CEDD INNOVATION SERIES







Tung Chung Eco-shoreline - A Sustainable Nature-based Solution in Coastal Development

Foreword

Civil Engineering and Development Department (CEDD) maintains a steadfast commitment to engineering excellence in infrastructure development, continually playing a pivotal role in shaping Hong Kong into a leading city in Asia.

CEDD acknowledges the importance of collaboration with academia and the construction industry in fostering innovation and technological advancement. Through University-Government-Industry (UGI) partnerships, we have been advancing and adopting innovative construction technologies, materials and nature-based solutions in our engineering projects. This integrated approach aims to build a more liveable and climate-resilient city, while achieving co-benefits that enhance productivity and promote environmental sustainability.

The successful adoption of these innovative solutions showcases how cutting-edge innovative engineering technologies and stringent construction protocols from both international and local contexts can be seamlessly integrated to achieve excellence.

I would like to commend the project teams for their tremendous efforts in pioneering novel technologies to effectively overcome Hong Kong's complex site constraints. I also extend my sincere appreciation for the exemplary spirit of collaboration among the project teams, the academia and industrial practitioners, which has been instrumental to the success of these innovative solutions. The adoption of these advancements has not only enhanced construction safety but also improved programme and cost efficiency, resulting in significant time and cost savings.

As always, CEDD is committed to fostering innovation and collaboration for driving the delivery of resilient, safe and sustainable infrastructure in Hong Kong. This CEDD Innovation Series documents these achievements, with a view to inspiring the local construction industry with proven practices and forward- looking solutions.



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Abstract

The Tung Chung eco-shoreline project represents Hong Kong's first major implementation of ecological shoreline technology, forming part of the Tung Chung New Town Extension (TCNTE) development. This pioneering initiative integrates sustainable green coastal protection with biodiversity enhancement, demonstrating how modern construction can work harmoniously with natural ecosystems while addressing urban development needs. The design is a deliberate act of ecological restoration, providing robust coastal protection for our future while simultaneously creating the complex, vital environments necessary for marine life to thrive. This is not merely a flawlessly engineered structure; it is a living, breathing interface that enhances both biodiversity and community well-being.

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1 Introduction

The Tung Chung eco-shoreline project is Hong Kong's first major implementation of ecological shoreline technology and forms part of the Tung Chung New Town Extension (TCNTE) development and a pioneering example of the global shift towards nature-based solutions in coastal engineering. This innovative approach, which incorporates ecological principles into shoreline design, is gaining worldwide recognition as a response to the dual challenges of urban development and climate changes. Crucially, the potential for carbon accreditation from eco-shorelines supports to the broader vision of achieving carbon neutrality in the near future.

2 Background

Tung Chung New Town Extension (TCNTE, the Project) is a major land supply project to support housing and economic development. Tung Chung, a newly developed residential area with long history and culture, is located next to our international airport with a high development potential. For Tung Chung East, there is a newly-reclaimed land of 130 hectares, providing some 50,000 housing units, with the infrastructure works now in full swing. The first population intake has commenced in 2025.

The eco-shoreline serves dual purposes. Firstly, it provides an enhanced intertidal habitat. The project attempts to mimic natural intertidal zones, so as to create a unique and dynamic environment that supports a wide range of marine intertidal organisms as well as shore-birds. Secondly, the eco-shoreline together with the open space would serve as a buffer zone against coastal hazards. This design enhances the vibrancy at the waterfront for public enjoyment when the weather is fine. When a storm is approaching, the wave wall would serve as an effective line of defence for the developments behind and dissipate the wave energy.

Taking into account the environmental factors such as seawater salinity, vulnerability to wave attack (wave exposure) and abundance of sunlight (heat factor), the mangrove eco-shoreline, rocky eco-shoreline and vertical eco-shoreline were set up at appropriate locations with a total length of 3.8 km (Figure 2.1; Figure 2.2 Mangrove eco-shoreline of 1.2 km; Figure 2.3 Rocky eco-shoreline of 0.8 km; Figure 2.4 Vertical eco-shoreline of 1.8 km). The eco-shoreline was completed in June 2023.



Figure 2.1 Map of the Eco-shoreline



Figure 2.2 Mangrove eco-shoreline



Figure 2.3 Rocky eco-shoreline



Figure 2.4 Vertical eco-shoreline

3 Technical Details and Design Concepts

Recognising the limited ecological value of standard artificial seawall design, the Project's Environmental Impact Assessment Report recommended that ecological enhancement measures would be considered in the seawall design for the TCE Potential Development Area and Road P1 (Tung Chung - Tai Ho Section) Extension reclamation. This would provide mitigation for marine ecological impacts resulting from the Project, which include the permanent loss of marine waters/seabed. Ecologically enhanced seawalls could compensate this impact by providing habitat for intertidal and subtidal marine communities.

3.1 Site Trial at Siu Ho Wan

In order to assess the performance of the eco-shoreline design, a site trial was undertaken at Siu Ho Wan, close to TCNTE (Figure 3.1). Modification of artificial shoreline at the trial site into rocky and mangrove eco-shoreline commenced in mid-2019 and mangroves were planted in December 2019. Monthly ecological monitoring was conducted during the establishment period from January 2020. The result and monitoring data helped optimize the final eco-shoreline design for TCE. For the mangrove eco-shoreline, six mangrove species (*Acanthus ilicifolius*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera gymnorhiza*, *Lumnitzera racemosa*, and *Kandelia obovate*) that are known to occur naturally in North Lantau were planted at the site trial to test the survivorship and growth of mangrove as well as suitable sediment levels and composition. For the rocky eco-shoreline, "bio-block" with enhancement features (such as water holding components and drillholes) with different levels or depth were installed to test the ecological performance.



Figure 3.1 Location of Proposed Eco-shoreline Trial Site

3.2 Mangrove Eco-shoreline

The concept for the Mangrove Eco-shoreline (Figure 3.2) is based on the wetland sill design, where a sill is constructed to provide a sheltered platform suitable for the establishment and growth of mangroves. The platform needs to be protected from wave action (which could lead to the scouring and loss of fine sediments from mudflats), while at the same time allowing tidal exchange required for mangrove growth and the movement of marine wildlife larvae in and out of the eco-shoreline area. The design would achieve this by using concrete blocks at the seaward edge of the eco-shoreline platform. Tidal exchange and the movement of wildlife through the sill will be facilitated by staggering the sill at approximately 30m intervals. Some limited additional tidal exchange would occur through the base of the platform, where a geotextile fabric would allow water exchange while preventing the loss of fine sediments from mudflats.

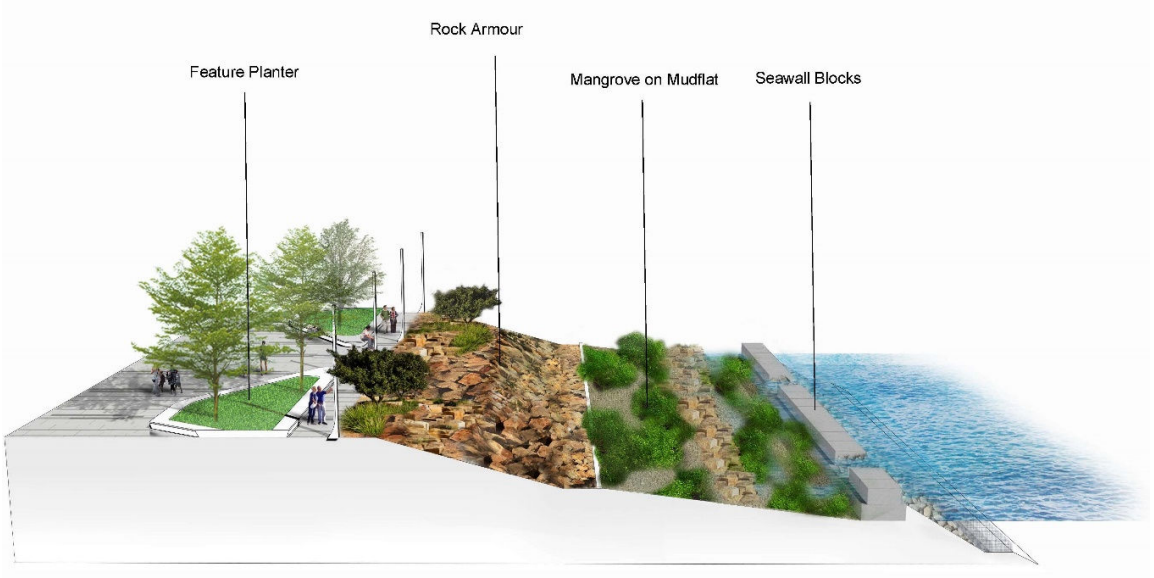


Figure 3.2 Design concept for the Mangrove Eco-shoreline

The mangrove eco-shoreline comprises mudflats and mangroves which are shown in the technical diagram (Figure 3.3) below.

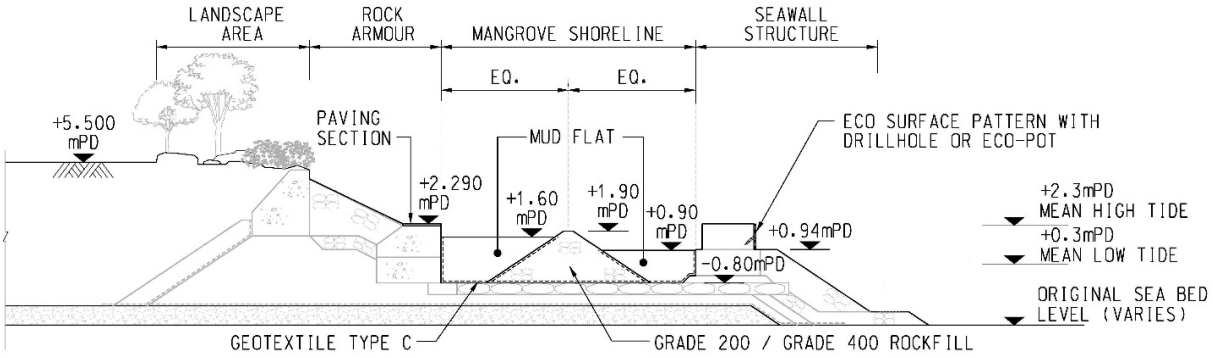


Figure 3.3 Technical diagram for the Mangrove Eco-shoreline

The mudflats (approximately 2m thick) should be graded to be at just below high tide (+2.29 mPD) at the landward side of the platform, down to mean low tide (+0.3 mPD) at the seaward side. This would create a range of potential mangrove and mudflats habitats.

Mangroves grow relatively poorly in pure saltwater: higher growth rates are achieved in brackish waters with lower salinity. While salinity levels in the TCE are thought to be within the range found at naturally occurring mangrove stands in Hong Kong, additional freshwater input to mangrove eco-shoreline would be provided by directing stormwater run-off landward of the eco-shoreline directly into the mangrove area.

To speed up the establishment of the eco-shoreline, mangrove seedlings are planted in the platform. A small mangrove nursery has been established in the Tung Chung East Site Office to cultivate and grow the locally collected fruits before the transplantation. Only mangrove species native to Hong Kong and common in the existing Tung Chung area are utilised. Six native mangrove species planned to be used in the planting include *Acanthus ilicifolius*, *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera gymnorhiza*, *Lumnitzera racemosa*, and *Kandelia obovata*.

3.3 Rocky Eco-shoreline

The basic concept for the rocky eco-shoreline (Figures 3.4 & 3.5) adopts square-shaped concrete blocks arranged to provide a natural looking shoreline.

The section has been designed with a low gradient to maximise the intertidal area of the rocky shoreline, increasing the number of niches available for intertidal organisms. The block-size is approximately 1 m^3. By positioning some of the seaward blocks at a higher level than adjacent landward blocks, rock pools will be formed at low-tide that can provide a refuge for intertidal organisms. Furthermore, holes, ledges and other surface structures will be cast into the blocks to

further increase habitat value. It is important to create rockpools at different tidal levels to maximise species diversity; some habitat-specialist species are tidal-height specific, while other species require different tidal height pools throughout their life-cycle.

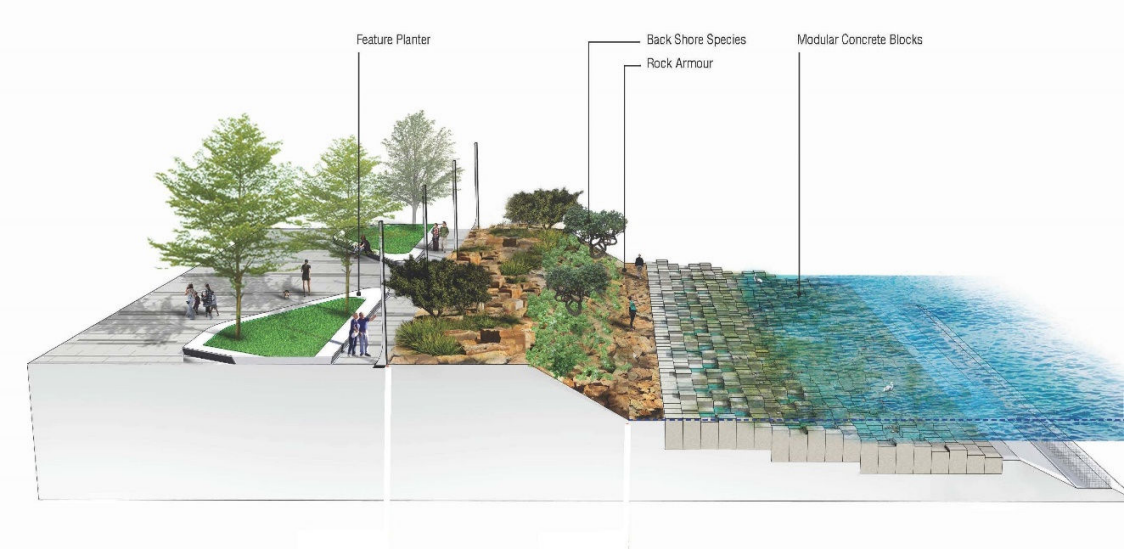


Figure 3.4 Design concept for the Rocky Eco-shoreline

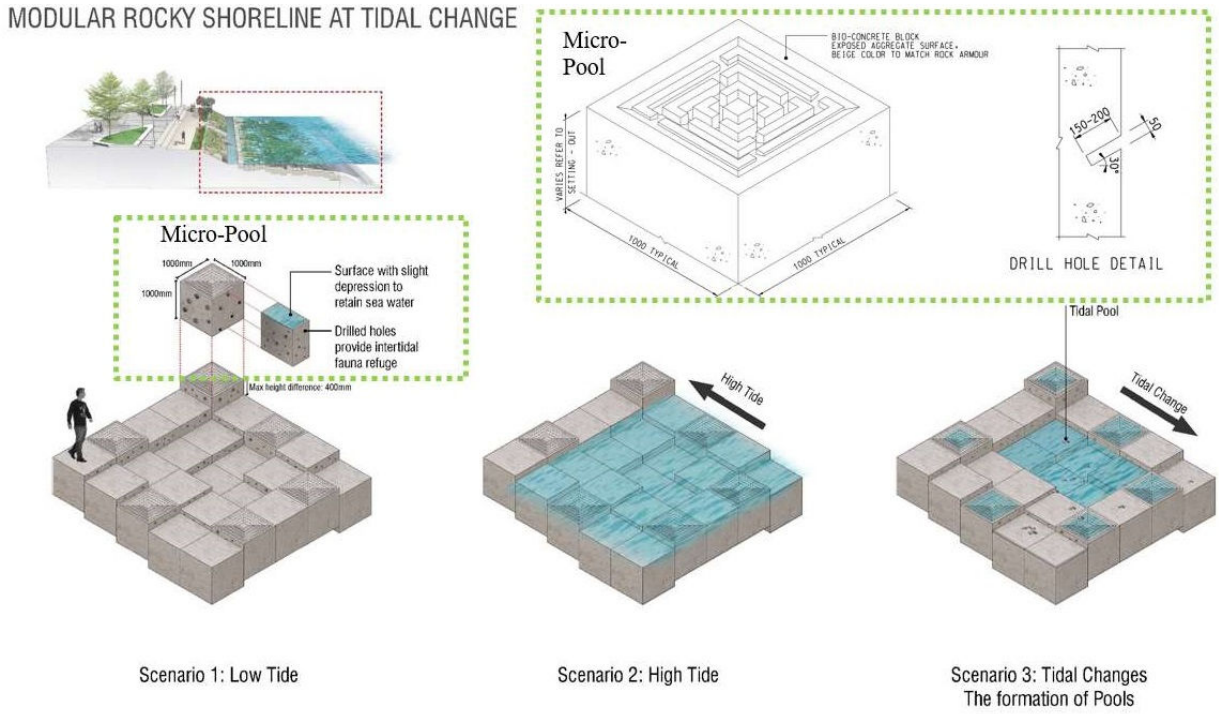


Figure 3.5 Design concept for the Rocky Eco-shoreline

Rocky eco-shoreline comprising of bio-blocks which is shown in the technical diagram (Figure 3.6) below.

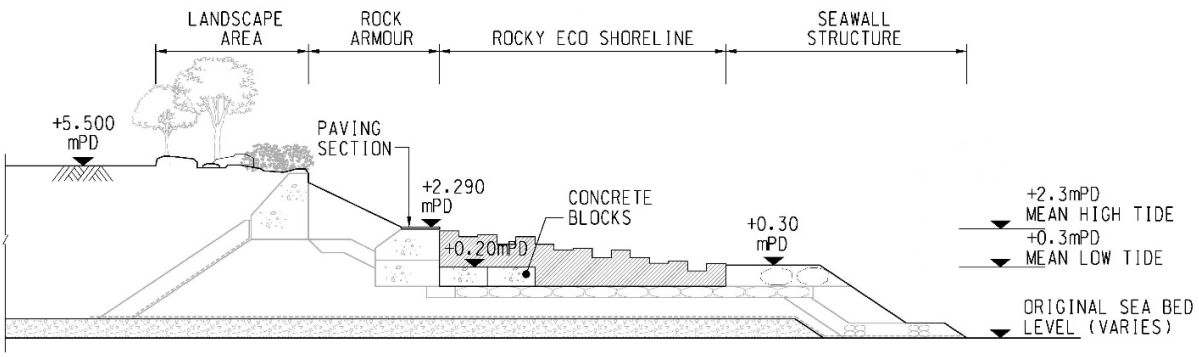


Figure 3.6 Technical diagram for the Rocky Eco-shoreline

3.4 Vertical Eco-shoreline

The basic concept for the vertical eco-shoreline is to provide surface treatment to block-work used to form the sea-wall. Additional enhancement features included in the vertical seawall design comprise:

- Small holes (e.g. 5 – 10 cm in diameter and 15 cm deep) will be drilled in the seawall at a 45 degree angle (so they retain water at low tide) to provide refuge for crabs, fish and other larger fauna. The holes will cover inter-tidal and sub-tidal areas of the seawall, and be provided at 50 cm – 100 cm intervals.

- Larger cavities (e.g. 80 cm high, 40 cm wide and deep) pre-cast into the concrete should be included above the high tide level every 10 m – 30 m. These will provide platforms for wetland birds (e.g. White Wagtail *Motacilla alba*) to hunt and rest.

- Eco-pots made of clay with internal dimension of 300 mm (length) x 150 mm (width) x 300 mm (depth) and pot thickness of 40 mm shall be attached to the vertical eco- shoreline at 10m intervals with the bottom of the eco-pot at +1.05mPD. This will provide a refuge for marine organism by retaining water during low tide.

Vertical eco-shoreline comprising of eco-pattern, eco-drillhole, eco-pot and bird resting area is shown in the technical diagram (Figure 3.7) below.

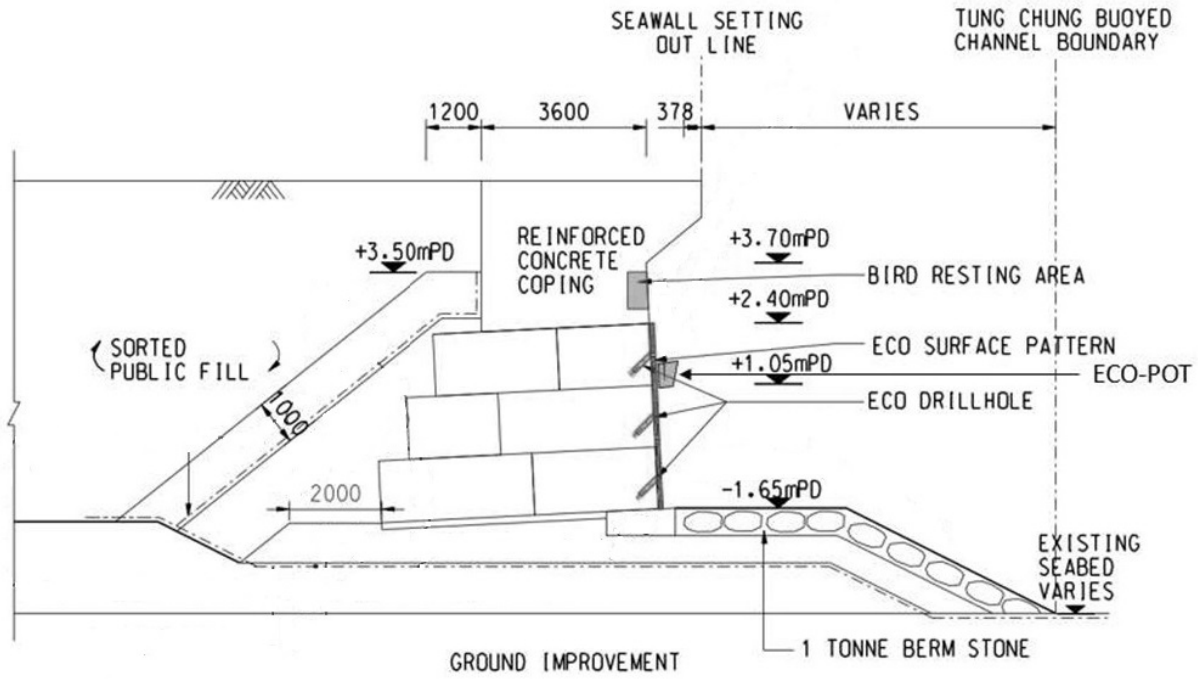


Figure 3.7 Technical diagram for the Vertical Eco-shoreline

4 Achievements

Tung Chung's eco-shoreline has delivered quantifiable ecological and engineering successes. Post-construction monitoring has already discovered around 250 different species of marine life.

4.1 Biodiversity Enhancement Results

The eco-shoreline features in Hong Kong have demonstrated remarkable improvements in biodiversity. Initial monitoring results (Figure 4.1) show successful colonisation by different species, including algae, coralline algae, crabs and gastropods, on eco-seawall components, whereas neighbouring conventional maritime structures showed no such colonisation. Comprehensive post-construction studies have documented around 250 species, including polychaetes, gastropods, bivalves, crustaceans, fish and shorebirds, at the three types of eco-shoreline.



Figure 4.1 Representative organisms recorded at the three types of eco-shorelines

For mangrove, rocky and vertical eco-shorelines, increasing avifauna and epifauna (all three eco-shoreline types) and infauna (mangrove eco-shoreline only) species richness and diversity over the first two years of monitoring (2024-2025) were observed and presented in the Table 4.1 below.

	Mangrove Eco-shoreline		**Rocky Eco-shoreline**		**Vertical Eco-shoreline**	
	1st Year	2nd Year	1st Year	2nd Year	1st Year	2nd Year
Avifauna	12	12	8	8	6	8
Epifauna	19	34	65	121	31	52
Infauna	6	8	N/A	N/A	N/A	N/A

Table 4.1 Species richness over the first two years of monitoring (2024-2025)

Throughout the second year of monitoring, the rocky and vertical eco-shoreline had a combined total of 141 species. A higher biodiversity and number of species were found in the eco-shoreline features than the conventional reference locations. This may be attributed to the intrusions and water pools which may provide microhabitats which lower heat and desiccation stress when the shorelines are exposed to direct sunlight, facilitating the settlement of intertidal species. For the mangrove eco-shoreline, the mangrove trees were found to be in a normal condition with acceptable percentage of mortality. Three species of mangrove i.e. *Avicernnia marina*, *Bruguiera gymnorhiza* and *Kandelia obovata* were survived and recorded. Mangrove trees are seemingly beginning to establish themselves in the mudflats of the mangrove eco-shoreline as signs of flowering as well as growth of aerial roots have been observed, as well as an increase in the average number of leaves on the trees.

4.2 Environmental Performance Indicators

CEDD has completed a study on "Report for Capital Carbon, Carbon Stocks and Carbon Sequestration of TCE Eco-shoreline" in November 2025. The study showed that despite the initial carbon investment, the eco-shoreline is already generating positive environmental returns. Field assessments across three newly established mangrove sites recorded a combined 9.47 MgC of above- and below-ground biomass, while soil carbon averaged 54.3 MgC/ha, reflecting the early development of carbon-sequestering capacity. The comparison with a mature reference site underscores the strong relationship between mangrove age and carbon accumulation potential. Long-term modelling further underscores the eco-shoreline's contribution to climate mitigation. Over a 100-year horizon, mangrove habitats are projected to sequester over 5,000 tCO_2/ha, representing a substantial carbon sink with an estimated HKD $71.4 million per hectare net present value by year-2125. These findings affirm the eco-shoreline as a high-value, nature-based solution capable of enhancing carbon storage, strengthening coastal resilience, and promoting sustainable urban development. Ecologically, the eco-shoreline now supports over 250 species of marine life, demonstrating the success of the habitat creation process. Monitoring programmes have established baseline data for ongoing performance assessment.

4.3 Educational and Community Impact

To encourage broad public involvement, the project features outdoor classrooms and community engagement programmes, including a mangrove planting scheme for local primary school students. Through these immersive site visits and educational initiatives, public awareness of coastal ecology, marine conservation, and sustainable development has been significantly enhanced.

5 Experience Gained

Eco-shorelines represent a revolutionary advancement over traditional coastal defence methods, which often disrupt coastal ecosystems and lack integration with the existing natural environment. The Tung Chung Eco-Shoreline is a prime example of this innovation, seamlessly integrating natural ecosystems like mangroves and rocky shores into urban development. Furthermore, Tung Chung's design incorporates community engagement, offering recreational and educational spaces that foster public stewardship of coastal resources. This multifunctional approach transforms shorelines from mere barriers into living systems that deliver ecological, social, and economic value.

5.1 Design Strategy

Our design strategically deploys different shoreline types based on a rigorous analysis of environmental factors. For instance, rocky eco-shorelines are allocated to areas heavily exposed to wave action or those receiving limited sunlight. Within the intertidal zones, bio-blocks featuring varying cavity depths and sizes are meticulously designed and installed to retain seawater during low tide, creating vital shelters and microhabitats for marine species. Meanwhile, mangrove eco-shorelines are positioned along sheltered coastal areas less susceptible to wave energy, thereby enriching the shoreline's overall habitat diversity. Where spatial constraints are unavoidable, vertical eco-shorelines incorporating eco-pots, cavities, and eco-tiles are implemented to foster the colonization of small marine organisms.

5.2 Nature-Based Engineering Solution

Eco-shorelines represent a paradigm shift in coastal protection methods, mimicking natural intertidal zones with specially designed concrete structures. Unlike conventional vertical seawalls, which create ecological barriers, eco-shorelines incorporate bio-blocks, tidal pools and textured surfaces that retain seawater during low tide, thereby creating viable microhabitats for diverse marine species.

5.3 Blue-Cool Eco Rock Pools

The Tung Chung rocky eco-shoreline features specially designed concrete bio-blocks arranged to create artificial rock pools. By retaining seawater during low tide, these pools serve as vital refuges for intertidal organisms while maintaining moisture and cooler microhabitats. Consequently, this microclimate regulation indirectly contributes to localized cooling effects within the immediate shoreline area.

5.4 Technical and Engineering Complexities

The synergy between structural integrity and ecological functionality opens up exciting new possibilities for coastal engineering. By precisely engineering surface textures, cavity sizes, and material compositions, we can create durable concrete structures that both withstand harsh marine conditions and provide thriving microhabitats for marine life. Seamlessly integrating these eco-shoreline features into traditional seawall construction represents a major leap forward, drawing on multidisciplinary expertise to masterfully optimize wave energy dissipation, sediment dynamics, and habitat suitability.

6 Technical Recommendations

The construction sector stands to benefit greatly from the adoption of eco-shorelines. First, it creates opportunities for new technologies. In Tung Chung, for example, the design and construction of the rock pool adopts the Modular Integrated Construction (MiC) concept in the creation of the rocky eco-shoreline. Furthermore, eco-shorelines align with global decarbonisation trends. Most significantly, by integrating stormwater management with urban greenery, construction companies could establish themselves as leaders in nature-based solutions. Although challenges persist, the shift towards eco-shorelines promises to transform coastal infrastructure into a catalyst for ecological regeneration and community resilience.

6.1 International Knowledge Transfer

Hong Kong's eco-shoreline project represents a global best practice in sustainable coastal development, joining the ranks of similar pioneering initiatives in Singapore and the Netherlands. International workshops and collaborative programmes have facilitated the exchange of cutting-edge knowledge and technology among these coastal regions. Furthermore, the project is actively shaping environmental policy and regulatory frameworks for coastal infrastructure. Its successful integration of ecological enhancement with infrastructure development provides a definitive blueprint for future regulatory standards and environmental mitigation strategies worldwide.

6.2 Innovation and Technology Development

It drives investment in new materials and monitoring technologies, such as underwater drones and AI camera sensors, as well as construction methods that are tailored to nature-based solutions.

6.3 Further Readings

- CEDD - Guidelines of Design, Installation & Maintenance of Eco-engineered Features on Artificial Shorelines https://www.cedd.gov.hk/eng/publications/ceo/guidelines-design-im-eco-as/index.html

- Greater Bay Area Standard WQ 1-262 "Technical guidelines to ecological design of sea dike海堤生態化設計技術指南" https://www.gbsrc.org.cn/standardSearchDetail?bzNumber=T%2FCHES%20139-2024

- Hong Kong Nature-based Solutions Design Guidelines https://www.cedd.gov.hk/eng/publications/miscellaneous/nm-santintech/index.html

7 Conclusions

The Tung Chung Eco-shoreline project stands as a pioneering example of sustainable coastal engineering, demonstrating how infrastructure development can actively enhance marine ecosystems. By leveraging innovative designs and advanced materials, it sets a new benchmark for the construction industry while delivering profound environmental and social benefits. Furthermore, this initiative shapes global coastal development practices, offering a scalable model for harmonizing urban growth with ecological restoration. Ultimately, it exemplifies the potential of eco-shorelines to provide resilient, future-ready infrastructure that tackles climate challenges through habitat restoration, meaningful stakeholder engagement, and the generation of carbon credits to advance global climate goals.

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