mangrove tree, as shown in Figure 1. These components are carefully crafted to mimic the natural structure and functionality of mangrove roots, offering coastal protection and sediment retention. The use of HDPE ensures durability and longevity, making FADS a reliable artificial solution for enhancing coastal ecosystems (Kasetsart University, 2016; Thanawatth, 2021).

FADS has been implemented to reduce beach erosion on various beaches across five provinces in Thailand: Rayong, Phetchaburi, Prachuap Khiri Khan, Phang Nga, and Chanthaburi.

This initiative, led by the National Science and Technology Development Agency (NSTDA) of Thailand, aims to address coastal erosion and improve the stability of these regions. As shown in Figure 2, the successful implementation of FADS has contributed to protecting the coastlines and mitigating the impacts of erosion in these areas.

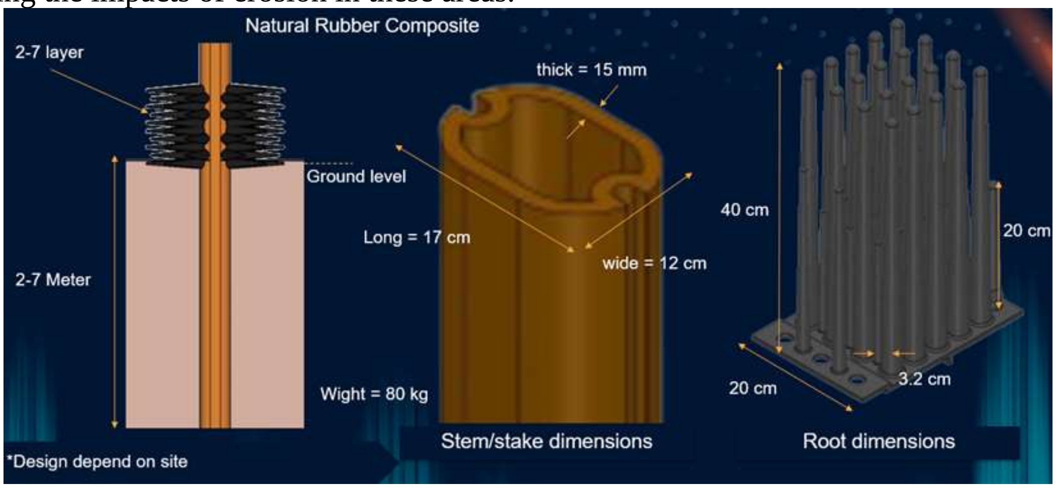

Figure 1. Dimension of FADS

Figure 2. Locations of FADS Implantation in Thailand

Methodology

CFD simulations are employed to predict the behavior of reduced water wave energy due to the installation of artificial mangrove plantings. In this simulation, Ansys Fluent software is used to model the movement of sea waves approaching a sandy beach with a slope of 1:20, as seen in Figure 3. The simulation results show that installing three lines of FADS is more effective in reducing water speed compared to a scenario without FADS. Adding additional lines is simple, allowing for installations ranging from three to five lines. The addition of more rows significantly reduces water speed, with a decrease of more than 50% compared to no FADS. This reduction in water speed corresponds to a decrease in the kinetic energy of sea water. When the kinetic energy decreases, there is a greater tendency for sand sediment to settle and accumulate, which helps in beach preservation and sediment retention.

Physical model testing was also conducted at the Coastal Engineering Laboratory at Chulalongkorn University, Thailand. The model was placed on the shore, and waves were generated to observe the impact of installing FADS. The results showed that sedimentation occurred behind the FADS model, indicating that the installation of FADS is highly effective in promoting the creation of beaches through sedimentation. This demonstrates that FADS can significantly contribute to beach formation and sediment retention, further enhancing coastal protection and stability.

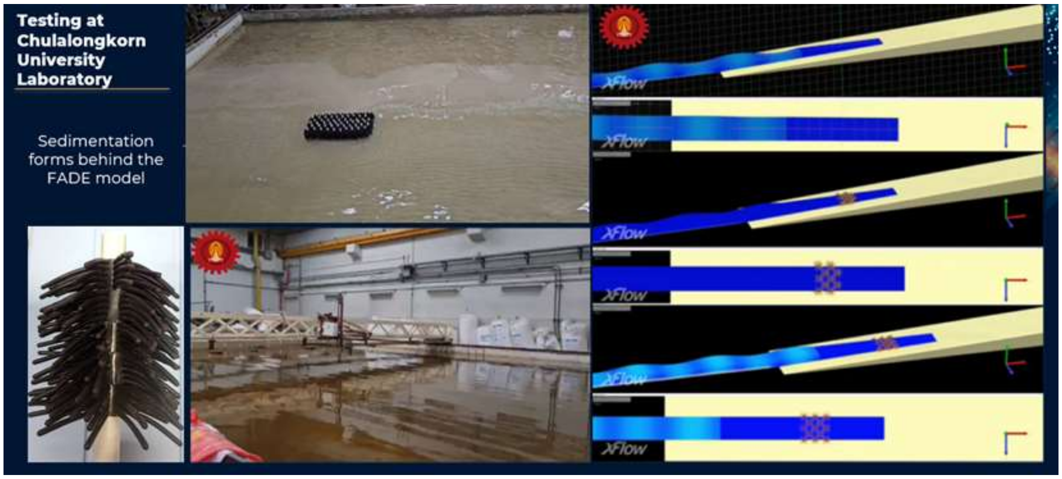

Figure 3. Laboratory testing and CFD simulation of FADS

Results and Discussion

The results of monitoring at Laem Rungruang, Rayong are shown in Figure 4. FADS was installed in July 2022 and monitored from August 2022 to September 2023. The sedimentation process can be clearly observed on beaches with FADS compared to those without it. This indicates that the installation of FADS is highly effective in preventing coastal erosion. Unfortunately, there is no data on the volume of sand retained to quantify the sedimentation process. However, the visible changes in the coastline clearly demonstrate that sedimentation has occurred, further confirming the positive impact of FADS in coastal protection.

The application of FADS on the muddy beach in Samut Prakan, Thailand, can be seen in Figure 5. After 5 months, the land was covered with sediment up to 10 cm thick. This sediment thickness is expected to continue increasing, and further monitoring is required to track the progress. The land resulting from the sedimentation process can be used for planting mangroves, providing a long-term solution to coastal erosion. Monitoring results on the muddy beach show that FADS is more effective than bamboo in preventing erosion and promoting sedimentation. The progress of sedimentation can be observed from July 2023 to March 2024 in Figure 6.

In order to advance the implementation of FADS in Indonesia, PT Frotilla Technology invited professors from three Indonesian universities: Udayana University, ITS, and Diponegoro University. Discussions and laboratory testing were conducted to review the progress of previous research. Additionally, site visits, as shown in Figure 7, were made to several locations where FADS had already been installed in order to observe the results firsthand. Seeing the success and effectiveness of FADS in capturing sediment and reducing wave energy, this technology is set to be further developed in Indonesia and other countries facing similar coastal challenges. FADS offers an environmentally friendly solution to reduce erosion by promoting sediment accumulation on sandy and muddy beaches. Moreover, FADS is made from eco-friendly materials that do not pollute or harm the environment, making it a sustainable choice for coastal protection (Kasetsart University, 2016; Thanawatth, 2021).

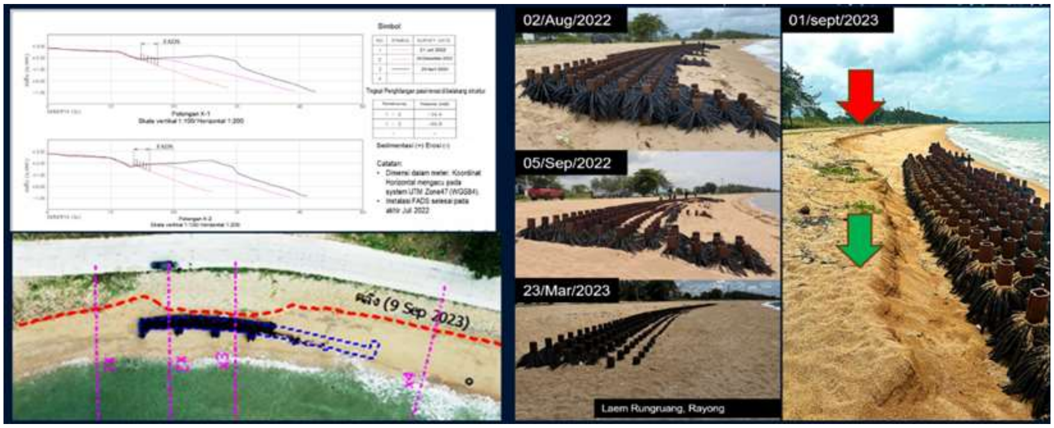

Figure 4. Monitoring FADS installation at Laem Rungruang, Rayong Thailand

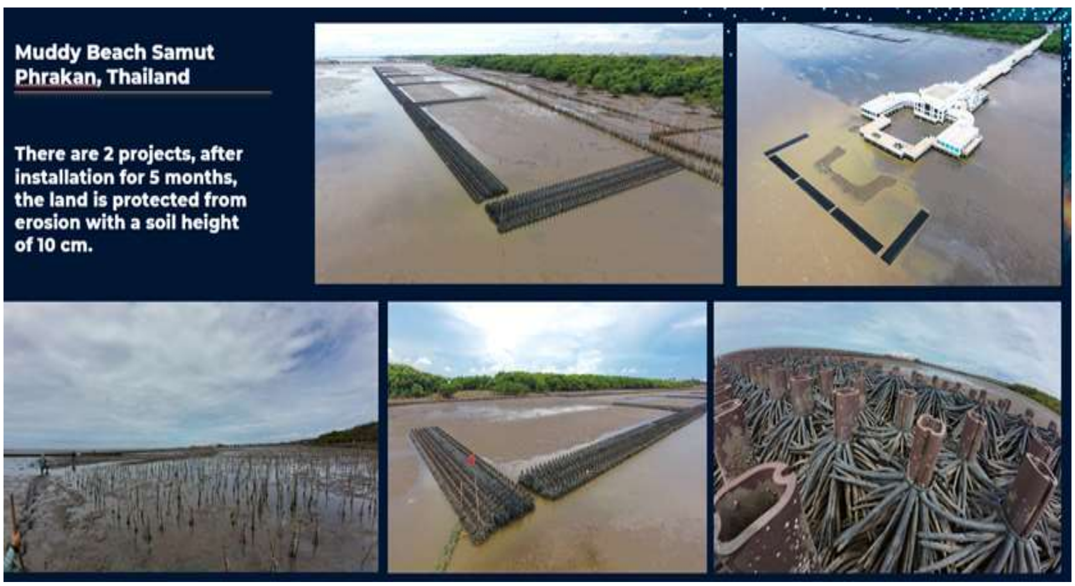

Figure 5. Implementation FADS on muddy beach Samut Prakan, Thailand

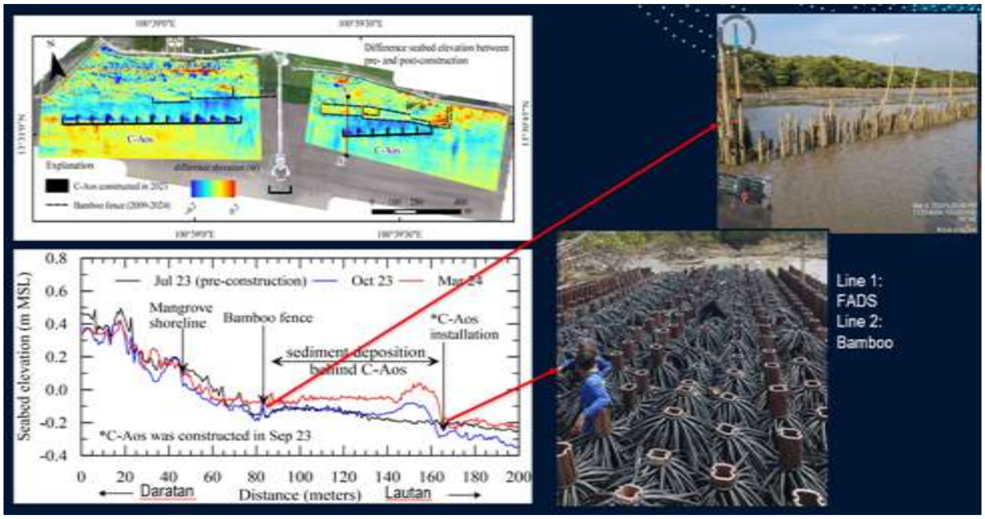

Figure 6. Result of FADS implementation on muddy beach

Figure 7. Site visit

Conclusion

The implementation of the Flotilla Abrasion Defense System (FADS) has shown significant potential in mitigating coastal erosion and promoting sediment retention in sandy and muddy beach environments. Through computational fluid dynamics (CFD) simulations and physical model testing, FADS has demonstrated its ability to reduce wave energy, enhance sediment deposition, and stabilize shorelines. Field applications in Thailand, including Rayong, Samut Prakan, and other coastal provinces, provide strong evidence of its effectiveness in both sediment accumulation and erosion prevention.

While the initial results are promising, further long-term monitoring is essential to quantify the extent of sediment retention and evaluate the durability of FADS over time. Additionally, international collaboration, particularly with Indonesian researchers and international institutions, can contribute to further advancements in design and optimization for different coastal conditions. Given its eco-friendly materials and sustainable approach, FADS offers a viable alternative to traditional hard-engineering structures for coastal protection. Expanding its implementation across regions facing similar challenges can contribute to long-term shoreline stability and the restoration of coastal ecosystems.

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