Coastal Dynamics and Shore Erosion in Songkhla

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Abstract
The survey of the Songkhla coastline since 2001 evidently reveals the loss of sand for the along-shore transport. Severe shore erosion adjacent to the engineering coastal structures has been found in several locations, especially, at Ban Bo Chon, Ban Na Thap, and Ban Bo It. Roads and houses have been undermined and washed into the sea. The coast is eroding at the accelerated rate of about 10 m/year. The most recent built T-breakwaters in 2002 at Ban Koa Seng cause the nearby stretch of the beach loosing about 20 m. For comprehensive understanding of the problem, the complexity of coastal dynamics including waves, water surface level, and bathymetry were investigated. The computed wave propagation patterns obtained from the Royal Thai Navy were analyzed. From that survey and backed up by years of field data collections at many locations, it is clear that the naturally shaped straight shoreline is the equilibrium between sand transport and temporally deposit at the beach. Obviously, such a coastline is remarkably sensitive to any disturbance along the coast.

Keywords: Shore erosion, Songkhla Beach, Coastal structure, Southern east coast, wave model

1. Introduction
1.1 Study area and wave-climate along the southern Gulf of Thailand’s coast
The study area is the 40 km stretch along the Gulf coast from Songkhla Port southeastwards to the village of Ban Sa Kom, at about 7° N in the humid tropics (Figure 1). The wave at the beach is generated by the northeastern winds from October-April, the stormy season. From May to September the southwest monsoon winds cause in general modest waves several miles offshore. Typhoons seldom strike this part of the coast directly. The coast is in essence a sandy beach with relatively low dunes. This sandy coast was until the 1970s fairly stable, with a net transport of sand towards the north. Consequently, the straight shoreline has been formed. Strong waves in the South China Sea may cause in stormy season local erosion in the study area, but during the southwest monsoon, the beach was previously restored rather quickly [1, 3]. One should understand that in the stormy season the beach profile is changed, with a lot of sand being moved seawards, forming temporarily longshore bar a couple of hundred meters off-shore.

Figure 1. Southern east coast of Thailand [3] from Songkhla to Nakorn Srithammarat and the study area

1.2 Sediment transport along the Songkhla Beach
Songkhla Beach consists mainly of quaternary alluvium deposits, namely sand and gravel, and of shells and silt. Between 1950-1977, there existed a significant sediment movement in the longshore...
direction. Due to shoaling difficulties at the channel’s mouth of the Songkhla Port, a training jetty of 640 m long was constructed in 1968 on the south side of the port and extended to 940 m in 1985 [6]. The jetty affected the longshore transport of sand in such a way that the beach south of it gained and moved seawards due to accretion. According to [5], the beach had moved seawards a rate of 2 m/year to 11 m/year, with the beach front at the jetty advancing more than 100 m in 1978 [13]. During the 1977-1990 period, the beach gradually stabilized, according to [14].

Erosion along Songkhla beach has been reported since 1995, with the beach retreating from 0.5-8 m/year [5]. During 1968-1989, the sandy beach south of Songkhla’s Ban Koa Seng was about 100 m broad, but then a rapid deterioration started. After constructing the pier for oil-tankers further south caused the beach to shrink to half its width in just 6 years, from 1989-1995 [4]. The most recent work has been documented by Rithphring (2002) [10]. The study indicates that engineering coastal structures causes severe erosion along the coastline.

The shoreline configuration developed adjacent to coastal structures can easily be described by Figure 2 [11]. The rate of downcoast erosion is approximately equal to the rate upcoast deposition. The shoreline will attempt to adjust so it parallel to the incoming wave crest positions as affected by refraction and diffraction. This is the same characteristics as Samila Beach where the rocks outcrop stabilize the coastal landform.

1.3 Hydrodynamics of coastal water

The Songkhla Beach is governed by tropical monsoons and by tides, which range about 0.6 m. The wave energy, predominantly, is generated from the northeasterly and easterly winds [7]. A study in 1993-94, the significant wave height from April to October did not exceed 1 m with wave periods of 3-4 s. In contrast, from November to March the wave height was typically some 1-3 m with the periods of 5-7 s. In the vicinity of the Songkhla Port, Ko Nu Island has strongly influenced on wave height reduction for incoming easterly and southwesterly waves [9].

The longshore sediment transport rate in the area north of Songkhla City is estimated to be about 200,000 m³/year [1]. During 1999-2000, isotope technique was employed to study sediment transport along the coast of the southern training jetty [8]. With an assumed depth of 0.15 m of sand layer, the net transport of 17,760 kg/m in the direction of 333° was estimated. A research conducted by McLaren, et. al [6] suggested that the southeast transport was dominant for 8 months of the year.

At Ban Sa Kom, pretty much accretion has been added to the beach behind the southern jetty which means that the sand is stopped completely at the jetty. The estimated longshore transport per year is around 360,000 m³ [4].

2. Research methodology

The research has the objective of identifying the shore erosion in the vicinity of the engineering coastal structures relating to the morphology of sandy coast. The coastline between the Songkhla Port and Ban Sa Kom has been visited since 2001 and the locals have been interviewed in order to gather the most recent information of the shoreline changes.

To comprehend the complexity of coastal dynamics and sand transport, wave propagation pattern in the Gulf of Thailand and field observations were analyzed. The waves forecasted by Department of Hydrographic, Royal Thai Navy, during 2001-2004 were used in the study. It is aimed at understanding the overall view of interaction between wave and the Songkhla shoreline. Detailed wave forecasting can be obtained from http://www.navy.mi.th/navymet/:

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The field observations were conducted in the vicinity area of the coastal structures to address the situation of the coastal erosion in Songkhla. The field data included wave, water surface level, coastal topography and bathymetry. The transaction lines of depth sounding at Ban Koa Seng and NICA were made during June-July 2003 using an echo sounder. The cross-shore beach profile along the pier at National Institute of Coastal Aquaculture (NICA) was investigated bi-weekly from October 2003 to November 2004. An automatic water level recorder (WAVELOG) was employed to measure nearshore wave and water level between June-November 2003.

3. Study results

3.1 Sea water level and wave characteristics

The measured water level and nearshore wave, at a distance of 170 m from the shoreline, at NICA are presented in Figure 3. As seen, the mean water level shows slowly rising from June to November. There
also exists the relationship between the wave height and the water level. As the mean water level rises, the wave height increases. In order to fully describe the sea level fluctuation in the area, the relevant water level at Ko Nu between 2001-2003 [2] predicted by the Royal Thai Navy (Figure 4) were compared with the observed. The result shows good agreement. As depicted in the figure 4, the mean water level is likely periodic with the lowest level between June and July, and the highest between December and January. The difference is approximately 55 cm which is important for coastal zone management and engineering design. The co-existence of the strong waves of the northeast monsoon and the high water level, the beach erosion can be expected from November to February.

Figure 3. Measured sea water level and wave height

Figure 4. Predicted tide and mean water level from 2001 to 2003

The first ever measurement of nearshore waves in Songkhla coastal water is shown in Figure 3. The measurement in 2003 indicates the sea was usually calm during the southwesterly winds between April and September. The average significant wave height ranged 0.1-0.2 m. In October, the prevailing easterly and southeasterly winds generated higher waves with the average significant wave height up to 0.45 m. To analyze the coastal dynamics in the area, the data were verified with the wave model obtained from the Royal Thai Navy. In average, the predictions fairly agreed with the observations. Unfortunately, there was no data available after October because the strong waves caused some problems with the instrument.

The development of the waves along Songkhla coastline can be simulated by the wave model. Based on the modeled results between 2001-04, the wave propagation in the Gulf of Thailand can be categorized into four patterns as shown in Figure 5. The dominance of westerly and southwesterly winds between May-July generate quite rather small waves propagating in the east and southeast direction (Figure 5a). There is no doubt that the sea at Songkhla is usually calm during the southwest monsoon season. Whereas from August to September, the stronger westerly wind cause the bigger wave field propagating in the southeast direction (Figure 5b). The beach is slowly accreted by the northward sediment transport and considerably stable.

On the other hand, during the northeast monsoon from October to April, the sea reaches its high state. The beach and shore erosion can then be pronounced. In Figure 5c, from October to December, the waves propagate between east and northeast direction approaching the coast of Songkhla at the angles varying between 55° and 90° to the shoreline. Subsequently, the sediment is being transported along shore to the south and normal to the shore. Meanwhile from January to March, the prevailing easterly winds associated with strong wave field in the South China Sea dominate the wave pattern in the Gulf of Thailand (Figure 5d). The waves approach eastwards of the Songkhla coastline with the angles between 55° and 65° causing the sediment transport along the shore towards the north.

Figure 5. Typical wave pattern in the Gulf of Thailand (Wave directions indicated by black arrow lines)

As far as the net northward longshore transport is concerned, the morphology sandy coast of Songkhla forms the unique straight smooth shoreline with narrow beaches. The evidences clearly identify that the coast is highly sensitive to any shoreline disturbances along the coast upstream from the beach under study. Experiences learned from the accretion and erosion around the rocks outcrop at Samila and Koa Seng evidently demonstrate the interruption of the along shore sediment transport.

3.2 Survey of shoreline changes

3.2.1 Survey at the north coast of Songkhla
Severe shore erosions have been found on the north beach of the breakwaters, at Ban Bo Chon, Ban Na Thap, Ban Bo It and Ban Kao Seng. At Ban Na Thap, the beach has been totally eroded and the road is undermined (Figure 6). Moreover, the impact has extensively spread downcoast to Ban Bo It undermining the road as well.

Figure 6. (a) Shoreline retreat caused by breakwaters and jetties at Ban Na Thap in May 2003 and (b) undermined road in January 2005.

Figure 7. Erosion at Ban Koa Seng in November 2002

There are evidences that a sewage pumping station built on the beach at Ban Koa Seng induced severe erosion to Songkhla municipal road (Figure 7). To stop sea eroding the seafront, in October 2002 the three T-shaped breakwaters were constructed at a distance 40 m from the shoreline. Such remedial measure has adverse impact on a nearby stretch of the beach. The beach of width approximately 20 m has totally lost.

Figure 8 presents the topography vicinity of the northern most breakwater at Ban Na Thap surveyed in 2003. As a result of constructing the jetties and breakwaters at Ban Na Thap in 1997, the shoreline has been rapidly eroded approximately 90 m. The problem has spread to Ban Bo It, situated at 2.3 km north of Ban Na Thap.

Similarly, at Ban Bo Chon (Figure 9) the coast has been lost to the sea approximately 60 m by the ashore breakwater since 1997. Here, the situation is critical because the shorefront is relatively steep. Once the overlying protecting layer has been lost, the shoreline easily collapses.

Figure 9. Shore erosion at Ban Bo Chon caused by an ashore breakwater

3.3 Beach profile and coastal bathymetry

The observed cross-shore beach profile at NICA during 2003-04 (Figure 10) reveals the complex dynamics of the beach zone. From November to February of the northeast monsoon, the sand was transported from the eroded beach face forming a sand bar at the distance around 90-110 m. As seen, dramatic changes of the beach profile was found in January. The comparatively steep beach face and the sand bar of about 1.5 m high were recorded.

Figure 10. Cross-shore beach profiles at NICA

For the southwest monsoon between March and October, the beach gradually built up. The beach slope decreased with gently dropping in the profile.
The observations also showed no significant changes of the beach profile. The field data clearly confirm the dynamic equilibrium of the coastal zone process. Noted that there existed sand accumulation around the piles at the end of the profiles. Further investigation is needed to identify spatial variation of the shoreline as described by Tanaka, et. al (2001) [12].

The sounding of bathymetry at Ban Koa Seng (Figure 11) unfolded the irregular seafloor resulted from the complex dynamic of the reflected waves at the breakwaters. Rolls of sand bar were found at the distance 100-300 m with the ruling depth of 2-3 m. Further that, the sandy seabed gently decreased till it reached the dead zone of sediment transport comprising mud and fine sand. The correspondent distance was range 500-600 m from the shoreline with associated ruling depth was 5.5-6 m. In contrast, the survey of the relevant nearby beaches, the north side of the breakwater and at NICA, showed the beach profiles receded smoothly to the dead zone.

4. Conclusions
Most researchs pertaining sediment transport along Songkhla coastline has been conducted surrounding the outlet of Songkhla Lake where the Songkhla Port is situated. To facilitate the Port, the first training jetty was built in 1968. Since then the coast has been disturbed and the along-shore sand transport process has been interrupted.

In the last ten years, groins, jetties and breakwaters have been constructed at all river mouths along the coast of Songkhla causing the severe erosion widespread. The engineering coastal structures pose a very complex hydrodynamic problem with strong interactive effects between the waves, currents and the structures. Information gathering from the field survey by years along the coast points out that erosion has been taken place the whole coastline and considerably critical. Houses have been washed into the sea at Ban Bo Chon, and roads have been undermined at Ban Na Thap, Ban Bo It and Ban Koa Seng. The problems announce adverse impact of human interference having on the coast, especially, adjacent to the coastal structures. The maximum shoreline retreat of 11 m/year has been observed.

The preliminary field measurements provide the basic information concerning the coastal process. The dead zone of sediment transport is located somewhere between 500-600 m from the shoreline where the seabed consists of mud and fine sand. The dramatic beach changes are from January to February as a result of the easterly and southeasterly winds. The beach then restores during the southwest monsoon from April to September and considerably stable.

Conclusively, the morphology sandy associated with the net northward transport of sand forms the straight shoreline of Songkhla, which indicates remarkable sensitive to the coastal disturbance. Experiencing the accretion and erosion around the rocks formation at Samila and Koa Seng clearly demonstrates the sensitivity to the shoreline disturbances. The coastal structures can absolutely cause severe erosion to the beach and coast. All this is going on in the last ten year without an integrated plan for coastal development.

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