Case study: Impacts of improper structure design on beach erosion and propositional measures for Cua Tung beach in Central Vietnam

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Cua Tung river mouth and adjacent beaches are located in Central Vietnam, where wave-induced currents and wind-driven currents are dominated. A bridge far from river mouth 400m and a port for fishing boats were built, at the same time a groin of 350m in length was constructed next to the river mouth with the aim to protect the port and nearby bridge. Due to improperly design, the groin has caused some bad effects as deposition in navigation line and beach erosion in nearby area.

A two-dimensional hydrodynamic model, MIKE 21, was used to assess the impacts of structure system (bridge, groin and port) on the morphological changes in Cua Tung river mouth and adjacent beach. Field surveys were conducted in order to investigate the bathymetric and hydrodynamic conditions of the region as well as to collect the data to calibrate and verify the model. The model used a flexible mesh formulation based on unstructured triangular elements with high resolution grid in near shore and around structure area. The model was well calibrated and verified with the field survey data. Then the model was used to simulate the local deposition and erosion processes in case of with- and without the presence of groin as well as to estimate the effects of some proposed solutions to improve the current situation.

1. Motivation

Erosion and deposition processes along the coastal line of Vietnam and their serious impacts on the social-economical development of coastal communities are the challenges of local authorities and scientists (Huy D. V., 1999; Haglund M. and Svensson P., 2002; To D. V., 2006; Phai V. V., 2007; Hanh P.T.T and Furukawa M., 2007; Boateng I., 2009;...). These phenomena are severely exacerbated in Central Vietnam where the coastline is directly prone to the open sea and frequently hit by typhoons and high waves during monsoons. In order to develop economy in these regions and to mitigate the negative effects of these processes, there are some protection structures designed and constructed such as harbors and ports, resident areas, tourist resort beaches or transportation infrastructures. The structures are obviously influencing on the hydrodynamic regime and therefore the local morphology (...). The reported events shown that, due to the improper designs, the structures may have negative impacts on the geohydrodynamic fields and require additional measures to improve the situation. Cua Tung beach is one of these kinds.

Cua Tung river mouth and adjacent beaches are located at the end of Ben Hai river in Quang Tri province, Central Vietnam (see Fig. 1). Ben Hai river is 64.5km in length from Truong Son mountain (between Vietnam and Laos) to the South China
Sea. Being mainly covered with good vegetation, the total area of the Ben Hai river catchment is about 906 km$^2$, therefore suspended sediment concentration in the river is not so high and there mostly are silt and clay and only significant during the flood season. The region is in low tidal range (0.5-0.8m) but prone to high wave from the sea (Tab.1).

The region is also affected by river flow during flood season (September to December), which also the season of typhoons.

The sediment transport is predominately alongshore in comparison with river sediment transport. The estuary of Ben Hai river is meandering with a narrow funnel shape. The estuary mouth has the main characteristics of the river mouth in Central Vietnam which are shallow (3~5m) and mainly confined by the sand bars and sand spits.

![Image](image)

**Figure 1.** Location of Cua Tung river mouth and nearby region, Central of Vietnam

In 2003, the local authority decided to build a small harbor for fishing boats and to dredge to maintain navigation channel annually. The bridge was then constructed in 2004 just at the river mouth to stimulate the economics activities in the region. In order to protect the bridge abutment and reduce the volume of annual dredging, in 2005 a groin was built with length of 350m in the south cape of the river mouth (see Fig. 2). Next to the river mouth, there are very beautiful beaches that attracting a lot of tourists. After building the groin, the sediment began to accumulate in its south side and at the same time the north part of Cua Tung beach is severely eroded. **Crowded beach becomes a desert beach** (see Fig. 3).
The objective of this study is therefore to examine the impacts of current structure system at Cua Tung on the sediment transport processes and morphological evolution in the region nearby, then to propose the proper measures. For this case study, it requires the field investigation and applying of mathematical modeling.

**Figure 2.** Description of structure system in study area

**Figure 3.** Cua Tung beach behaviors

a) Crowded beach (before)  
b) Desert beach (now)

2. Sediment transport analysis based on field investigations and available data
The 1st field survey in Ben Hai river, Cua Tung river mouth and the nearby open sea was carried out in August, 2009, covering both spring and neap tide. Bathymetry of the study area (2km x 10km) for the region of coastal sea and 5 km of Ben Hai river was surveyed using echo sounder linking with DGPS equipment attached on the boat (Fig. 5a). The bed elevation was then extracted from the surveyed water depth in linking with the water surface level of a station in the harbor. The samples of the bed sediment were also collected during the survey (Fig. 5b).

Figure 5a. Layout of bathymetry survey
Figure 5b. Sediment sampling locations

Four fixed stations were setup in the study area to observe hydrodynamic data including current velocity, water level, wave and suspended concentration etc. (see Fig. 5). Wave and flow velocity were measured continuously at offshore station (B1 in Fig. 5) using the acoustic wave and current system (AWACS). Water depth was also measured at station K1 in surf zone (500 m far from shoreline) using OBS3+ and tidal levels were observed at station K2 in the harbor. The river discharge was observed at Hien Luong bridge (S1), about 11km upstream of the river mouth, in order to provide boundary data for modeling.
The second survey was conducted in end of April 2010 repeating the previous method and location in order to investigate the change of bed elevation after a winter season as well as to collect the sedimentation and flow data for modeling calibration and verification in the following steps.

Example result of wave observations are shown in Fig. 6 and the statistical characteristics of collected wave data at Con Co island (about 30km far to the sea from Cua Tung) are presented in Table 1.

**Table 1.** Wave characteristics at Con Co (island) station

<table>
<thead>
<tr>
<th>Wave interval (m)</th>
<th>Wave direction</th>
<th>Calm</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>NE</td>
<td>E</td>
</tr>
<tr>
<td>Calm</td>
<td>16.0</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>.25-.99</td>
<td>3.1</td>
<td>4.9</td>
<td>13.4</td>
</tr>
<tr>
<td>1.0-.2.49</td>
<td>11.0</td>
<td>3.5</td>
<td>2.9</td>
</tr>
<tr>
<td>2.5-3.99</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.0-.5.99</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6.0-6.99</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7.0-8.99</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>&gt;9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>15.1</td>
<td>8.5</td>
<td>16.3</td>
</tr>
<tr>
<td>Hmean (m)</td>
<td>1.4</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>-----------</td>
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<td>-----</td>
</tr>
<tr>
<td>Hmax(m)</td>
<td>3.0</td>
<td>2.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Fig. 7 shows the monthly wave roses in Con Co (deep water, 34 km far from the shore) and Cua Tung (shallow water). According to these roses, E wave direction is dominated from September to March, and SE direction is dominated from April to August.
From the investigations, the concentration of suspended sediment is about 20-30 mg/l in the Ben Hai river, and 30-50 mg/l in coastal areas. The sediment median grain size $d_{50} = 0.27$ mm and $\sigma = 1.4$ are approximately estimated. Based on the wave climate, one can consider the sediment balance as shown in Fig. 8.

Also, the sediment transport mechanism can be shown as: due to E and SE waves, longshore currents bring fine white sand from the south to the beach, due to
NE waves, longshore currents bring coarse yellow sand from the north to the south (Fig. 9) while sediment from the Ben Hai river is negligible.

![Figure 9. Proposed sediment transport mechanism](image)

### 3. Model setup

#### General introduction

The MIKE of Danish Hydraulic Institute (DHI) is one of the most well known, user-friendly and professional tools for studying many aspects of marine hydrodynamics and environment. MIKE21 is a comprehensive modeling system for simulation of hydraulics and related phenomena in estuaries, coastal water and seas (Vaselali and Azarmsa, 2009).

The results described in this study were from MIKE 21 modeling system. The hydrodynamic module (MIKE 21 HD) is the basic module that calculates the depth-averaged hydrodynamic conditions in the area (Rasmussen et al., 1999). Basic output from the model is water fluxes between grid points from which depth averaged current velocities and directions can be derived. Radiation stress changes caused waves breaking were calculated using the Near-shore Spectral Waves module (MIKE 21 NSW) in order to generate of longshore currents by HD module. The Sand Transport module (MIKE 21 ST) is the non-cohesive sediment transport one that...
calculates the rates of non-cohesive sediment (sand) transport for both pure current and combined wave and current situations making the bed elevation changes.

Since all of the model have been widely used (Carević et al, 2009; Vaselali and Azarmsa, 2009; Strauss et al, 2007; Jose and Stone, 2006; Abbaspour, 2005) therefore the description for each model will not be given in this paper.

![Figure 10. Domain and mesh used in calculation](image1)

**Figure 10.** Domain and mesh used in calculation

*Domain and grid*

The modeling system used in this study consists of two domains: the large one with coarse mesh extending from the shore to Con Co island, where the wave observed data available, and the detailed domain with fine-mesh covering the Cua Tung beach, Ben Hai river and adjacent beaches (Fig. 10). The calculations are implemented in flexible mesh for wave propagation and current as well.

*Boundary data, inputs and model validation*

For the current calculation, tidal levels in the sea sides and water levels at Hien Luong bridge are used as boundary conditions. For wave calculation, wave height, period and direction are used at the offshore side, both of lateral sides use symmetrical conditions. The calculations were implemented using MIKE21-FM model. In modeling, radiation stresses of wave of N, NE, E and SE are included. Then the hydrodynamic fields were used for bed change modeling.

The field survey data were used for model validation. Although the model showed the better agreement between calculated and observed data for water level (Fig. 11) than for velocity (Fig. 12), the trend of water level and current velocity changes at K1 station in surf zone were satisfactorily simulated. Therefore the model
could be used as a tool to assess the impacts of structure on hydrodynamic field in the study area.

![Comparison of current velocity at K1 station](image)

**Figure 12.** Comparison of current velocity at K1 station

### 4. Impacts of existing structures

Cua Tung shoreline is almost parallel with longitudinal direction (Fig. 2) so it is affected significantly by waves in NE, E and SE directions. Before building the bridge, fish port and the groin, the morphology was almost stable (in balance) in study area. But since 2005 with the presence of these structures, Cua Tung beach (north side of groin) became to be eroded and sediment tend to concentrate in the south side. Since the bridge is far from the river mouth and the fish port seems not to affect so much on Cua Tung shoreline, therefore this study focuses on the impacts of the groin by analyzing two situations: with groin (present situation) and without groin (past situation) under some significant scenarios of currents and waves. The results of simulation are shown in Fig. 13 to Fig.21.

With the presence of the groin both wave field and wave-induced current field have been changed significantly in the region around groin, then it might cause some differences in bed elevation changes. These impacts could be shown clearly in Fig. 14, 17 and Fig. 20, where the flow tends to interact with groin in the southern side of river mouth in comparison with the case of without groin. This effect might be taken in account for the deposition of navigation line, which contrary with original purpose of groin of reducing dredging works.
Figure 13. NE wave field in study area (left: without groin and right: with groin)

Figure 14. Current pattern in study area induced by NE wave (left: without groin and right: with groin)

Figure 15. Bed elevation changes in study area under NE wave scenario
The similar phenomena also could be seen in Fig. 15, 18 and Fig. 21. Due to the presence of the groin, longshore current tends to be pushed from the shoreline resulting in less sediment reaching to the north beach of river mouth. In one aspect, it is useful for navigation line by cutting the sediment source for deposition within the river mouth, but in other, it also breaks the balance of sediment load in the north beach causing erosion there.

**Figure 16.** E wave field in study area (left: without groin and right: with groin)

**Figure 17.** Current pattern in study area induced by E wave (left: without groin and right: with groin)
**Figure 18.** Bed elevation changes in study area under E wave scenario
*(left: without groin and right: with groin)*

**Figure 19.** SE wave field in study area *(left: without groin and right: with groin)*
Figure 20. Current pattern in study area induced by SE wave
(left: without groin and right: with groin)

Figure 21. Bed elevation changes in study area under SE wave scenario
(left: without groin and right: with groin)

Discussion

As mentioned above, Cua Tung beach is exposure to South China Sea and situated nearby the Ben Hai river, so it is strongly affected by the river flow, tide and wave, in which the wave characteristics seem to be the most important factors. The beach morphology was balanced before the building of fish port, bridge and the groin. Among the structures, the groin has the bad impacts: deposition in south and erosion in north side.
At the first look, we can see that the groin affects too much on current and wave patterns. With the present of the groin, currents are pushed offshore and the wave characteristics are somewhat different. The sediment from the south needs to bypass to reach to the north. It may be the reason of accumulation of sand in the south side of the groin. The bed change calculations also show the differences in sand bar formulation under the impact of the groin, especially near the groin. Applying CERC formula to calculate sediment transport across typical section at Cua Tung beach, one can find the value of 37784 m3/s transported by 33% wave in a year (NE, E and SE directions).

![Figure 22. Shoreline evolution without existing groin](image1.png)  ![Figure 23. Shoreline evolution existing groin](image2.png)

To look more detailed into the impacts of the groin on the change of shoreline, the LITPACK model was applied with the inputs of hydrodynamic conditions extracted from above simulation (MIKE 21) using four common modules including STP, DRIF, LITLINE and LITPPROF. The results show that without the presence of the groin, sand is deposited in Cua Tung beach and Ben Hai river mouth but erosion occurs in the northern coast line of Cua Tung beach (Fig. 22). The simulation with the groin shows that (Fig. 23) the groin already hold back the send from southward but due to the northeast wave in winter, the send also is moved from the beach into the harbor thus it needs a lot of dredging works to maintain navigation line at river mouth for the fishing harbor (as at present). Therefore, it implies that the groin has great contribution to break down the sediment balance in the region consequently creates Cua Tung beach erosion and could not protect sand coming into the navigation line. These impacts are dominant causes comparing to the impacts of bridge and harbor.

5. Proposal of rehabilitation

From the point of view that any measure must improve the situation: to restore Cua Tung beach and not to destroy build structures, the selection is to build a new groin in the noth side of the estuary. The new groin will store the sand
transported from the north for recovering the beach and will protect sand intrusion into navigation channel.

Based on the present situation in Cua Tung region as well as in consulting with local stakeholders, the objectives of the proper works are to try to recover the sand beach at Cua Tung in the context of minimizing intervention to the existing structures. Therefore, four main resolutions were proposed and tested within this study including: a) to construct the new groin in northern side of river mouth; b) to construct a new groin in northern side concurrently with removing 50% length of existing groin; and d) to implement c) with building the detached breakwaters. In order to assess the impacts and effectiveness of each solution, the same LITPACK’s modules as above were also applied.

In the solution a), the northern groin was supposed to be parallel with the existing one, with total length from abutment of 100m which has the role to block sand in the beach coming directly to the navigation line, therefore it would protect the beach erosion and also avoid the dredging works for navigation line in river mouth. The right position will be determined exactly in future design stage, but it must not to be close to existing groin since it might limit the flood passage of Ben Hai river, but it also must not too far to the North because it might limit the space for entertainment of Cua Tung beach. Preliminarily, it should be located in the cape of bazan rock right at the southern end of Cua Tung beach. The effect of this solution could be seen in Fig. 18 with the deposition processes in outer side of two groins and very few sand coming to the harbor.

The solution of removing a half of existing groin (solution b)) was proposed under the pressure from local stakeholders, but simulation results (Fig. 25) do not present any significant change comparing to solution a).
The detached breakwater is the common measure in protecting the coastline especially the submerged breakwater in the tourist beaches and resorts, and its impacts of this solution c) in our case could be seen in Fig. 26 that, the shoreline at Cua Tung beach is coming toward the sea faster. However, this solution is often a bit expensive in the context of local economy.

Figure 26. Shoreline in case of two groins and detached breakwaters

6. Summary and conclusion

This study showed that, the improperly designed coastal structure might lead to the negative impacts to the local morphology and socio-economic activities. In case of Cua Tung beach, the existing groin lost its designed function in blocking the sand coming to navigation line neither creating more serious problem of adjacent beach, therefore the rehabilitation works are needed. Some solutions were proposed in the context of local economic conditions as well as minimizing intervention to the existing structures. Among them solution of constructing the new groin at the south end of eroded beach seems to be the most effective measure.

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Reference


