Chapter 15

Beach Erosion Management with the Application of Soft Countermeasure in Taiwan

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/45883

1. Introduction

The total length of Taiwan's shoreline is approximately 1,100 kilometers including sand, rock, cliff, gravel and reef coasts (see Figure 1). Almost half of the shoreline has been protected by seawalls. From the viewpoint of shore protection in coastal area, these seawalls actually play an important role of costal protection that prevents people and infrastructure from coastal disasters. Furthermore, detached breakwater and groyne are built to protect the coastal area with serious erosion problem. These efforts made our land safe over the last fifty years to some extent. Due to the martial law, it was not so easy for people to walk or visit near the coastal area in Taiwan during 1949 to 1987. However, after 1987 people gradually valued the coastline for environmental protection and, recreational use as well as the economic activity. The purpose of the coastal protection is diversified by these new demands. In this study, we will introduce environmentally and user-oriented coastal protection works as well as technically sound creditable coastal protection works to meet these new trends. Therefore, the purpose of this study is to evaluate on how to join soft solution strategies into current shore protection system throughout Taiwan's coast. Moreover, a feasible application for hard solutions complemented by soft issues for beach erosion management has also been evaluated. In Taiwan, beach erosion has become more serious in the recent past. The time for this beach erosion to become apparent chiefly depends on how fast the rate of longshore sediment transport decreased from the up-coast area and on the river sediment supply. Many industrial, commercial and fishery harbor construction projects were also observed to have disturbed the continuity of littoral sediment transport, and lead to the retreat of the shoreline in the downcoast area. However, sufficient knowledge on nearshore hydrodynamic forcing (incoming wave energy, wave-induced currents in the surf zone and tidal range), sediment transport processes and morphological features along coasts, will be helpful to the improvement of shore protection work. Countermeasures for beach erosion control should depend on the local conditions of hydrodynamic forcing characteristics, littoral sediment transport and various morphologies. Therefore better applications of the various soft methodologies available for beach erosion management will be proposed in this study.

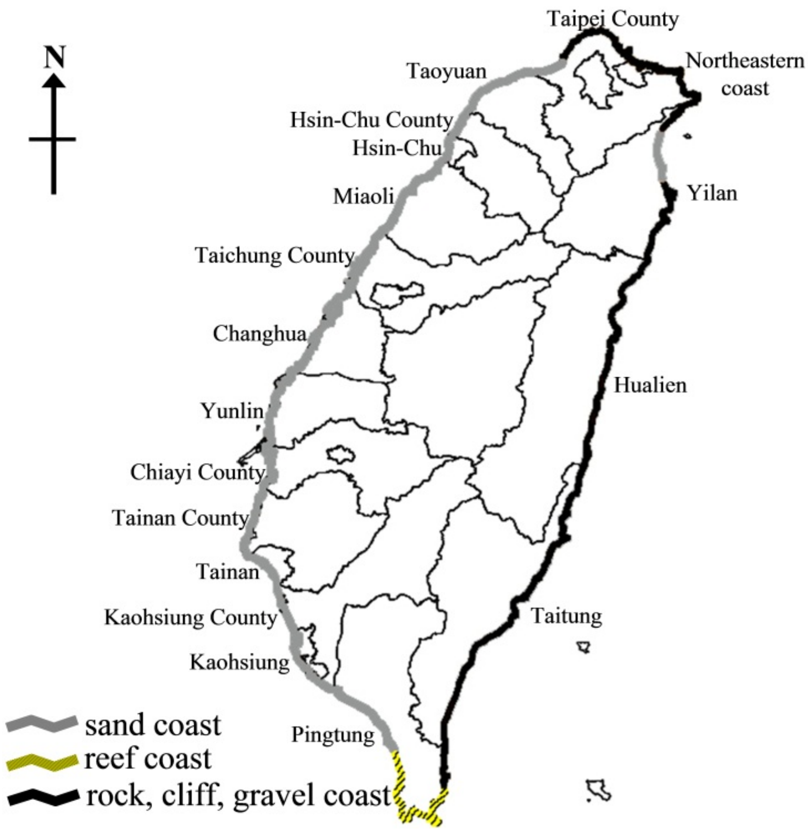


Figure 1. Different types of coasts in Taiwan

2. Evaluation of soft engineering structures

The protection of beaches against erosion has always been an important aspect of coastal engineering works in Taiwan. History is replete with the loss of valuable coastal lands such as beaches, reclamation areas, harbors, and other valuable coastal property to erosion induced by sea encroaching. On the other hand, there are also some cases of harbors being abandoned because of infilling by sediments, which is quite a different coastal engineering problem but a significant one. Erosion control measures should incorporate a reduction in the cause of the beach erosion where possible, when, for example, the erosion is caused by human activities along the coastal areas such as hard engineering structures or harbors. For each coastal erosion mitigation measure, it is important to know how they work. In fact, some of the mitigation schemes are able to reduce the wave energy at the shoreline, or simply provide a sacrificial beach, whereas others try to impede the long shore transport of sand. In a particular situation, one mitigation scheme will work better than some others owing to the difference in operation. In fact, some methods will fail in one situation and do very well in others. Therefore, in order to mitigate the erosion problems due to the current hard shore protection system around Taiwan coast, detailed evaluation of various feasible soft engineering structures should be conducted in advance. The evaluation of soft countermeasure includes beach nourishment, near shore disposal berms, geosystems, artificial oyster reef, fluid-elastic sheet and aquatic vegetation.

2.1. Beach nourishment

Beach nourishment is the mechanical or hydraulic placement of sand on the beach and/or shoreface to advance the shoreline or to maintain the volume of sand in the littoral. It is a soft protective and remedial measure that leaves a beach in a more natural state than hard structures and preserves its recreational value. Of the many remedial measures for beach erosion, beach nourishment is the only approach that introduces additional sand sources into the coastal system. Without the construction of coastal structures, beach nourishment seldom causes damage to the landscape, and can flexibly responds to changes of the littoral environment. Beach nourishment, with its expected widening of beach, is used to accomplish several goals as follows: formation of additional recreational area; land reclamation; maintenance of shoreline; reinforcement of dunes against breaching; protection of coastal structures; reduction of the wave energy near shore and creation of a sacrificial beach to be eroded during a storm; provide, in some cases, environmental habitat for endangered species.

Sand nourishment can be carried out at various locations in the profile or along the shoreline. The options of nourishments in cross-shore profile are shoreface (underwater nourishment or profile nourishment), dune zone (landward and seaward above dune toe), beach and swash zone. Leonard et al., 1990 evaluated 155 beach nourishment projects in the U.S.A. In all, about 300 million m^3 of sand was placed along 700km of shoreline (470km along Atlantic coasts, 180km along Gulf coasts and 50km along Pacific coasts). In 1996, Rijkswaterstaat also evaluated nine nourishment projects (volumes between 50 and 100 $m^3/m/yr$; sand size between 0.15 and 0.3mm) carried out along the coasts (tidal range of about 2m) of the Netherlands in the period 1975-1994. Several characteristics, including ratio of design nourishment volume and required volume to compensate annual erosion volume in active zone before nourishment and after nourishment, were analyzed in his evaluation. Leo C. van Rijn, 1998 summarized the sand nourishment characteristics under micro and meso-tidal conditions in great detail from five projects (Delft Hydr., 1987; Dette & Raudkivi, 1994; Mϕller, 1990; Rijksw, 1996; Work & Dean, 1991). From his result, it shows that beach nourishment can be mostly utilized on coastal areas of low or moderate wave energy with micro-tidal condition. Meanwhile, the three basic elements including the eroded area, the borrow area and the transportation/ dumping methods should be investigated in detail when sand nourishment is applied to beach erosion control. Dean, 1986 recommended a mitigative approach for armoring on an eroding coastline that calls for the placement of sand annually in the amount that has been prevented from entering the system by the armoring structure. This approach maintains a more natural littoral system. Often, the nourishment scheme is remedial rather than preventive (Hamm et al., 1998). In summary, beach nourishment is the approach that directly addresses the deficit of sand in the coastal system without at least the potential of causing adverse effects on adjacent property. Bridges & Dean, 1996 concluded that beach nourishment is the most benign and acceptable approach to beach erosion mitigation. However from the new demands of shore protection now in Taiwan, beach nourishment can not be the only option of beach erosion control.

2.2. Near shore disposal berms

Open-water disposal of dredged material has been practiced worldwide for over sixty years. The initial attempts have arisen from the search for a beneficial use of the large amounts of dredged material obtained from navigation channel maintenance operations. The removed material which varies in size and quantity has been placed in nearshore disposal sites seaward of the surf zone. A major cost savings often accrues if beach fill material can be placed offshore rather than on the beach in the expectation that natural processes will move the material to the beach. The performance of underwater berms has been investigated both in the laboratory and through field monitoring programs. Hands, 1991 provided a thorough review of the behavior of 11 berms and their performance. Furthermore, Otay, 1994 presented a summary of submerged berms and their characteristics, including whether they were judged to be stable or migrated. Of the berms placed to benefit the landward beaches, possible designs could be a feeder berm, in which sand would be transported to the beach from an active berm or as a stable berm that causes damping of the waves and thus sheltering of the landward beach. In his research, Otay also described the monitoring results of an underwater berm placed off Perdido Key, Florida. Monitoring included repetitive beach profiles and wave measurements. His result showed that the berm had exerted a stabilizing effect on the beach leeward of the berm.

2.3. Geosystems

Geosystems (tubes, containers) have already found various applications in coastal engineering. The tubes and containers are mainly applicable for construction of groynes, perched beaches, and offshore breakwaters, and as bunds for reclamation works. Application of these systems has executed by a number of projects in the Netherland, Germany, Japan and U.S. Some information on U.S. experience with geotubes can be found in Fowler et al., 1995 including the application of geotubes for dewatering of contaminated maintenance dredged material. Geosystems have much applicability in erosion control, water control (small weirs and reservoirs), flood control, etc. For example, breakwaters made of sandbags, geotubes, etc, have been used successfully in the United States of America under conditions for low tidal range and low wave activity (Krystian, 2000). Under gentle wave climates such structures may not only attenuate waves, but can also encourage the accretion of sediment between them and the shore. Geotube can also be used to assist in dike, groin and breakwater construction. Krystian summarized the examples of application of geotube, as dune reinforcement, core of breakwater, and bunds for dike construction, from a number of projects executed in the Netherlands and Germany. The main advantages of geosystems in comparison with more traditional methods (rock, concrete armor units, block mats, asphalt, etc.) are: a reduction in work volume, execution time and cost, the use of local materials, low-skilled labour and locally available equipment. However, until now, geosystems were mostly applied as temporary structures. The reason for that was their relatively low resistance to the loading of waves and currents, the lack of proper design criteria, and a low durability in respect to UV-radiation and vandalism.

2.4. Artificial oyster reef

There is increasing interest in oyster reefs used to restore eroding coastlines. Occasionally, subtidal oyster reefs can be found offshore. These immense natural submerged breakwaters protect the beaches from storms and wave erosion by dissipating wave energy. The study of how artificial and natural reefs have protected shorelines has been conducted by Hamaguchi et al., 1991. They investigated the effects of an artificial reef on the Niigata coast in Japan. It was found that a significant amount of sand was deposited landward of this artificial reef. This reef was developed to mimic the effect of the natural coral reefs in the area. There has been an effort to find different methods of restoring oyster reefs in various estuaries around the world. O'Beirn et al., 2000 conducted the experiments by using oyster shell, concrete, and rubber tire chips as oystercultch material. A structure termed an "oysterbreak" was designed to stimulate the growth of biological structures in an optimal shape to serve as submerged breakwaters (Foret, 2002). Oysterbreak can form immense structures that can protect shorelines and coastal communities by reducing wave energy.

Currently, mineral accretion amelioration on gabion that was filled with oyster cultch & rock to form a new biological unit has been investigated in field experiment by Hwung et al., 2008. It is hoped that this combination of oyster cultch, mineral accretion and cage meshed into berm breakwater can improve the toe revetment and berm advance, and simultaneously enrich the local environment to a higher level.

2.5. Fluid-elastic sheet

Fluid-plate hydro-elastic interaction problems have been of common interest for a long time because of their engineering applications. During the past decades, for instance, there has been a gradual increase in interest in the use of flexible plates or membranes as alternative effective inexpensive wave barriers in a beach zone. Currently, developing of the new design of floating wave breakers in a beach zone using coating of the sea surface by an elastic plate, which absorbing the energy of sea waves, is investigated by Hwung et al., 2008. A properly designed horizontal flexible membrane can be a very effective wave barrier and its optimal design can be found through a comprehensive parametric study using the experiments, theory and computer programs developed. In particular, the membrane is light and rapidly deployable; thus, it may be an ideal candidate as a portable temporary breakwater. Since a horizontal membrane does not directly block incoming waves, the transmitted and motion-induced waves need to be properly cancelled for it to be an effective wave barrier.

2.6. Aquatic vegetation

Aquatic vegetation provides important ecosystem services to coastal marine systems. They influence their environments through wave attenuation, the stabilization of sediments, increased setting of the suspended particulate particle and nutrient cycling. For environmental and esthetic purposes, projects on natural development of wetlands and restoration of river basins toward natural development have been promoted recently. The growth of vegetation in these areas is favored. Such vegetation increases the resistance of the watercourse, leading to an increase in water depth and reduction of flow velocity. In estuarine and coastal areas with vegetation, in addition to freshwater flow upstream, waves and tidal currents exist and will play a significant role in the hydrodynamics and mixing processes. Waves over vegetation will be attenuated due to the resistance offered by the vegetation. The bidirectional nature of wave motion will increase the mixing between the water column and that within the vegetation (Li & Yan, 2007). Wave motion tends to be highest in the shallow waters where, in combination with tidal currents, water movement imposes a shear stress on bottom sediments. If bottom shear stress exceeds a critical value, sediment will be resuspended, increasing turbidity and light attenuation (Wright, 1995).

For waves propagating over vegetation, Kobayashi et al., 1993 developed an analytical model to predict wave attenuation over vegetation by assuming an exponential decay of incoming regular waves. Vegetation meadows can reduce suspended sediment concentrations; friction from vegetation leaves reduces current velocity and attenuates waves, thus reducing the stress on bottom sediments, decreasing resuspension, and promoting sediment settling within the vegetation bed (Fonseca & Cahalan, 1992; Rybicki et al., 1997). Vegetation beds may also increase particle settling shoreward of the bed (Chen et al., 2007).

3. Hydrodynamic energy and morphology classification of Taiwan coast

The hydrodynamic and morphological processes in the coastal zone are governed by two primary phenomena, namely, winds and tides. The winds are directly responsible for the transport of sand on the dry beach and for the generation of waves, currents and water-level fluctuations, while the tides express themselves in a periodic rising and falling of the water and in tidal currents. Therefore, coastal classification based on hydrodynamic energy was presented by Davis & Hayes, 1984. The classification is shown in Table 1. The wave climate is generally characterized, as: low wave energy, if annual mean significant wave height at edge of surf zone (say, depth of 6m) is $H_{s,am}<0.6$m; moderate wave energy, if $H_{s,am}$ between 0.6m and 1.5m; high wave energy, if $H_{s,am}>1.5$m.

However, tides are classified as micro-tidal, if the tidal range (TR) <2m, meso-tidal for TR between 2m and 4m and macro-tidal for TR>4m. Furthermore, the relative strength of tide-induced (tidal range TR) and wave-induced forces (mean annual nearshore wave height H) acting in coastal system, the following classification may also be given as: wave energy-dominated coasts (TR/H=0.5 to 1.0), tide energy-dominated coasts (TR/H>3); mixed energy coasts (TR/H=1 to 3).

Regarding the long-term marine observation data, we refer to the research reports analyzed by Tainan Hydraulics Laboratory [THL], 2002 and then summarize the hydrodynamic energy classification of Taiwan coast shown as Figure 2 and Figure 3. Therefore based on Davis and Hayes's classification, the results show that northeastern coast, east coast and south coast of Taiwan belong to micro-tidal coast. However, Yun-Lin, Changhua (mid-western coast) and north coast are meso-tidal coast. As mentioned about classification of wave energy coast, the coast from Taipei county to Hsinchu county (northwestern coast), and coast between Yun-Lin county and Tainan county (west coast) are moderate wave energy coast.

Wave Energy	low	moderate	high
	Hs,am<0.6m	0.6m <Hs,am<1.5m	Hs,am>1.5m
Tidal Energy	micro-tidal	meso- tidal	Macro- tidal
	TR<2m	2m<TR<4m	TR>4m
Coastal classification based on hydrodynamic energy			
Wave Energy-dominated			TR/ Hs,am=0.5~1
Tide Energy-dominated			TR/ Hs,am>3
Mixed Energy			1<TR/ Hs,am<3

Table 1. Hydrodynamic forcing in the coastal zone

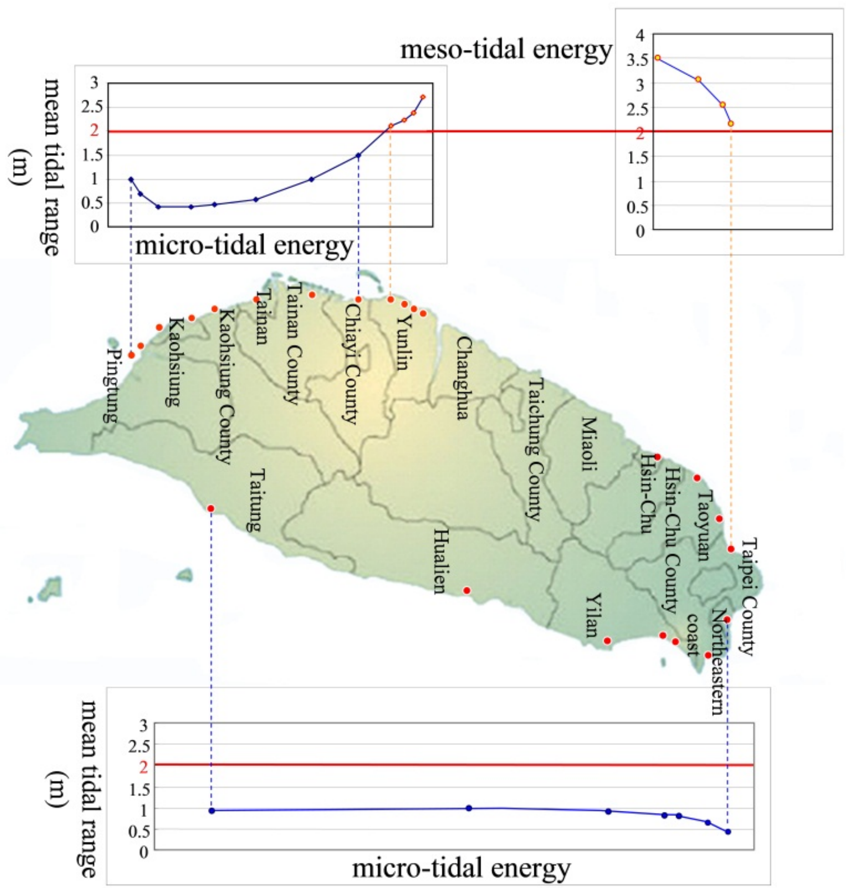


Figure 2. Tidal energy classification of Taiwan coast

However, southwestern coast from Tainan city, Kaohsiung to Ping-Tung county belong to low or moderate wave energy coast. Regarding to the east coast of Taiwan, besides partial coast of Taitung county is moderate wave energy coast, most parts of the east coast, (Hualien, Yi-Lan) and northeastern coast, are high wave energy coasts. For morphology classification, the slopes of beach profiles around Taiwan coast are shown in Figure 4. Due to these hydrodynamic energy and morphology classification of Taiwan coast, a strategic management proposal can be made to integrate soft countermeasure into the current hard shore protection system around Taiwan coast.

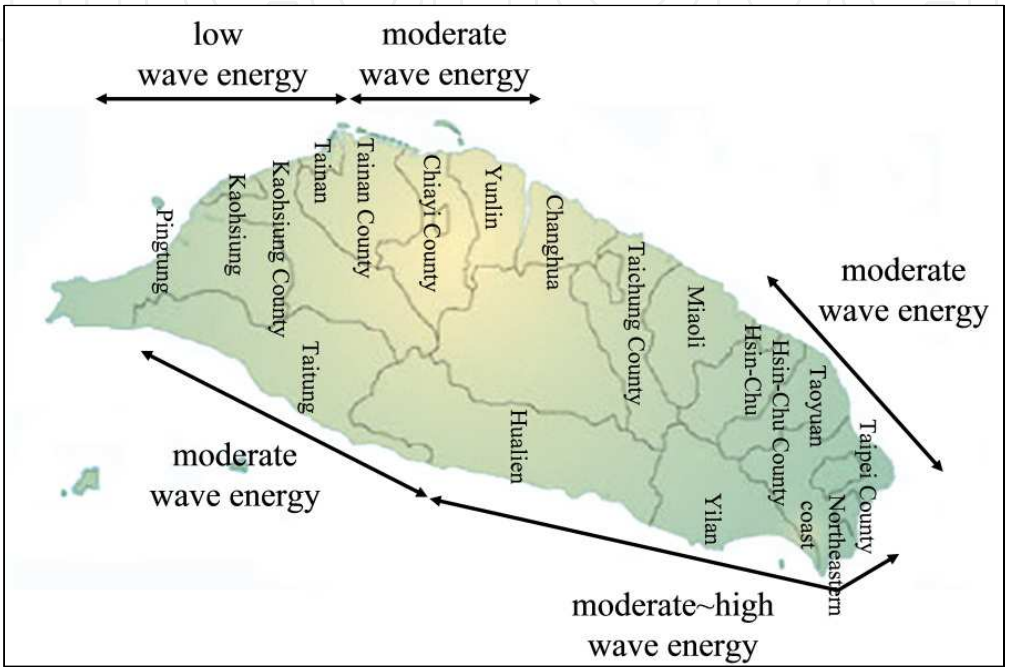


Figure 3. Wave energy classification of Taiwan coast

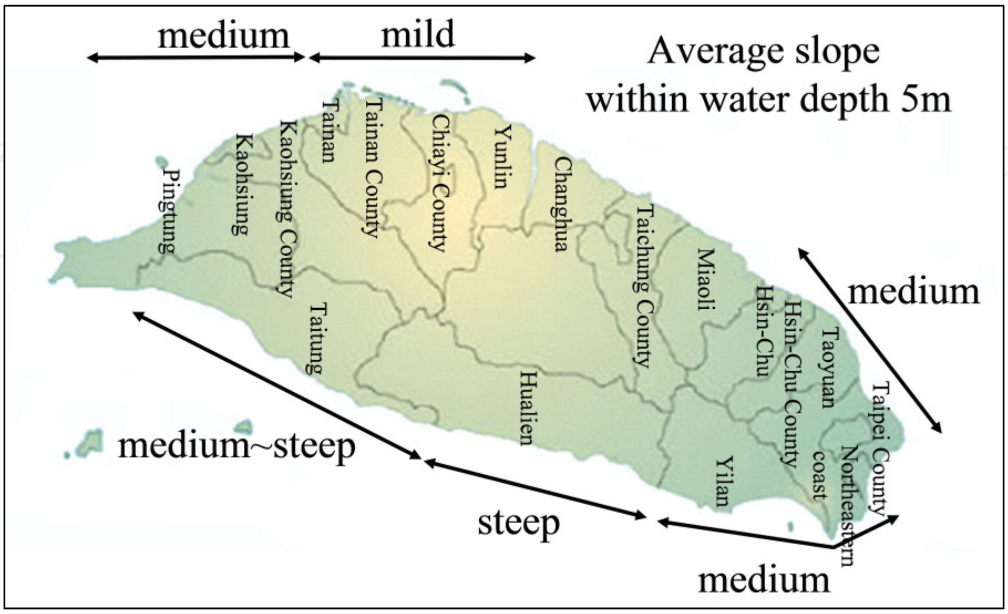


Figure 4. Morphology classification, the beach slopes around Taiwan

4. Discussion on application of combining hard and soft solutions for beach protection in Taiwan

Water Resource Agency, Taiwan, has claimed nearly 95 percent of fulfillment on coastal protection after more than 30 years' efforts. However, under the disaster prevention demand in earlier days, coastal protection has been accomplished mostly be lining up the hard engineering structures such as seawalls, groyne and armour units along the coastlines. Until now, the constriction of the seawalls for shore protection does not always work well on each coast around Taiwan. Some shores still get eroded seriously with seawalls being damaged partially. Meanwhile, the coastal engineering development in Taiwan currently has changed the previous strategy, only focused on shore protection, to a new one taking into consideration several aspects like safety, economy, construction, recreation, landscape and ecology. According to this new trend, the current shore protection system around Taiwan can be properly mended by soft countermeasures, however, the specific characteristics and requisite at each local site should be taken into consideration. Therefore, we have divided Taiwan coast into several categories based on the collected long-term observation information such as geological characteristics, hydrodynamic forcing, the intensity of beach erosion and shore protection. Then, the national beach management and protection problems were evaluated and the solutions for shore protections and further improvements were proposed.

After evaluation of a number of soft solution results, it is indicated that beach nourishment is a natural and popular soft shore protection technique that has been applied worldwide recently. This method can be utilized on the coastal areas under low or moderate wave energies with mild or moderate bottom slope for engineering purpose. However from the new demands of shore protection now in Taiwan, beach nourishment can not be the only option of beach erosion control. Another soft solution should be also taken into consideration for integration. Based on these criteria and the categories of Taiwan coast, the countermeasure of integrating soft solution into current hard shore protection system around Taiwan coast will be proposed as follows:

Because the north coasts in Taiwan are meso-tidal and moderate wave energy coasts, and their beach profiles are of mild slope, the eligible improvement criteria for current shore protection scheme are based on headland control strategy plus sand nourishment. However, volume of sand, sand size, beach and swash zone placement should be taken into account in the works of beach nourishment.

On the other hand, many barrier islands in the offshore of Yun-Lin, Chia-Yi and Tainan coast, can be treated as natural offshore breakwaters. In fact, those barrier islands can form a defense line of low-lying coastal plains and back-barrier basin against storms attacking these areas. Therefore, the shore protection strategy for these areas should be focused on how to protect these barrier islands. However, most important for the formation and maintenance of barrier islands and inlets is the relative strength of the wave processes and of the tidal processes. In order to protect these barrier islands, detailed field investigations on sediment supply (sources and sinks), hydrodynamic forces (waves, tides and rate of sea level change) and geomorphic setting (shoreface profile shape, sub-strata composition) should be carried out in advance. Meanwhile, oyster cultivation is an important fishery industry in the coast of these areas. Thus, there is large volume of oyster cultch in these coasts. Therefore, one new shore protection technology using mineral accretion technique is proposed by Hwung et al., 2008. Regarding to this new technology, mineral accretion (an advance on cathodic protection) amelioration combined with oyster cultch and rock is used to form the new biological unit in order to enhance the efficiency of anti-rusting and function of shore protection. Several field experiments of this new shore protection technology have been done on Chigu Lagoon in Tainan County. It is hoped that this new shore protection technology can be successfully applied to coastal engineering in the near future.

Offshore sills or breakwaters have proved to be much effective when used in combination with beach nourishment schemes. The retention capacity of a perched beach not only helps to reduce wave attack but is clearly beneficial from a recreational point of view. Since many offshore breakwaters already exist in the coasts of Kao-Shung and Pin-Tung counties, sand sources can be filled in the region between offshore breakwaters and sea dikes. The expanding beach faces will be helpful for wave damping and sightseeing. However, as many successful fisheries exist in the coastal regions of Kao-Shung and Pin-Tung Counties, when the beach nourishment is taken as the shore protection method in these areas, the influence of beach nourishment to coastal fisheries should be taken into considerations.

As for steep beaches and high wave energy, such as those of the east coast region, more specific parameters should be taken into account. For example, the erosion problem at the Tou-Chen beach in Yi-Lan County can be remedied by headland control strategy plus sand nourishment. The Tou-Chen beach now is defended only by a seawall and some short groynes. The headland control strategy can be based on reconstructing two long arc-shaped groynes with a submerged breakwater to support the recreational beach fill in front of seawall. Meanwhile, for the purpose of recreational activity, the fluid-elastic shirt can be applied as a portable temporary breakwater in this beach zone for wave damping. However in order to mitigate the erosion of gravel beaches in Hualien and Tai-Tung counties, the beach nourishment of mixed grain sizes is to become an alternative solution. Since there is little experience on the movement of gravel on steep coast of Hualien and Tai-Tung counties, a comprehensive field investigation should be done on the mechanism of sediment movement especially for action of typhoon wave. Moreover, a detailed physical model study about the effect of dynamic nourishment as a countermeasure against erosion should also be conducted before gravel nourishment can be carried out on the Taiwan eastern coast.

5. Experimental application study on integration of soft solution into current hard shore protection system

Two local sites in the southwestern Taiwan coast and one biggest offshore barrier island in Taiwan are selected for the experimental application study on integration of soft solution into current hard shore protection system. These in-situ experimental studies are therefore designed to improve the security as well as to involve ecological and scenic remediation for the beach erosion problem.

5.1. Ching-Tsao-Lun coastal area

With the length of 5 kilometer, Ching-Tsao-Lun coastal area is located between Zeng-Wun River mouth and Lu-Erh-Men River mouth at the middle section of Tainan coast. Without manmade intrusion, Zeng-Wun River mouth was once a natural estuary for more over three decades ago. Unfortunately, nowadays Ching-Tsao-Lun coastal area was invaded by constructing concrete and pebble dikes or other artificial protection. Therefore, the beach in front of Ching-Tsao-Lun concrete dike had been eroded ten years ago (Figure 5 and Figure 6). In order to have an overall study on rebirthing Ching-Tsao-Lun coastline, the in-situ study (Figure 7) focuses not only on safety evaluation of remedial Ching-Tsao-Lun sea dike but also on low to reform the beach back with ecology evaluation (Liou et al., 2007). Furthermore, by joining government resource and local manpower together, advance coastal management will enlighten the environment and landscape of Ching-Tsao-Lun coast again. The overall coastal protections and environment rebirths for Ching-Tsao-Lun coastal are listed as follow:

The coastal area around Ching-Tsao-Lun concrete dike:

1. Short-term goal: If rebuild is required, dike section adjustment could be put into consideration.
2. Long-term goal: Three schemes with beach nourishment and offshore breakwater are proposed for beach rebirth. Physical remediation will be half the way whiles the beach reversible.

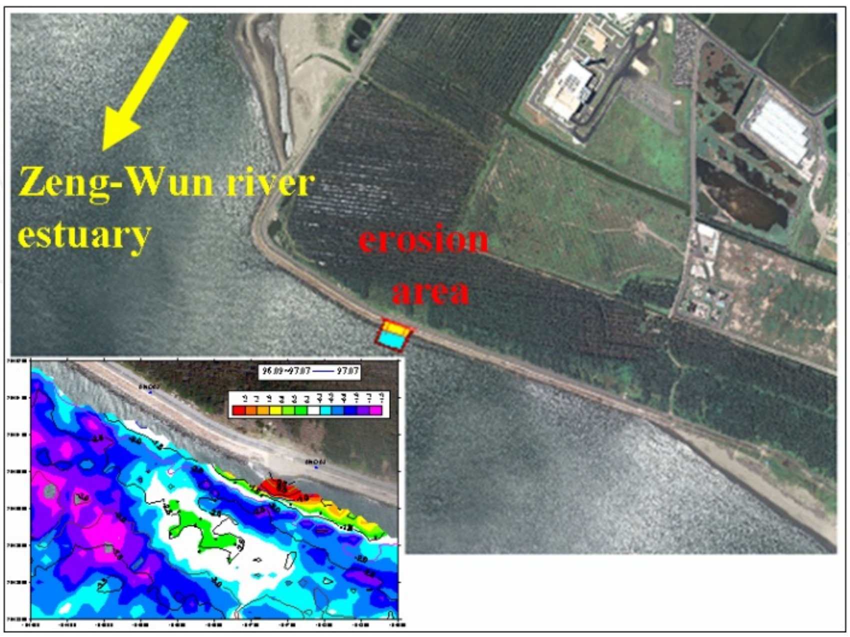


Figure 5. The erosion area in the Ching-Tsao-Lun coastline

The coastal area around Ching-Tsao-Lun pebble dike:

1. Apply "Vegetation Evolution Method" to enhance vegetation diversity and landscape.
2. Advance coastal management and use floating logs to enlighten the environment and coastal protection.

The natural beach zone:

1. Short-term goal: Build wind fence with planting to enhance the environment and landscape.
2. Long-term goal: Build artificial sand dune and increase dune elevation by using local floating logs, oyster cultch or dredged sedimentation form Lu-Erh-Men River.

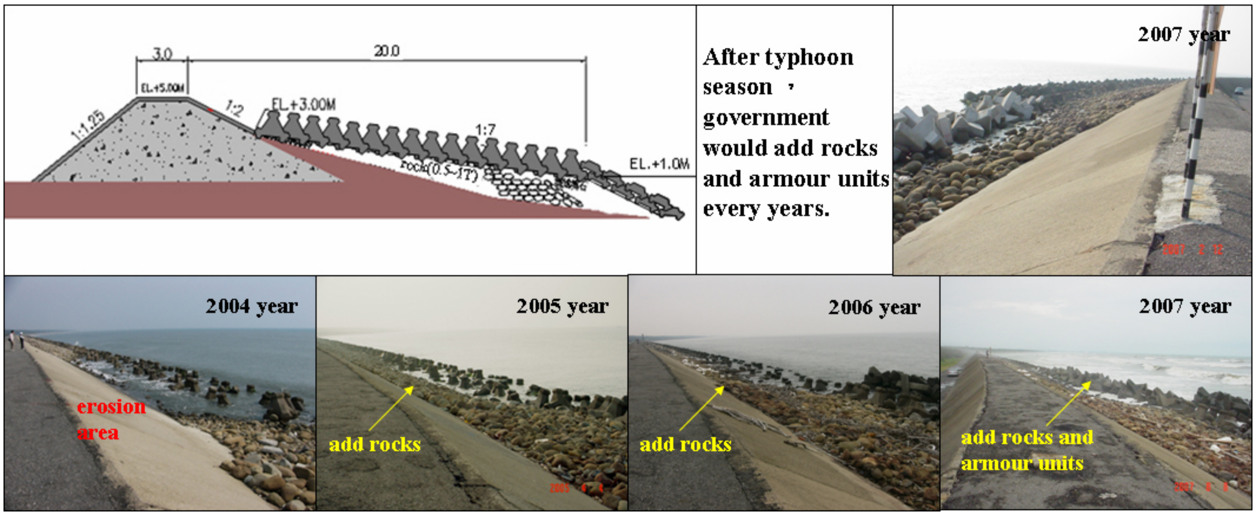


Figure 6. The erosion beach in front of Ching-Tsao-Lun concrete dike

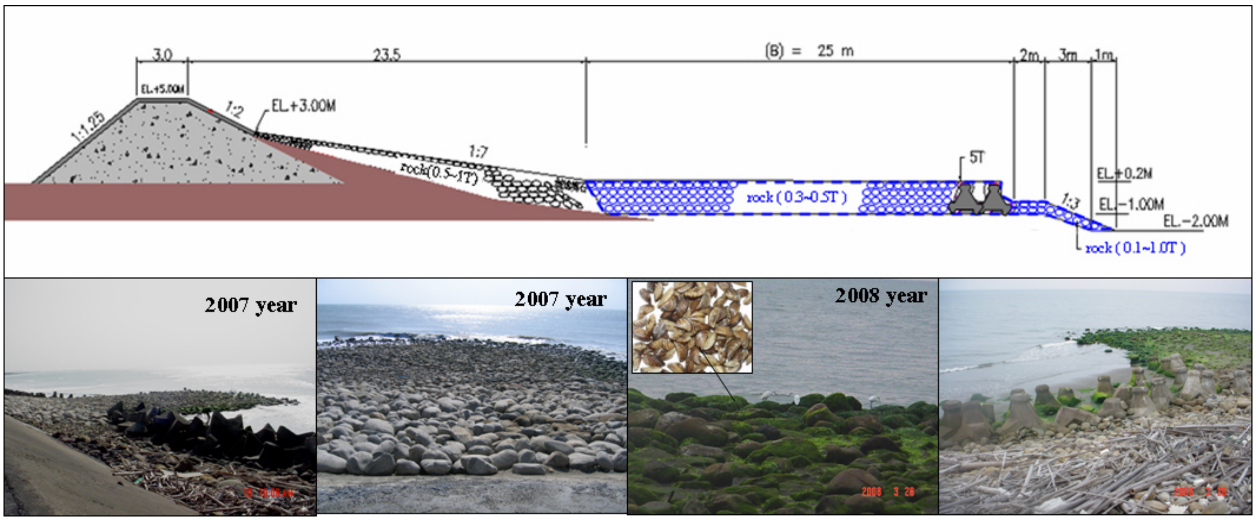


Figure 7. In-situ study on beach erosion control in the Ching-Tsao-Lun area

5.2. Shuang-Chun coastal area

With a beautiful sight and a mangrove ecosystem preservation area, Shuang-Chun coastal area (Figure 8) locates between Ba-Jhang River mouth and Ji-Shuei River mouth at the northern section of Tainan coast. Historical evolution of the coastal morphology shows that one third of the Shuang-Chun coastline at northern section has revealed shoreline retreat problem in the recent years. It can be shown by the evolution of coastline, satellite photos and aerial photographs from 1993~2002 (Figure 9, Figure 10 and research reports by THL, 2004).

Figure 8. The location of Shuang-Chun coast between two river mouths

After analyzing the long term field investigation data, the hydrodynamic characteristics of Shuang-Chun coast are moderate wave energy coast and micro-tide condition. The dominant hydrodynamic characteristics (incoming wave climate, tidal range) and local morphological information are considered for the proposed countermeasure to control beach erosion. Based on parabolic bay orientation on equilibrium shape (Hsu & Evan, 1989), the final select countermeasure is show in Figure 11 and Figure 12. The design is to establish three offshore breakwaters with a southwest stretched breakwater as a down-coast artificial headland on the existing seawall of Ba-Jhang River mouth (Yang et al., 2004). All the new breakwaters are set up by geobags filled with sand from the northern deposited area of Ba-Jhang River mouth. Behind the shelter areas of three offshore breakwaters, oyster booth is used as wave energy dissipation and sand trapping. Meanwhile, the existing dune is reinforced by dune zone nourishment. Monitoring of this experimental application study has still been conducted from 2008~2012. The final results of this proposed countermeasure will be verified by measurements of hydrodynamics and topography, sand sampling and monitoring of geosystem and oyster booth for their function of anti-damage and suitably applied environment.

Figure 9. The satellite photos of Shuang-Chun coast from 1993~2002

Figure 10. The comparision of Shuang-Chun coastal morphology between 1993 and 2002

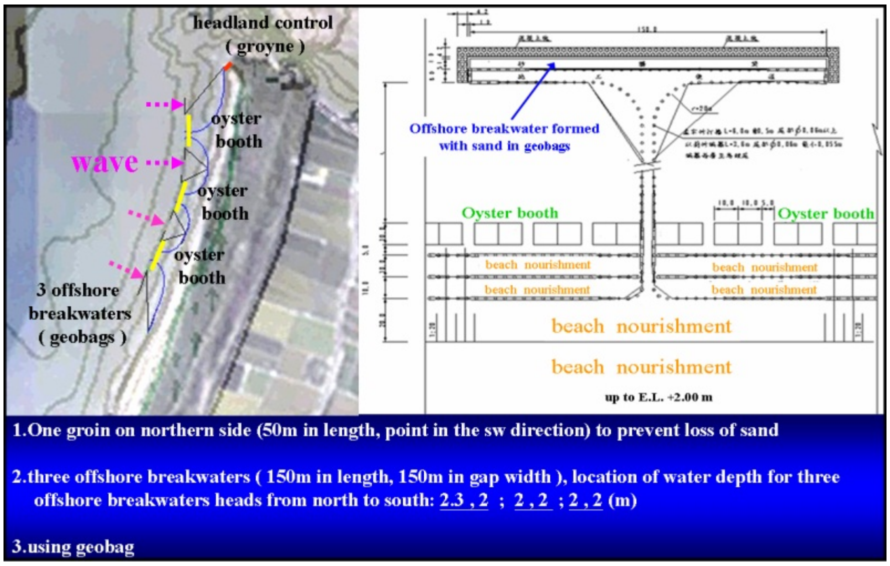


Figure 11. The final sketch of shore protection countermeasure for Shuang-Chun coastal area

Figure 12. Beach nourishment and geobag application in experimental study of the Shuang-Chun

5.3. Wai-San-Ding barrier island

Barrier islands as their name implies, they form a protective barrier between coastal shorelines and wave action that originates offshore. Barrier islands are also ecosystems that border coastal shorelines and physically separate the offshore oceanic province from inshore wetlands, bays and estuaries. Coastlines fronted by barrier islands also include some of the greatest concentrations of human populations and accompanying anthropogenic development in the word. The native vegetation and geological stability of these ecosystems are coupled and vulnerable to erosion events, particularly when also disturbed by development.

The Wai-San-Ding barrier island (Figure 13), protruding at about a forty-five-degree angle from the natural trend of the mainland shoreline at the mouth of the Peigang Shi River, is the largest remaining barrier island off the Taiwan coast. The overall length of this barrier is twenty kilometers, and her area is around two-thousand hectares during the Mean Water Level (M.W.L.). Much of the island shoreline is investigated to have been eroding at a rate of 50m~60m per year in recent years. Furthermore, this island holds some sort of "land speed" with continuing 0.2 degree/year counter-clockwise rotation to migrate southeastware to the mainland shoreline and gradual submerging into the sea. The Wai-San-Ding barrier island located on the southwestern Taiwan, is normally treated as natural offshore breakwater. In fact this biggest barrier island can form a defense line of low-lying coastal plains and back-barrier basin against storms attacking the southwestern coastal area in Taiwan. However, the erosion problem of the Wai-San-Ding barrier island has become more serious in the recent past. Therefore, how to protect this barrier island is always an important issue both from the consideration of coastal hazard and sustainable environment in Taiwan.

The objective of this experimental application study is to find the suitable measure for mitigating the existing erosion problem of the Wai-San-Ding barrier island. After collecting enough hydrodynamic and morphodynamic data from the long-term field investigation, the erosion mechanisms of the barrier island were analyzed in detail. Figure 14 shows that the time for this beach erosion to become apparently chiefly depends on how fast the rate of longshore sediment transport decreased from the up-coast area and on the river sediment supply. Meanwhile, run up mechanism under various waves, storm surge and overwash threshold on sand barrier during typhoon are also the important factors to be investigated. However, sufficient knowledge on nearshore hydrodynamic forcing, sediment transport processes and morphological features along this offshore barrier island, is helpful to the countermeasure control work. Based on the analysis of the erosion mechanisms, consideration of some measure options were proposed and firstly simulated by numerical model to find the two better solutions. Then two better applications (Figure 15) of the various soft methodologies available for the beach erosion control were proposed after numerical model analysis and further investigated by physical model test in the Near-shore Wave Basin (NSWB, 150x60x1.5m) at the Tainan

Hydraulics Laboratory (THL), National Cheng Kung University (NCKU), Tainan, Taiwan to validate their effect. The results showed that soft groins in the downstream and submerged artificial berms in the midstream are the effectively integrated measure to mitigate the continuing erosion problem of the Wai-San-Ding barrier island. Meanwhile, the plant evolution method and oyster cultch with aquatic vegetation were also proposed to apply in mitigation of wind sand transport and stabilization of sand dune. In order to protect this offshore barrier island, the more detailed field investigations on sediment supply (source and sinks), hydrodynamic forces (waves, tides and rate of sea level change) and geomorphic setting (shoreface profile shape, sub-strata composition) should be continuously conducted. Furthermore, the in-situ experimental study based on two proposed countermeasures is suggested to apply in improving the security as well as to involve ecological and scenic remediation for the erosion problem of Wai-San-Ding barrier island.

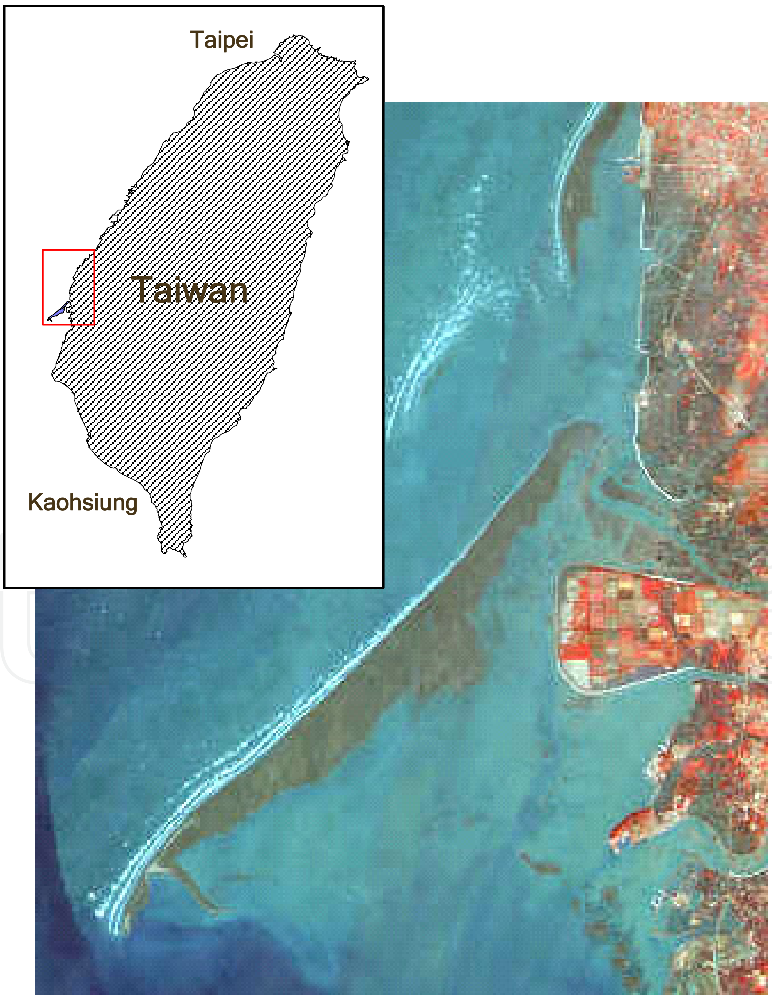


Figure 13. Studied area Wai-San-Ding Barrier Island image from satellite SPOT(2001)

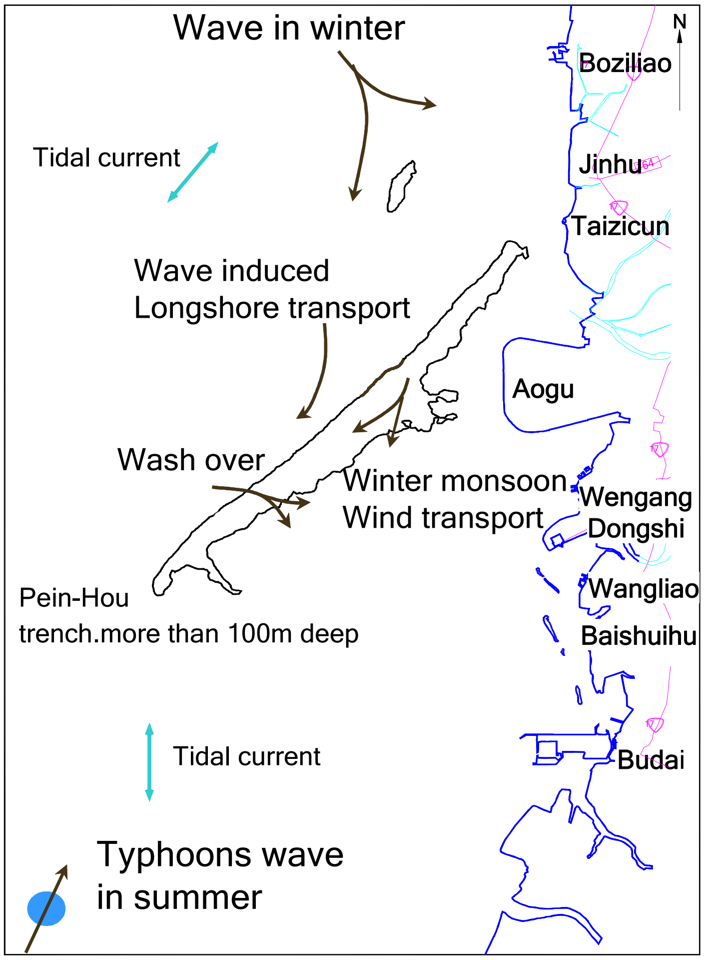
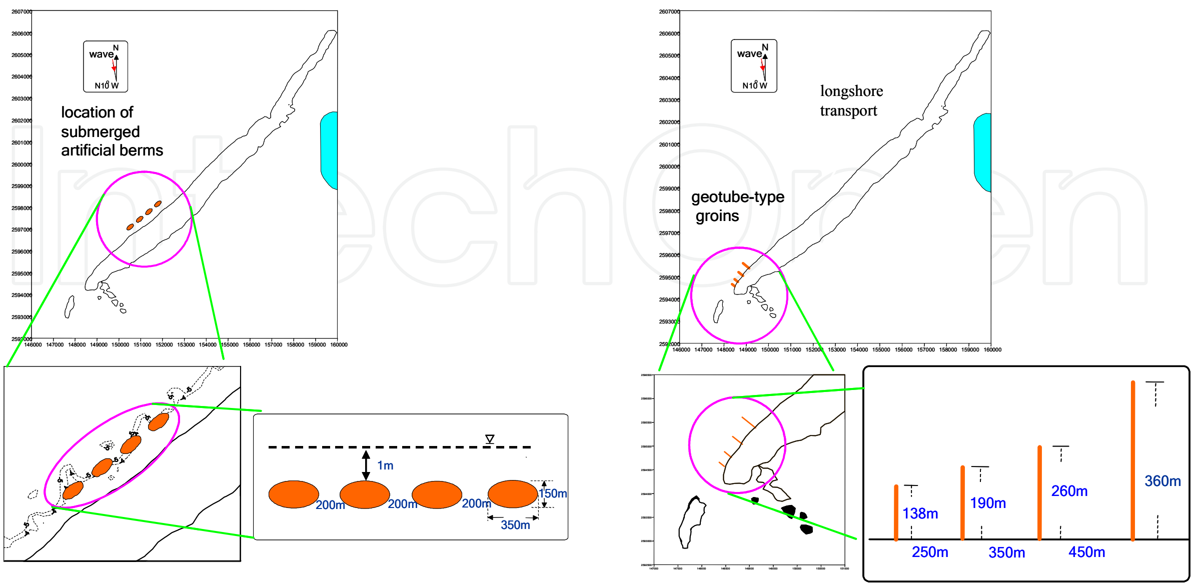


Figure 14. Hydrodynamic forcing characteristics, littoral sediment transport and morphology dynamics of the offshore barrier island



(a) submerged artificial berms

(b) soft groins used by geotube

Figure 15. Two better countermeasures for mitigation the erosion problem of Wai-San-Ding Barrier Island

6. Conclusion

The efficiency and productivity of the infrastructure facilities is strictly required nowadays owing to escalating fiscal deficit of the government. We have questioned ourselves about what the people in Taiwan expect on coastal protection work for the next decade; moreover, is it worth applying soft solution instead of keeping the previous reinforced concrete revetment under this tight budget condition? The objective of this study is therefore to present various soft solution strategies available for beach erosion control in the hope of providing better efficiency and cost-effectiveness as well. The results also reveal that the current shore protection system around Taiwan can be properly controlled by beach nourishment. However, the specific characteristics at each local site should be taken into consideration. Accordingly, we divide Taiwan coast into categories based on the collected information such as geological characteristics, hydrodynamics, and the intensity of beach erosion. The national beach management and protection problems will therefore be evaluated followed by the offering of resolutions for shore protection and further improvements. For the purpose of beach erosion management, we also have completed collecting and analyzing coastal data around Taiwan and constructed a database as well a geographic information system (see Figure 16) as reference. Related units of coastal management agency, in Taiwan, are permitted to log on to and use the system via the Worldwide Web with an authorized username and password. The actual locations and related information of the current shore protection constructions with suitable principle and countermeasure of the future beach erosion control around Taiwan can be obtained via this geographic information. It is helpful for future reference of beach erosion management for the governmental agency in charge of shoreline policies.

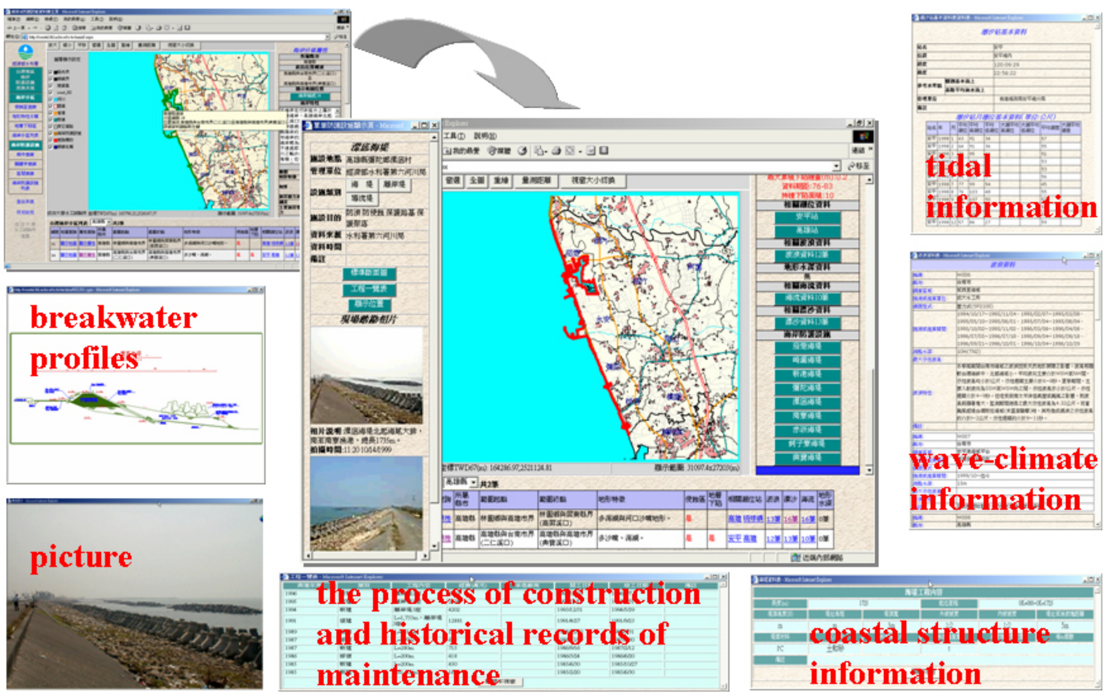


Figure 16. GIS information system of Taiwan coast

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Acknowledgement

The authors wish to acknowledge the generous support from Water Resources Agency, Ministry of Economic Affairs and National Science Council through the project "KUN–SHEN" of ANR (France) and NSC (Taiwan) joint funding initiative -- grant no. NSC-100-2923-E-006-001-MY3.

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