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## Sediment Transport Model In Sayung District, Demak

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**Abstract.** Demak has 34,1 km coastline and located in 6°43'26" - 7°09'43" South Latitude and 110°27'58" - 110°48'47" East Longitude. In the last few years rapid shoreline and erosion has threatened Demak coastal area. No less than 3000 villages on Java suffer similar problems. Hard structures such as dykes and breakwaters is one of the method that is commonly used to solve this problem. However, this method may fail to provide adequate protection to the environment and become counterproductive. One of the alternative to solve the problem is using hybrid engineering concept. This study aims to assess the distribution model of the sediment on the application of technology as a hybrid structure for the mitigation and rehabilitation of coastal areas in Demak. This research using quantitative method, including field surveys and mathematical modeling methods. The model show that the sedimentation is quite big in highest flood condition and must have the right structure for the hybrid engineering. This study is expected to answer the question of the erosion problem in the District Sayung, Demak.

**Keywords :** Sediment Transport, Experimental Method, Demak, Erosion

### 1. Introduction

Demak, Central Java is one of the area that has many problems related with erosion and shoreline degradation. The lost of the flood protection that the mangrove forests once offered has caused coastal retreat from a few hundred meters up to kilometer (at some places) in recent decades [1] No less than 3000 villages on Java suffer similar problems [2]. These vulnerabilities will further exacerbate if the growing degradation and erosion problems are not addressed. Establishment of aquaculture ponds along low-lying sedimentary reaches resulted in the near total destruction of mangrove forests since the 1980's [3]. Mangrove Forest were converted, mostly in western Indonesia [4]. The removal of the mangroves and confinement of the intertidal range due to construction of earth bunds around the shrimp ponds caused changes in sediment dynamics. This triggered massive erosion and the related land loss, inundation and saltwater intrusion problems [2]. In order to solve this problem hard structures such as dykes and breakwaters is one of the method that is commonly used. Locally, these hard structures were even found to intensify erosion by blocking sediment transport towards the coast and enhancing wave effects due to wave reflection. [5] However, this method may fail to provide adequate protection to the environment and become counterproductive. For that reason hybrid engineering is one of the alternative to solve the problem. Hybrid engineering is a friendly environment method that



accommodates economic and livelihood development needs, and combines technical and ecosystem-based solutions [6]. Semipermeable dams made of bamboo piles and brushwood have successfully reduced erosion and stimulated sedimentation in comparable muddy environments.[7]

The first step is identify the mechanisms controlling mixing and stratification as a product of physical input such as bathymetry, tidal, wind driven circulation, and sedimentation. The next step is identify the sediment source domination that is happening in this coastal area, predicting the suspended sediment concentration and fine sediment fluxes that is happening in the area would be the study that has to be done. Than characterize the dominant currents and quantify the associated residual transport on sediment.

After all the physical parameters have been analysed hopefully it will give the best elements for the Hybrid Engineering. The study aims is to know the ocean curenets pattern and to predict the sediment transport dispersion as if the dredging process.

## 2. Material and Method

### 2.1 Material

#### 2.1.1 Hydrodynamics Model

The hydrodynamic model is used to simulate the currents in the research area. In general, a two-dimensional equation of hydrodynamic consists of the main components which include:

conservation equations of mass (continuity) and momentum conservation equation. Circulation caused by tidal currents and wind in coastal waters and assume as a homogen water mass by depth. In this model the sea water assume as an incompressible fluid.

The continuity equation is [8]:

$$\frac{\partial \xi}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = Q_s$$

The momentum equation is:

$$\begin{aligned} \frac{\partial U}{\partial t} + \frac{U}{H} \frac{\partial U}{\partial x} + \frac{V}{H} \frac{\partial U}{\partial y} + gH \frac{\partial \xi}{\partial x} + rU \frac{\sqrt{U^2 + V^2}}{H^2} \\ + A_h \left( \frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2} \right) = \lambda W_x \sqrt{W_x^2 + W_y^2} \end{aligned}$$

$$\begin{aligned} \frac{\partial V}{\partial t} + \frac{U}{H} \frac{\partial V}{\partial x} + \frac{V}{H} \frac{\partial V}{\partial y} + gH \frac{\partial \xi}{\partial y} + rV \frac{\sqrt{U^2 + V^2}}{H^2} \\ + A_h \left( \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} \right) = \lambda W_y \sqrt{W_x^2 + W_y^2} \end{aligned}$$

where :

x,y : space coordinat grew to the east and north (m).

u,v : current velocitu in x and y (m/s)

U : transport in x direction ( m<sup>2</sup>/s )

$$U = \frac{1}{h + \xi} \int_{-h}^{\xi} u dz$$

V : transport in y direction ( m<sup>2</sup>/s )

$$V = \frac{1}{h + \xi} \int_{-h}^{\xi} v dz$$

t : time (s)

ξ : elevation from sea water level from mean sea level (m)

g : gravity (m/s<sup>2</sup>)

H : Real depth = h + z (m)

h : fixed depth (m)

r : friction coefficient

A<sub>h</sub> : eddy frictionn coefficient (m<sup>2</sup>/s)

λ : wind friction coefficient

W<sub>x</sub>,W<sub>y</sub> : Wind Speed in x and y (m/s)

Q<sub>s</sub> : debit (m<sup>2</sup>/s)

The hydrodynamics model is solved using the semi implicit where the variabel is calculate from the space cell in each time step. This method is chosen because it doesn't depend in time step option in the Courant-Friedric-Lewy stability criteria like in the explicit methods, so the computer memory can be use effective and efficient. This model using bathimetri data, tides data, wind and the physics condition in the research area ( inlet outlet, beach building, etc).

### 2.1.2 Sediment Transport Model

The sediment trasport model in a canal and sea basically is determine as a suspension material dispersion in water, such as :

- With the velocity of fluid flow result in a sediment transport dispersed directly by the flow. This movement is called advection process.
- Turbulent diffusion process relating to variations in the speed of the flow direction of the cross section by the motion of turbulence

Both the process and the exchange between the air-sea sediments formulated in the following equation[8]:

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} + v \frac{\partial C}{\partial y} = K_x \frac{\partial^2 C}{\partial x^2} + K_y \frac{\partial^2 C}{\partial y^2} + \frac{A}{\rho A_p h} (C - C_E) + Q_C$$

where :

C = Actual sediment Concentration (kg/m<sup>3</sup>)

C<sub>E</sub> = Natural sediment concentration (kg/m<sup>3</sup>)

Q<sub>C</sub> = rate of change in sediment concentration (mg/l s)

K<sub>x</sub>, K<sub>y</sub> = koefisien difusi turbulen arah x, dan y (m<sup>2</sup>/detik)

A = (4,48 + 0,049T) + f(1,12 + 0,0180T + 0,00158T<sup>2</sup>) = sea air interaction coeffiecient(kkal/m<sup>2</sup>s °C)

f = 3,6 + 2,5W<sub>3</sub> ; wind factor for A coefficient

W<sub>3</sub> = wind speed that is measured in 3 m above water level (m/s)

ρ = Sea water density (kg/m<sup>3</sup>)

A<sub>p</sub> = specific sediment in constant pressure (kkal/kg °C)

h = depth (m)

For practical purposes it can be assumed the water area is small enough to be reviewed, the value C<sub>E</sub> is taken from the value of the natural sediment concentration of sea water in places far away from the point source pollutant concentrations.

Vertical distribution of sediment concentration reasonably assumed homogeneous or variation is not great because there has been a turbulent mixing is almost perfect from the surface to the seafloor, so that two-dimensional sediment transport models can be used horizontally and approached the dispersion process at the pool / canal / sea. 2D model equations are solved by numerical methods upstream and sediment exchange coefficient between the sea and air using empirically derived formulation. The model simulated sediment distribution in accordance with the scenario that is designed the same as the current model simulation scenarios as described in advance, due to hydrodynamic models and models of sediment run concurrently or so-called model coupled from the two models.

### 2.2 Method

Bathymetry Sayung coastal waters, Demak ranging from 1 meter to 15 meters to the north (offshore). Broadly speaking, the location of the model can be seen in Figure 1 below.

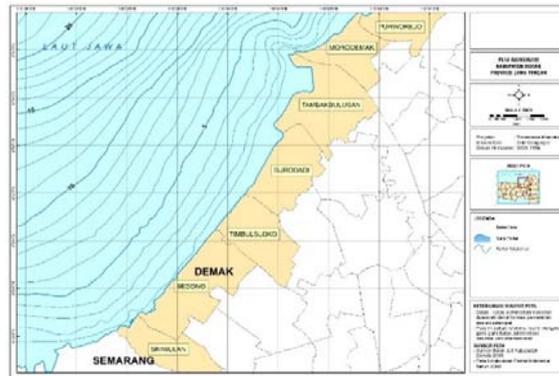


Fig 1. Research area in Sayung District, Demak (Source : Data Processing,2015)

The area of this model is divided into 455 x 422 grids (455 grid east-west direction and 422 grid north-south direction) with the size of each grid  $dx = dy = 50$  m. Calculation time step ( $dt$ ) is 1 second. By simulating 15 days old.

Hydrodynamics and sediment dispersion models simulated by inserting force generating tidal, and wind simulation was performed under various scenarios with tidal conditions

### 3. Result and Discussion

#### 3.1 The validation of result

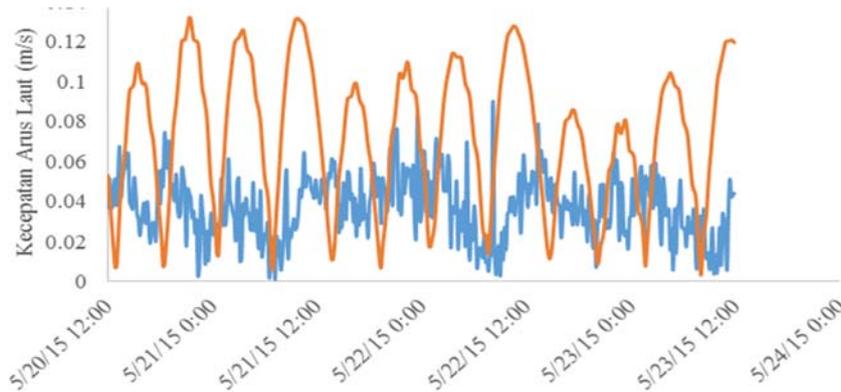


Fig 2. Validation result graphic between model and field current (Source : Data Processing, 2015)

$CF = 1.1258$ .  $CF$  (Cost Function) is a non-dimensional value to indicate a match two kinds of data. The criteria used are  $CF < 1$  is very good, good 1-2, 2-3 enough,  $> 3$  less. The results validate the model results with field results indicate that the ocean current modeling results Demak has a good criterion.

#### 3.2 Hydrodynamics Model Result

The pattern of ocean currents in the period of flood toward ebb tide has current velocity ranges from 0.01 to 0.5 m / s with the movement direction leading toward south. In the period of lowest ebb flow velocity ranges from 0.01 to 0.4 m / s with the direction of movement leads to the south. On the condition of ebb tide toward flood current velocity ranges from 0.02 to 0.4 m / s with the direction of movement in the north. In the period of the highest flood the current dominance of speed ranges from 0.1 to 0.5 m/s, during this period the flow rate appear higher than the speed of currents in the other tidal period. Distribution of the current direction in this period also just leads to the north of Demak waters.(see figure

3). Bappenas & KOICA (2012)[9] reported a wave-induced current of about 0,5 m/s when west-northwest in Demak Coastal area., but expert think the current velocity is an order of magnitude lower.

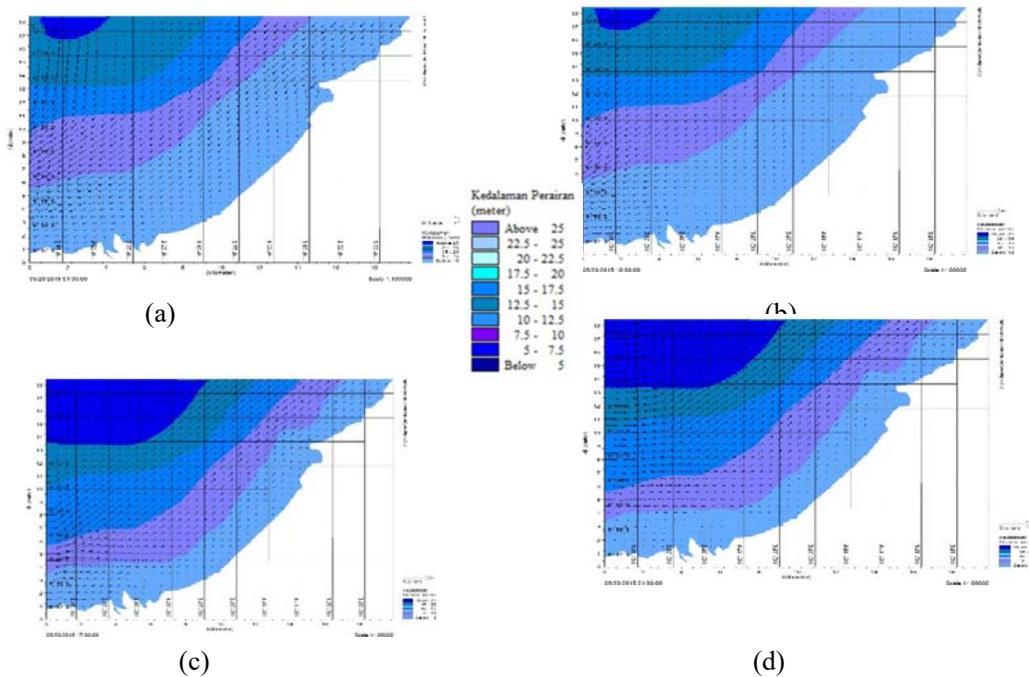


Figure 3. The pattern of ocean currents in (a) flood toward ebb(b) lowest ebb (c) ebb toward flood (d) highest flood

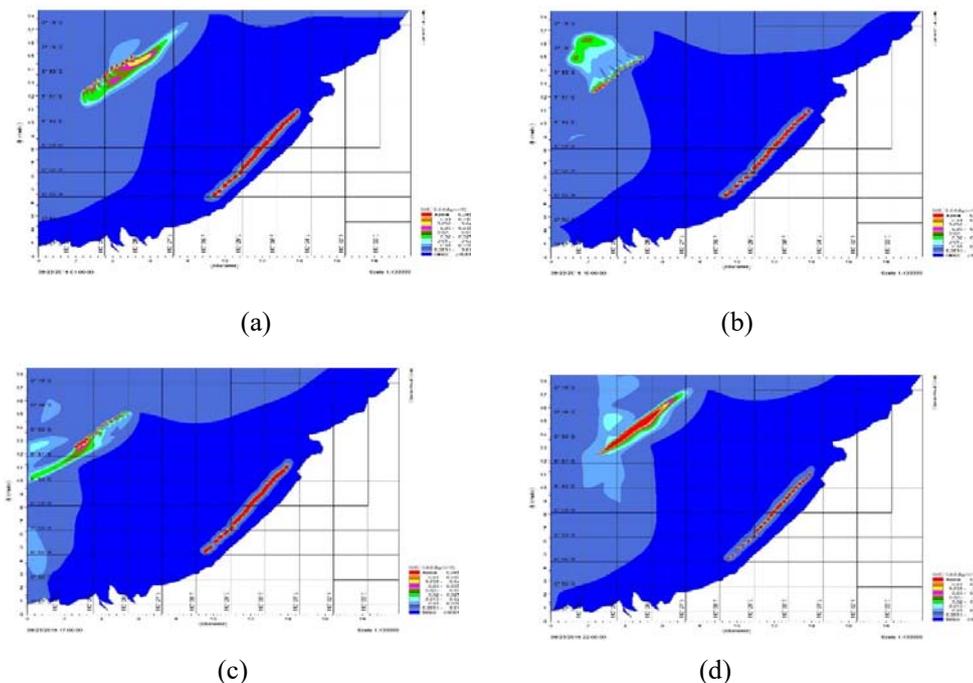


Figure 4. The pattern of sediment transport in (a) flood toward ebb(b) lowest ebb (c) ebb toward flood (d) highest flood

### 3.3 Sediment Transport Model Result

Sediment concentration distribution model results in Figure 3. Seen from tides scenario that the highest flood tide (Figure 3a) change the concentration of sediment dominant with a distance of 6 km from the source of pollutants where sediment concentration values ranging between 0,015 - 0,045 kg / m<sup>3</sup>. While the condition of the lowest tide ebb sediment concentrations scattered small enough dominance in which the value of sediment concentration ranges between 0,01 - 0,03 kg / m<sup>3</sup> with a distance of 3 km distribution (Figure 3b). This sediment transport patterns affected by the tidal patterns, where the pattern of sediment transport and the direction of ocean currents towards to near the shore in accordance with the conditions of simulated at high tide. It is adapted to the statement of Gyr and Hoyer [10] that sediment transport patterns that are influenced by the mass of water flow patterns also depend on monsoon different wind conditions. The simulation shows that the distribution of sediment is quite small because of the small ocean currents velocity (See figure 4).

## 4. Conclusion

The sediment transport modeling has been done in Sayung District Demak for the existing condition as well as after the hybrid engineering concept, with the following

1. In the period of the highest flood has the biggest ocean current speed appear than the speed of currents in the other tidal period where the speed ranges from 0.1 to 0.5 m/ s
2. The simulation shows that the distribution of sediment is quite small because of the small ocean currents velocity that happen in Demak Waters

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