インドネシア、アチェ川河口周辺の海浜流解析
Near-shore current analysis around Krueng Aceh river mouth, Indonesia

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Abstracts

The construction of the floodway of Krueng Aceh river mouth in Indonesia decreases the discharge of the river leading to develop a sand spit at the mouth. The sand spit in turn causes river mouth clogging and troubles in navigation. Nearshore current field near the mouth has complex distribution due to complexity of the topography near the mouth. In this paper, the wave deformation and near-shore current to evaluate sedimentation near the mouth was analyzed by means of data-collection, interview and field reconnaissance.

Keywords: river mouth, sand spit, longshore current, and flood way

1. Introduction

The Krueng Aceh river in Indonesia, having a catchment area of 1,775 km^2 runs through Banda Aceh City and pours into Malaca Straits as shown in Fig. 1. At the deep sea at a distance about 15 km or more from the mouth, there are several islands, among others are Weh Islands in the north side and Deudap Islands in the west-side off the mouth. These islands shelter the river mouth from wave impinging which propagate from north direction. Fishermen used Krueng Aceh river mouth as a navigation route. The 5 years return period flood is about 1,300 m^3/s. Owing to the flooding problems in the catchment the floodway was constructed in 1992 to divert the river out of the estuary. The construction of the floodway decreases 70 % of the flood discharge of the river leading to develop a sand spit at the mouth. The sand spit are formed under the combined influence of riverine and marine factor. The sand spit in turn causes river mouth clogging and troubles in navigation. Fishermen who always navigated in and out off the mouth easily, now cannot do that again as easy as in the past, since diversion has lost navigability for small craft except at high tide.

The topographical characteristic near the mouth is characterized by the changes from 1/100 or more near the mouth and 1/20 or more offshore in the bottom slope as shown in Fig. 2. The contour line is depicted in every 1.0 m.

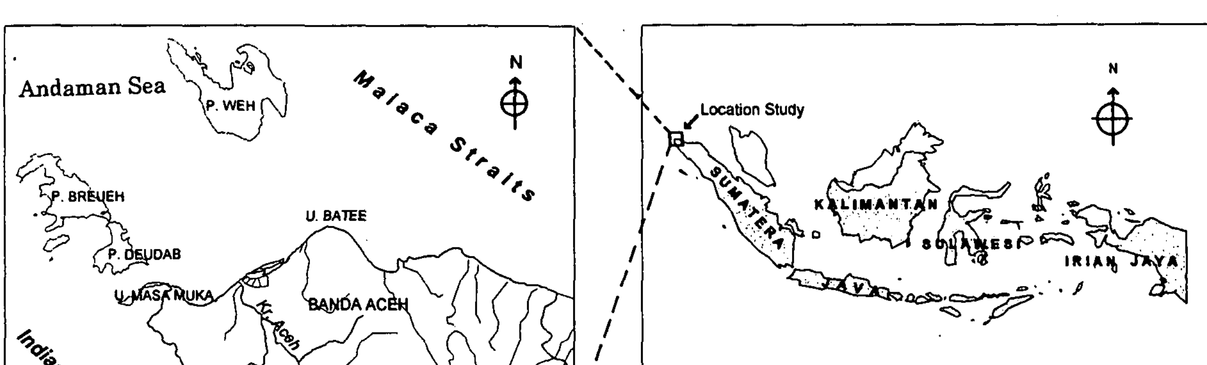

Fig.1. Map of the Krueng Aceh river mouth, Indonesia

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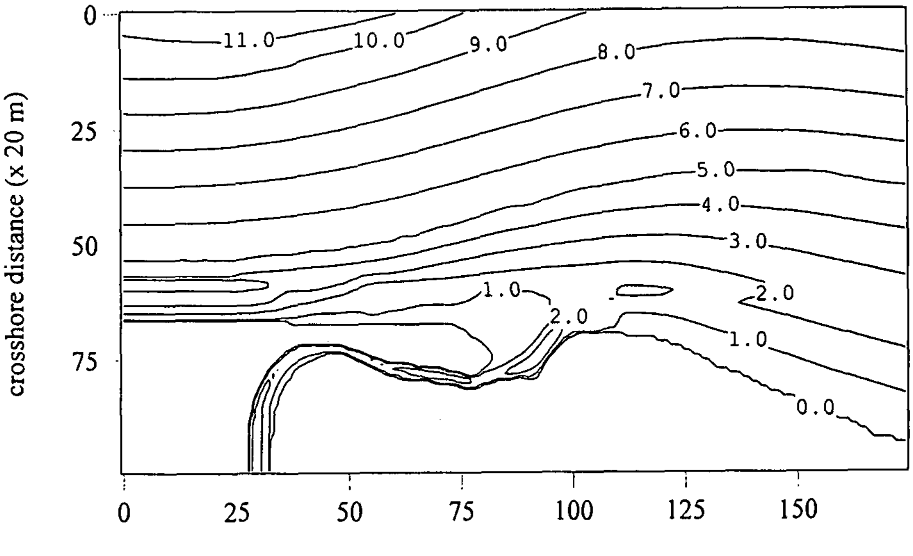


Fig. 2. Topographic map around Krueng Aceh river mouth

2. Refraction analysis

Wave observation has scarcely been done in this area. Therefore the dominant waves were estimated by judging the arrangement of islands off the site as well as the wind data observed in the Banda Aceh city during the period 1991-1995. By assuming that waves are fully developed by winds and the direction of the waves is the same as the direction of the winds, wave analysis was conducted for waves from north west direction only. Otherwise not be analyzed because the mouth and the beach near the mouth is sheltered from wave impinging by presence of several islands and headland. Based on the analysis, it is found that the waves generated by the winds from north west direction occurred about 6 % of time in a year.

During the propagation of waves from deeper sea to the coast the waves undergo refraction due to bottom variations. Analysis of the wave refraction has been conducted using wave ray method. The wave ray method is especially superior in grasping physical images, moreover has the advantage in computational feasibility (Mano and Sawamoto, 1996).

Figure 3. shows wave rays for the wave in the bay around the Krueng Aceh river mouth for the wave period 7 s and have an and angle 55^0 from north direction. The waves developed in the Andaman sea propagate between the Weh and Breueh Islands to approach the site almost normally. The contour lines of depth are drawn by solid line for every 5 meters. Near the mouth, the rays have slight longshore component directed north-east due to refraction by the terrace topography which is supposed to be made by the long-term sedimentation of the river.

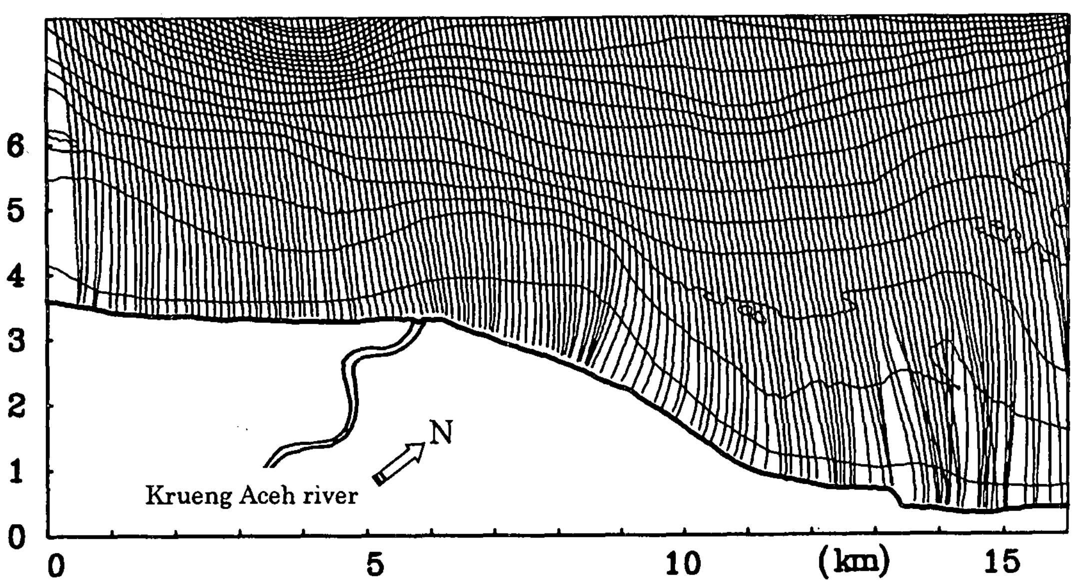


Fig. 3. Wave rays around Krueng Aceh river mouth

3. Nearshore current analysis

Near-shore current field is obtained through the numerical simulation of the wave and current field. Parabolic mild slope equation with including wave-current interaction given by Kirby (1986) was used for the wave model.

The governing equation in the linear form is :

$$(C_g+U)A_x+VA_y+i(\bar{k}-k)(C_g+U)A+\frac{\sigma}{2}\left\{\left(\frac{C_g+U}{\sigma}\right)_x+\left(\frac{V}{\sigma}\right)_y\right\}A$$

$$-\frac{i}{2}\left[(CC_g-V^2)\left(\frac{A}{\sigma}\right)_y\right]_y+\frac{i}{2}\left\{\left[UV\left(\frac{A}{\sigma}\right)_y\right]_x+\left[UV\left(\frac{A}{\sigma}\right)_x\right]_y\right\}$$

$$+\frac{w}{2}A+\frac{1}{4k}\left\{\left[(CC_g-V^2)\left(\frac{A}{\sigma}\right)_y\right]_{yx}+2i\left(\sigma V\left(\frac{A}{\sigma}\right)_y\right)_y\right\}$$

$$-\frac{\beta}{4}\left\{2i\omega i\left(\frac{A}{\sigma}\right)_x+2i\sigma i\left(\frac{A}{\sigma}\right)_y-2UV\left(\frac{A}{\sigma}\right)_{xy}+\left[(CC_g-V^2)\left(\frac{A}{\sigma}\right)_y\right]_y\right\}$$

$$+\frac{i}{4k}\left\{(\omega V)_y+3(\omega U)_x\right\}\left(\frac{A}{\sigma}\right)_x=0\ , \qquad (1)$$

where x and y are coordinates in the crosshore and alongshore direction respectively, $A(x,y)$ is the complex wave amplitude, C and C_g are the phase and group velocity, $\omega=\sigma+U.k$, $\sigma^2=gk\tanh kh$, k and $\bar{k}$ are the wave number and its mean in y direction, and w is the energy dissipation coefficient in the surf zone.

The initiation of the breaker zones is computed by using Sakai's breaking criterion (1989) which is based on Goda's expression (1974) and modified to include current effects.

$$H_b/L_0=0.17\left[1-\exp\left\{-1.5\frac{\pi h}{L_0}\left(1+15\tan^{3/4}\theta\right)\right\}\right]C_1(\varepsilon_d)$$

$$C_1(\varepsilon_d)=\begin{cases}1.13-260\varepsilon_d, & for\ \ \varepsilon_d>0.0005\\ 1.0, & otherwise\end{cases}$$

$$\varepsilon_d=\frac{q^*}{H_b/L_0}\sqrt[4]{\tan\theta},\qquad q^*=q/g^2T^3$$

where H_b is the breaking wave height, L_0 the wave length in deep sea, T the period, $\tan\theta$ the bottom slope, and q the total discharge of the current in the unit width.

The depth averaged continuity and momentum equation was used for the current model to compute flow field near the river mouth. The momentum source is the gradient of the radiation stress. The momentum sink is represented by the bottom shear stress and is easily implemented as a function of the Manning roughness coefficient.

$$\frac{\partial\bar{\eta}}{\partial t}+\frac{\partial P}{\partial x}+\frac{\partial Q}{\partial y}=0\ , \qquad (2)$$

$$\frac{\partial P}{\partial t}+\frac{\partial}{\partial x}\left(\frac{P^2}{D}\right)+\frac{\partial}{\partial y}\left(\frac{PQ}{D}\right)+\frac{gn^2}{D^{7/3}}P\sqrt{P^2+Q^2}-Mx+\frac{1}{\rho}\left(\frac{\partial S_{xx}}{\partial x}+\frac{\partial S_{xy}}{\partial y}\right)+gD\frac{\partial \overline{\eta}}{\partial x}=0, \quad (3)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{PQ}{D}\right)+\frac{\partial}{\partial y}\left(\frac{Q^2}{D}\right)+\frac{gn^2}{D^{7/3}}Q\sqrt{P^2+Q^2}-My+\frac{1}{\rho}\left(\frac{\partial S_{xy}}{\partial x}+\frac{\partial S_{yy}}{\partial y}\right)+gD\frac{\partial \overline{\eta}}{\partial y}=0, \quad (4)$$

in which D is total water depth ($h+\overline{\eta}$), h is still water depth, $\overline{\eta}$ mean water level, P and Q are the flow rates in x- and y- direction respectively, n Manning roughness coefficient, g gravity acceleration. Mx and My are the lateral mixing and are written in the following form

$$Mx=\nu_e\left(\frac{\partial^2 P}{\partial x^2}+\frac{\partial^2 P}{\partial y^2}\right), \quad (5)$$

$$My=\nu_e\left(\frac{\partial^2 Q}{\partial x^2}+\frac{\partial^2 Q}{\partial y^2}\right), \quad (6)$$

ν_e is calculated according to Longuet-Higgins (1970) as

$$\nu_e=Nl\sqrt{gD}. \quad (7)$$

Furthermore S_{xx}, S_{xy}, and S_{yy} denote the radiation stress components. The leap-frog scheme and the upwind scheme for convective term are used.

Figure 4 shows the result of the near-shore current around the river mouth. The river discharge is directed by long-shore current towards north east direction. The topography near the mouth is complex cause wave distribution also complex leading to a meandering long-shore current pattern. Corresponding to the wave rays, there exists long-shore current directing north- east that transports sediments in the direction.

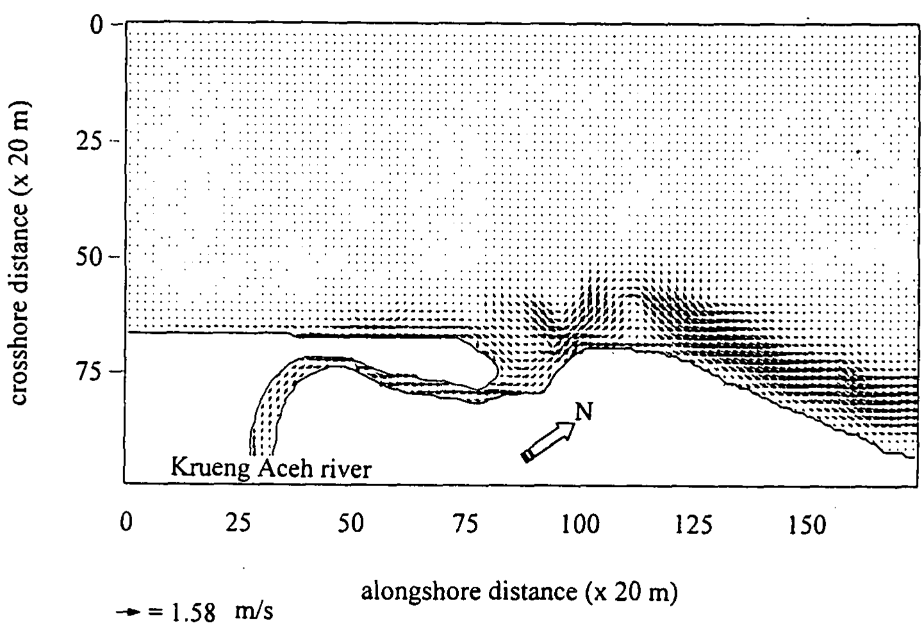


Fig.4. Near-shore current near Krueng Aceh river mouth

4. Sand spit development analysis

The development of sand spit around Krueng Aceh river mouth is analyzed by means collection of secondary data, reconnaissance survey, and interview with fishermen who live near the mouth as eyewitness which could explain how deep the mouth has been.

Before construction of the floodway, fishermen always could navigated their boats easily in and out off the mouth. Such condition due to the fact that, the water depth at the mouth was deep enough maintained by flood. During floods, the water shelf dredged to scour river mouth bed and

flushed sand spit. Eroded sand is carried offshore forming flood terrace in the front of the mouth.

In the normal condition of the river discharge, littoral movement of material might occur along shoreline of the mouth subject to wave action. The littoral material, a portion might be deposited in a shoal in front of the mouth forming sand spit, and a portion of the littoral material, especially the finer ones is transported to the neighboring zones. The waves also affect the configuration of the sand spit extends across the opening. According to the refraction analysis, wave rays near the mouth is refracted to south-east direction by flood terrace leading to a near-shore current toward north-east direction. Consequently, sand spit attached at the left bank of the mouth and stretched north east direction. But sand spit does not well developed, because when floods occurred at the following year flush developing sand spit. The interaction of floods terrace and sand spit around river mouth before construction of the floodway is shown in Fig. 5.

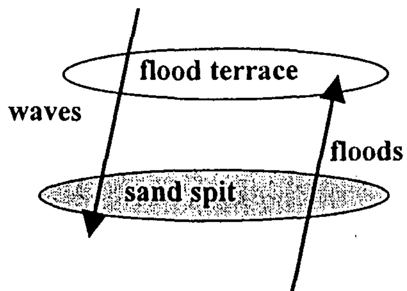
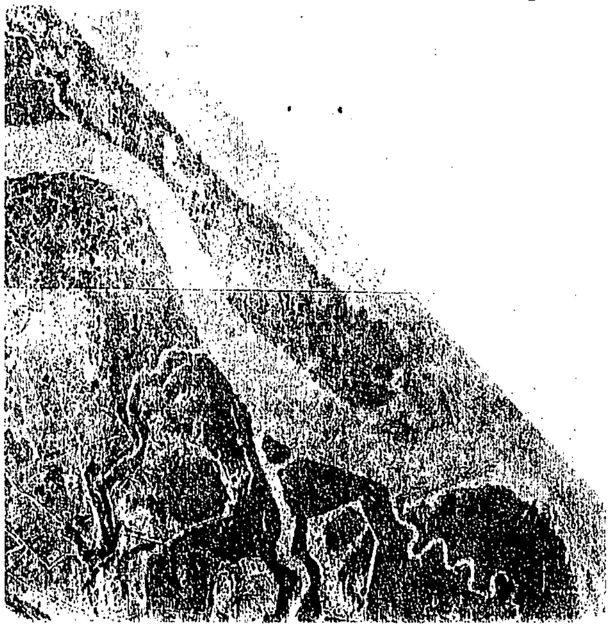


Fig. 5 The river mouth system at the Krueng Aceh river mouth before construction of the floodway

After the construction of the floodway, flood discharge is regulated and diverted into floodway. The decreased discharge of Krueng Aceh river in the downstream intake of the floodway in turn decrease external force to flush developing sand spit. Consequently, sand spit is well developed.

Figures 6.a and 6.b are aerial photographs of the river mouth before and after the construction of the flood way, respectively. The river meanders considerably to the right hand side near the river mouth to make large scale of a sand barrier that exists rather in long time scale, judged from the mangrove forest growing on the barrier. Also substantial deposition is seen at the left hand of the floodway jetty. The computed near-shore current well match with the sedimentation. It is considered that the sand spit at the tip of the sand barrier is developing after the floodway construction due to the decrease of flushing out in the old river.



a.

b.

Fig. 6. Aerial photograph of Krueng Aceh river mouth
a. before construction of the floodway (1992)
b. after construction of the floodway (1997)

5. Conclusions

1. The rays near the Krueng Aceh river mouth tend to bend to south-east direction yielding on near-shore current towards north-east direction.
2. Before construction of the floodway, there was interaction between sand spit and floods.
3. Sand spit was well developed after construction of the floodway owing to decreasing on flood discharge as an external force to flush out sand spit.

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