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HYDRO- AND MORPHO-DYNAMICS AT RIVER ENTRANCES

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A mathematical model for calculating river mouth morphology change is overviewed, in which longshore sediment intrusion into a mouth by waves, as well as sediment flushing out of a mouth by river and tidal discharge is considered. Behavior of an analytical solution is discussed for various combinations of opposing forces acting at a river mouth. For model verification, as well as for planning, management and serving as the information for the engineering projects in a river mouth area, in-situ monitoring of morphology changes is important and inevitable. Thus, recent monitoring method of river mouth morphology is also introduced, which enables us to make an accurate and frequent survey of river mouth. Furthermore, quantitative discussion will be made for wave set-up, water level rise due to wave breaking, in a river entrance.

Key Words **:** *river mouth, morphology, sand spit, mathematical model, monitoring, wave set-up*

1. INTRODUCTION

In numerical modeling used for solving hydrodynamic behavior in a river, there are various levels of model complexity, from a simple 1-D model to a very complicated 3-D model, and most suitable model should be chosen considering objectives, accuracy and computing time, etc. Similarly, for river mouth morphology, there are several types of models with different complexity. De Vriend[1)] overviewed existing models such as empirical, semi-empirical and process-based models. Similar to river flow simulations, there can be practical situations in which considerably simplified model yields results of reasonable accuracy for engineering purposes.

In this paper, one-dimensional model for river mouth morphology change is introduced. Furthermore, hydrodynamic characteristics observed in a river mouth will be discussed.

2. MATHEMATICAL MODEL FOR RIVER MOUTH MORPHOLOGY CHANGE

De Vriend[1)] classified tidal inlet or river mouth model into the following categories based on model approach.

- -*Data-based model*: making use of measured data only and aiming directly at the phenomena to be described.
- -*Empirical relationships*: also observation-based, but establishing a relationship between input and output of the system.
- -*Process-based model*: describe waves, currents, sediment transport, and bed level changes via a set of mathematical equation based on first physical principles (conservation of mass, momentum, energy, etc.).
- -*Formally integrated, long-term models*: derived from a process-based model by formal integration over time (and space), with empirical or parametric closure relationship.
- -*Semi-empirical, long-term models*: describe the dynamic interaction between large elements of the system, using empirical relationships to represent the effect of small-scale processes.

A mathematical model proposed by Tanaka et al.[2)], for predicting closing process at a river mouth owing to predominant wave motion, belongs to the fourth category in the above classification. It is assumed that the wave motion is responsible for the intrusion of sediment into the mouth, while the river discharge is effective for flushing sediment out of the mouth. Thus, the corresponding governing equation is expressed as follows.

$$(1-\lambda)Lh\frac{dB}{dt} = e_r q_r B - e_w (1-\lambda) Q_w \qquad (1)$$

where λ the porosity of sand, L the width of sand spit, h the water depth at a mouth, B the width of a river mouth, and e_r and e_w the efficiency of sediment inflow by waves and that of sediment outflow by current, respectively. Similar model was used by Kraus[3] and Totok and Mano[4] to reproduce well-known tidal inlet relationship between tidal prism and equilibrium cross-sectional area.

The sediment transport rate due to current, q_r, and that induced by wave motion, Q_w, can be evaluated by means of conventional formulae, Eq.(2) and Eq.(3), respectively.

$$q_r = K\left(\frac{u_*}{sgd}\right)^m u_* d \qquad (2)$$

$$Q_W = \alpha (Ec_g)_b \sin\theta_b \cos\theta_b \qquad (3)$$

where K is the constant, u_* the shear velocity, s the immersed specific weight of sediment, g the gravitational acceleration, d the grain diameter, m the power, α the empirical coefficient, $(Ec_g)_b$ the incident wave energy flux evaluated at the breaker line, and θ_b the breaking wave angle to the shoreline.

Time-variation of river width and duration required for reaching equilibrium state can be obtained analytically for a for a constant forcings acting at a river mouth[2].

3. MONITORING OF RIVER MOUTH MORPHOLOGY

The knowledge of shoreline changes is important and inevitable for planning, management and serving as the information for the engineering projects in the coastal area. This information can be traditionally acquired from the continuous field observation to collect the historical of the morphology in the interesting area. However, the survey data within a long period is not available in various places in the world because the field observation method consumes a lot of time, human works and budgets.

The new method for monitoring of the morphodynamics in the intertidal beach was proposed (Aarninkhof and Roelvink[5]). The tool used in this study is full-color ARGUS video image, which are the automatic video stations for taking high solution image over a wide range of space and time scales. The color information in the video image was used to identify the waterline. This study presented the use of more intuitive color information comprised of HSV (Hue, Saturation, Value) of the image pixels. The discriminator function used for detecting water line was empirically derived from histogram of two components, hue and saturation, from a number of sample pixels in both dry and wet pixel.

Srivihok and Tanaka[6] also applied an image analysis to determine the waterline around a river mouth by the concretely mathematical criterion, instead of manual digitizing of shoreline position in the river mouth photos. HSL (hue, saturation and lightness) color space of the processed aerial photographs was successfully used to classify land and water pixel in the photos. The combination of hue and lightness histogram was utilized to locate the land-water demarcation criterion by the assumption of normal distribution of land and water pixel group in those histograms. Land pixel is detected when hue value is less than the criterion in the hue histogram and lightness value is simultaneously greater than the criterion in the lightness histogram. The normal distribution is useful since it can distinguish the similarity of color between wave breaking and sand area.

From the set of processed aerial photographs, the long-term morphological change at the Nanakita River mouth was monitored[6]. Various geometric parameters were measured such as; throat width, location of right and left sand spit alongshore and cross-shore direction. Additionally, the yearly average probability and standard deviation of land area at the river mouth were calculated for describing the frequency of sand spit intrusion into the channel and the fluctuated-stabilized geometry of the river mouth during the last decade.

4. WAVE SET-UP IN A RIVER MOUTH

Wave set-up is the water rise at the coast due to breaking waves on the beach. The height of this piling up is directly proportional to the breaking wave height. There have been a lot of observations of wave set-up caused by breaking waves, though, most of them have been limited to laboratory flume experiments. The reason of the scarcity of field observations might be its considerable difficulty of measurement in the surf zone, especially during high waves. In recent years, several field observations have been reported on wave set-up height in a river entrance (e.g., Tanaka and Lee[7]). It can range from 10 and 20 percent of deep water wave height. It means water level rise due to wave set-up attains to around 1m during severe storm condition.

According to the previous studies, it can be concluded that the height of wave set-up has a dependence on the morphology at a river entrance. Data on river mouth topography obtained at short intervals is quite rare, whereas field data of water level variation in a river mouth can now be easily obtained using an automated measuring device. Thus, even though we have sufficient data sets of wave set-up at a river entrance, it is difficult to correlate them with river mouth morphology due to lack of corresponding field surveying data of river mouth topography, caused by inconsistency of data acquisition interval of water level and river mouth morphology. This is one of the reasons why quantitative relationship between the magnitude of wave set-up height and river mouth morphology has not thoroughly been clarified yet.

It should be here noted that water level rise due to wave set-up is equivalent to enhancement of tidal prism in a river entrance, resulting in more intrusion of salinity into a river. Nguyen et al.[8), 9)] made quantitative investigations regarding the role of wave set-up on salinity intrusion using ANN (Artificial Neural Network) modeling, as well as using a 3-D numerical modeling.

REFERENCES

1) De Vriend, H.J.: Mathematical modeling of meso-tidal barrier island coasts, Part I: Empirical and semi-empirical models, Advances in Coastal and Ocean Engineering, P.L.-F. Liu, ed., Vol.2, World Scientific, pp.115-149, 1996.
2) Tanaka, H. et al.: Complete closure at the Nanakita River mouth in 1995, Proceedings of 25th International Conference on Coastal Engineering, pp.4545-4556, 1996.
3) Kraus, N.C.: Inlet cross-sectional area calculated by process-based model, Proceedings of 26th International Conference on Coastal Engineering, pp.3265-3278, 1998.
4) Totok, S. and Mano, A.: A dynamic model on the river mouth change, Proceedings of 2nd Conference on IAHR Symposium on River, Coastal and Estuarine Morphodynamics, pp.433-442, 2001.
5) Aarninkhof, S.G.L. and Roelvink, J.A.: ARGUS-based monitoring of intertidal beach morphodynamics, Proceedings of Coastal Sediments Conference, ASCE, pp.2429-2444, 1999.
6) Srivihok, P. and Tanaka, H.: Analysis of river mouth behavior change by using aerial photographs, Annual Journal of Hydroscience and Hydraulic Engineering, Vol.48, pp.733-738, 2004.
7) Tanaka H. and Lee, H.: Influence of Jetty Construction on Morphology and Wave Set-up at a River Mouth. Coastal Engineering Journal, 45(4), pp.659-683, 2003.
8) Nguyen, T.V., Tanaka, H. and Hoc, D.X.: Application of the ANN model considering the effect of morphology change and wave set-up on salinity distribution in the Nanakita River mouth, 2007. (submitted)
9) Nguyen, T.V., Tanaka, H. and Yamaji, H.: Influence of morphology change and wave set-up on salinity concentration in an estuary, Annual Journal of Coastal Engineering JSCE, Vol.53, pp.936-940, 2006. (in Japanese)

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