INITIATIVES ON ENGINEERING SOLUTIONS FOR CUA TUNG AND THE NORTHERN BEACH OF THE ESTUARY IN QUANG TRI PROVINCE

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Abstract: *Cua Tung estuary is one of the largest estuaries of Quang Trị province in Central Vietnam. The beach here is beautiful and well-known for tourist in the past. But it has been eroded thus reducing tourist attraction. Cua Tung estuary serves as an important waterway, flushing out floodwater from Ben Hai river to the sea. The complexity of hydrodynamic regime in Cua Tung estuary and vicinity area is a main driver to cause high variation on erosion and sedimentation. Erosion occurs in the north beach area leading to reduction of open space for tourist, meanwhile deposition accumulates in the south beach area of the Cua Tung estuary. The paper provides some initiatives on engineering solutions for Cua Tung estuary area and rehabilitating measures in the northern tourism beach of the estuary.*

1. INTRODUCTION

The coastal strip from Cua Tung to Cua Viet estuaries, located in Vinh Linh and Gio Linh districts, plays an important role in the socio-economic development of Quang Tri province. These estuaries belong to Ben Hai and Thach Han rivers, respectively. They are ranked the two largest estuaries of the province, currently serving as the gateway for waterways and fishery boats. On this coastal strip, there are also beautiful beaches with potential for developing resorts such as Cua Tung, Trung Giang, Gio Hai, Cua Viet. Although some development projects have been established, this land is still a potential area that attracts infrastructure investment projects [1].

In recent years the coastline are being eroded causing the beach retreated significantly, especially the beach in the north of Cua Tung estuary, while the deposition is accumulated at Cua Tung estuary channel [2] and the beach in the south of the estuary. There have some construction works to stabilizing the channel at Cua Tung and Cua Viet estuary, but the effectiveness of these works is still limited. Jetties at Cua Viet estuary can prevent sand that deposits the waterway, however, the reduction of wave effect caused by the structures is not so high thus the channel route at the estuary is still varying. Jetties in the south and north sides of Cua Tung estuary can prevent most of the sand entering the estuary from longitudinal directions. But they can't stop the sand coming from the seaside by wave propagation and cause the deposition of the estuary. On the contrary, with sand deposition at Cua Tung estuary and on the southern beach, the beach in the north of the estuary has been lowering and eroding thus narrow down the beach for tourism [2].

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Some studies were carried out to find a stable solution for the northern beach and Cua Tung estuary [3], [4], but so far, the erosion is happening there and deposition remains at the estuary and on the southern beach. The paper will provide some initiatives on engineering solutions and rehabilitating options for Cua Tung estuary and the northern beach.

2. EXISTING CONSTRUCTIONS, COASTAL EROSION AND CHANNEL DEPOSITION AT CUA TUNG ESTUARY

2.1. Existing constructions at Cua Tung estuary

2.1.1. Revetment at Cua Tung beach

In 2009, Quang Tri province built a revetment system along Cua Tung beach with a length of 700m that comprises of 3 sections having the same reinforced concrete vertical wall structure. The revetment starts from a populated area (the rocky headland close to the mouth of the Ben Hai river), to the revetment of the marina (Figure 1). In November 2010, due to the impact of high tide, large waves caused subsidence and damages to 200 meters of the revetment, broke the asphalt road along the coast. In order to cope with the emergency situation, the Quang Tri province mobilized available resources to quickly overcome the consequences by pouring rocks to mend the damaged roads and arranging protection with Tetrapod concrete blocks [3]. However, due to the unreasonable design of these structures, they has certain effects on the beauty of the beach area, limiting tourism activities in the area.

Figure 1: Incident of bank and revetment wall erosion at Cua Tung beach in 2010

In 2011, Quang Tri province built a revetment of 487m length. Up to now, the work is still stable and functioning as a shore protection structure. The revetment has foot support with prestressed reinforced concrete piles; The revetment has an incline slope of 2.5:1.0 in the form of stairs made of M300 reinforced concrete on the base of geotextile filter bed TS65 or equivalent and 2 layers of crushed stone. Although the system of beach revetment works is still stable, the outer

beach is tended to gradually disappear due to lack of protection and the current revetment only protect from further erosion to the beach infrastructure.

2.1.2. Jetties at Cua Tung

2.1.2.1. Jetty in the south side of Cua Tung

The jetty was built in 2004, with the length of 430m, the height of 1.5m, the width of 6m with a structure made of stone and reinforcement stretching to the sea (Figure 2) for the purpose of breaking waves, blocking sand, reducing erosion of Tung Luat bridge piers and reducing deposition inside Cua Tung estuary to enable navigation and maritime for Cua Tung fishing port.

2.1.2.2.Jetty in the north side of Cua Tung

The northern jetty has a length of 150m stretching from Thua Luong cape (near the Border Guard station) to the sea and parallel to the jetty in the south side of Cua Tung. The northern jetty has a core structure made of poured stone with 3 layers of different sizes: The bottom layer in contact with natural soil is layer D4 with a thickness of 20cm, the size of stones is from 10-15cm. Next is the core of the rock dike D3 with the size of 10-30cm. The outer cover is a layer of 80cm thick D2 stone with the size of 40-50cm. On the top of the jetty there is a rock layer with 20cm thickness.

The top surface of the dike is 4m width, paved with 60cm thickness of M300 reinforced concrete slabs, around the roof and toe of the dike reinforced with 2 layers of Tetrapod T2 (2.5T) and T1 (4.2T).

Figure 2: Jettt at north and south sides of Cua Tung estuary

2.1.2.3. Cua Tung fishing port

Cua Tung fishing port was built in 2004, when the Quang Tri Department of Fisheries (now under the Quang Tri Department of Agriculture and Rural Development) implemented the project of storm shelter and fisheries logistics with the goal of providing anchorage, storm shelter, fisheries logistics and modernization of coastal fisheries production zones.

2.2. Coastal erosion and estuary deposition

2.2.1. Erosion in the northern beach of Cua Tung

In recent years, the northern beach of Cua Tung has been narrowed due to increasing erosion in both scale and intensity. From the hundreds of meters width of white-gray sand beach with a gentle slope, now the width is only about 20-30m and the slope of the beach has increased dramatically, thus reducing drastically the number of tourists coming to this beach (Figure 3).

Figure 3: Cua Tung beach before and present

2.2.2. Deposition in Cua Tung estuary

Historically, Cua Tung estuary has always tended to be deposited. The strong development of sand dunes on the south bank of the mouth moving to the north has greatly affected the ships and boats go in and out of the Cua Tung estuary (Figure 4). To improve that situation, a 350 m length southern jetty and a 150 m length north jetty of Cua Tung were built in 2001 and 2017, respectively in order to limit the accumulation of sand and mud into the waterway channel. However, up to now, the phenomenon of accretion in the mouth has been happening and increasing in recent years, causing a lot of damage to the fisheries and waterway sectors.

Figure 4: Deposition at Cua Tung estuary

3. CAUSES OF THE BATHYMETRY CHANGES AT CUA TUNG ESTUARY

3.1. Studies related to accretionary and erosion at Cua Tung estuary

Up to now, some studies on erosion and deposition at Cua Tung estuary have been carried out by organizations and individuals. They are including: 1) The University of Natural Sciences has performed 2 researches on erosion for Cua Tung estuary: Investigation and assessment of erosion at Tung estuary beach, Quang Tri province (2010) and; Additional research project on investigation and assessment of erosion at Cua Tung beach, Quang Tri province (2019); 2) Ha noi Water Resources University: Research and propose solutions to stabilize estuaries in the Central region (2010); Beach nourishment for central coast of VietNam, pilot for Cua Tung beach (2012). 3) Vietnam Academy for water resources: Studying the process of erosion and accretion in the coastal strip, estuary from Quang Binh to Thua Thien - Hue, considering the influence of impacts from upstream and proposing solutions to stabilize (2020). Consulting project on designing measures for Cua Tung coastal protection, emergency erosion treatment (2011). 4) Institute of Geography: Forecasting the phenomenon of coastal and estuarine erosion, accretion, and solutions to prevent it (2003-2005); and there are some others more research relating to Cua Tung. The above research results have given an overview of the evolution of the estuary and coast in the central region, the causes of beach erosion, estuarine accretion. Some studies have analyzed in detail the causes of Cua Tung beach erosion such as a study by the University of Natural Science in 2010, 2019. However, at present, Cua Tung beach still has problem: small beach width, beach is lowering level and the beach become unstable.

3.2. Causes of beach erosion and lowering due to the direct impact of large waves

The central coastal region has a wave regime directly affected by two monsoon systems: Northeast monsoon in winter and Southwest monsoon in summer. In the offshore, the wave direction is roughly the same as the wind direction of the two monsoon systems

mentioned above, but in the near shore due to the influence of seabed topography and shoreline morphology, the wave direction as well as the wave height have changes corresponding to latitude. Central coast is at deep-sea area, the slope of the shoreline is quite large, the 20m deep isoline close to the shore. Through many years statistical data at Con Co station near the study area, the wave characteristics shown that the wave regime here can be divided into two main seasons:

- In the winter: Sea waves have a prevailing direction in the NE, the average height is 0.8÷0.9m, especially in the first 3 months of winter, the average wave height is about 1.1÷1.2m, the largest is about 4. 0÷4.5 m.

- In the summer: The prevailing wave direction is SE, sometimes there are also waves in the NE and E direction. The average wave height is about 0.6÷0.7m, the maximum can reach 3.5m. From July to August, the prevailing wave direction T, TN dominate, the average height is about 0.7 m, the highest can reach 4m. Especially in the months of September and October, there are often active storms, so the height of the waves can be up to 6.0÷7.0m and can be higher (at Con Co station, the maximum wave is up to 9m).

3.3. Causes of northern beach erosion due to lack of sand and mud supply

The sand at northern Cua Tung beach was previously supplied by 2 sources: one source from the upstream north coast brought down in the northeast wave (NE), this sand source has yellow color, and coarse; an other source from the south coast raised in the southeast wave (SE), this source of sand has white color, and smooth [2]. However, after the construction of a jetty at southern bank of Cua Tung estuary, the beach in the northern bank was almost no longer supplied with sand from the south bank, leading to a shortage of sand (Figure 5).

Figure 5: Diagram illustrating the mechanism of sediment transport in Cua Tung beach area

Figure 6: Sand at Cua Tung beach before and after construction of jetty dike on the south bank (white fine sand on the left, yellow coarse sand on the right)

3.4. Sediment balance in CuaTung estuary area

A study by the University of Natural Sciences on the sediment balance at Tung estuary showed that the sand flow from the south bank to the north bank of Cua Tung estuary is dominant to the sand flow from the north bank to the south bank [2]. This result is also consistent with satellite observations on Google Earth software (Figure 7) and calculation results in research coded KC08.16/16-20 [5]. As captured by satellite images for the past years, it is found that the sand bar on the south bank encroached on the north bank to narrow the river mouth. After the construction a jetty at southern bank, this jetty prevented the flow of sand and mud supplying for the northern beach, thus the northern beach has been deficit in sand. One clear evident on sand transport from south to north direction is that the white sand color on the northern beach turned to yellow color due to the lack of white sand from south bank of Cua Tung estuary since building the southern jetty [2].

4. ORIENTATION FOR SOLUTION TO RESTORE CUA TUNG BEACH AND TO STABLE CUA TUNG ESTUARY

The general shoreline protection options of the Cua Tung estuary includes:

- Restore northern beach of Cua Tung, prevent erosion of the northern beach and create a landscape space for tourism and local socio-economic development.

- Preventing sand deposition/accretion at estuary entrance channel, ensuring flood drainage, and stabilizing the route for ships going in and out of Cua Tung estuary.

Basis for the proposed solutions:

- Based on the causes of beach lowering level, hydrodynamic factors (waves, currents) and sediment transport in the area to orient solutions to prevent accretion of estuary channel route and to rehabilitate beach.
- Based on the current topography of the beach area and shoreline at the present time
- Based on the current state of existing works and infrastructure, practical experiences and lessons in researching, consulting, construction, and management of coastal beach protection works in the Central region.

For the northern tourism beach of Cua Tung:

- The beach has been eroded and lowered level due to high wave, current and lack of sand sources supply. To restore the beach, it is necessary to provide additional sand sources by beach nourishment combined with offshore wave reduction works. Due to the requirements of tourism, the reasonable works should be submerged breakwaters. Structural solutions should reduce effectively waves however they have to be stable and convenient for construction, maintenance, and management. In addition, it is necessary to periodically nourish sand to compensate for the sand loss at the northern beach. Sand sources can be from the south bank of Cua Tung.
- Revetment and coastal infrastructure: Currently, there are revetment works which are stably along the current alignment and suitable for this coastal area.

For stable waterway channel and flood drainage route:

With the characteristics of the estuaries in the Vietnam central coast which have sand bars blocking the river mouth and a huge amount of long-shore sediment transport. To facilitate the flood drainage, waterway and fishing boats, 2 jetties on the north and south bank of Cua Tung were built to limit the sedimentation of the estuary, however, the waves from east and northeast directions still directly propagate inside into the mouth, bringing large amount of mud and sand from the sea to accreting the entrance channel, extending through the fishing port to the upstream of the storm shelter area. Requirements for exploitation of Cua Tung estuary and vicinity coast are as follows:

- Ensuring flood drainage in flood season of Ben Hai river basin.
- Preventing sedimentation in estuary entrance channel to maintain waterway for ships

entering the fishing port and the anchorage shelters.
- Overall solution for flood drainage, navigation in estuary combined with embellishing the north beach to serve tourism and socio-economic development.

With the above requirements, it is necessary to adjust the jetties at 2 sides of estuary (it is possible to lengthen or shorten the jetties, change jetties direction to prevent wave propagation to upstream of estuary) to limit the accretion of the navigation channel in the estuary, protect the northern beach from erosion.

On the basis of the above analysis, proposed overall solution orientation includes:

- Building a system of breakwaters to reduce waves in combination with beach nourishment to restore and embellish the northern beach of Cua Tung.
- Lengthen the northern jetty and narrow the gap width between the 2 jetties to limit waves and mud entering from sides into the estuary;
- Periodically nourish sand to northern beach of Cua Tung in order to prevent sand loss. Sand source for nourishment can be taken from south side of Cua Tung.

Figure 7: Accumulation at southern beach of Cua Tung from 2010 to 2020

Figure 8: Orientation of the overall engineering solution of Tung estuary

4.1. Analysis of breakwater measure to reduce waves and to stabilize the beach

Design conditions

- Based on collected data (the map and topographical survey of the area in 2015). - Breakwaters roughly estimate of grade IV works, with design frequency of p = 3.33%.

According to TCVN 9901:2014, the following preliminary design boundary conditions parameters are determined: - Design water level ztk = +1.51m ; - Deep wave high H = 10.37m; - Wave period: T = 12.27s; - On the basis of determining the layout of breakwater, determine the following parameters of the layout of the TCVN 9901:2014 route: - Distance from the shore about X = 250m; - Waves high at the construction toe Hs = 3.2m.

Comparison between breakwater structures

It is expected that the structure of breakwater include: 1) Breakwater with sloped roof and Tetrapod protection layer (Figure 9) and 2) Breakwater with the sloped roof combine with the hollow pillar dike (Figure 10).

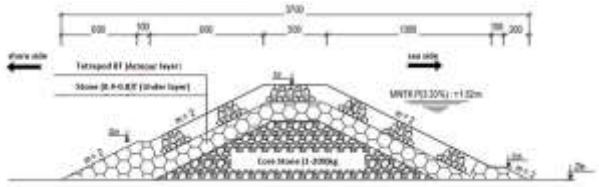

Figure 9: Typical cross-section of the sloped roof breakwater with Tetrapod protection layer

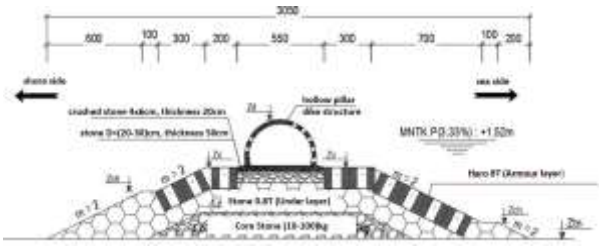

Figure 10: Typical cross-section of the sloped roof breakwater with Haro protection layer, combined with hollow pillar dike

Based on analyzing the advantages and disadvantages of each solution, it can be preliminary shown that the solution of "Breakwater with sloped roof, combined with hollow pillar dike" has more advantages, thus this solution is recommended to choose for the northen beach of Cua Tung estuary and need to study in detail in next stages.

Table 1: Comparison and evaluation about breakwaters

Content	Breakwater with sloped roof with Haro protection	Breakwater with sloped roof, combined with hollow pillar dike
Materials uses	Mixed stone and precast concrete with high strength	Mixed stone and precast concrete with high strength
Cross section area and stability	Ensure stability, high settlement due to large embankment block	Ensure stability, reduce subsidence
Beach accretion ability	Good	Good
Flexibility ability	Difficult to move to another area	Easy to move to another area

4.2. Propose measures to improve Cua Tung estuary

With existed jetties on the north and south banks of Cua Tung estuary and condition of accretion in the estuary, these jetties have partly promoted its technical efficiency in limiting accretion to the estuary navigation channel for years. In order to reduce estuary sedimentation to serve flood drainage, maintain navigation channel, restore and stabilize northern beach of Cua Tung, it is necessary to improve the system of constructions with research intensions: prolong jetty at northern side, adjust length jetty at southern side of Cua Tung estuary. To rehabilitate the northern beach, sand nourishment combine with the far shore breakwaters can be a proper solution. These solutions can be implemented basing on the existing conditions of construction structures provided that technical and economic requirements has to be meet.

Further studies are needed to look on the overall spatial and structural layout of the cluster of estuary works, the works to rehabilitate and stabilize the northern beach under the influences of hydrodynamic and sediment transport factors in seasonal weather conditions as well as in extreme weather conditions (large floods, storms, combination of high tides and storm surges). Reliable tools should be used for research such as topographical and hydrological survey, mathematical modeling, and physical modeling experiments.

CONCLUSION

With the above analysis, the article has oriented an overall solutions for Cua Tung estuary area to serve multiple purposes, with particular focus on the goal of rehabilitating and stabilizing the northern beach. The causes of beach lowering level and coastal erosion in

the northern beach area are mainly due to the resonance of high waves and currents in this area, combination with shortage of sediment sources to feeding the northern beach. The predominant direction of sand moving from the south to the north in this area, therefore beach nourishment solution should be an appropriate solution to restore northern beach of Cua Tung estuary. To minimize the phenomenon of lowering the beach level, it is necessary to have a solution to raise the beach level in combination with wave-reducing works (submerged breakwaters can be used). The structural plan of the breakwaters have been preliminary introduced but the parameters should be studied in detail, especially the spatial arrangement of the wave-damping system with 2 jetties to prevent sand from both site of Cua Tung estuary.

The problem of sediment transport and morphological changes of river, estuary and coastal geomorphology is still a difficult problem in both theory and practice. Therefore, in order to fully and objectively assess the phenomenon, it is necessary to have more detailed observations and additional studies to understand the hydrodynamics and sediment transport problem in the area to facilitate scientifically determining the parameters of spatial layout and structures of the overall system of estuary works.

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