論 文 の 内 容 の 要 旨

論文題目　Analysis and modeling of long-term shoreline changes and alongshore sediment characteristics on the Nile Delta Coast
(ナイル川河口周辺部における長期汀線変化および砂粒子特性の分析)

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Coastal morphology changes are commonly experienced phenomena. While several coastal countermeasures are applied along the coasts to control the morphological changes, the interference of these human activities upon the coasts might make it hard to achieve its perceived goals. In order to prepare an overall and sustainable strategy for the coastal management, reliable long-term shoreline change data and forecasting of the future changes are required. Investigations of historical coastal changes are essential to understand the physical mechanisms of the changes and to predict the future shoreline evolutions. It is thus crucial and worthwhile to quantitatively estimate the areas of erosion and accretion, sediment sources, sediment transport rates, and sediment characteristics along the coast.

The general aim of this research is to study the long-term shoreline changes through the analysis of shoreline locations, investigations of sand materials, and application of numerical models. As a case study site, this research focuses on the Nile Delta, where is suffering large scale and long term coastal erosion. The study site has 250 km stretch of the coast line from Iduku lake in the west end to Port-Said in the east and faces to the Egyptian Mediterranean Sea. To fully capture the physical characteristics of the coastal dynamics, this study applied multiple different methodologies: analysis of the land-sat images, investigations of sampled sand grains around the swash zone, and the numerical analysis based on the shoreline model.

First, the past coastal line changes were quantitatively monitored around the study site. The coastal lines were automatically extracted based on the local XY-coordinates from Land-sat satellite images over 37 years from 1973 to 2010 with unequal time intervals. The extracted coastal lines were quantitatively investigated based on the linear regression technique as well as the empirical orthogonal function analysis.

Second, a field survey was conducted in March 2011. Sand samples were collected at more than 60 various locations along the shoreline. Samples were collected from the layer at 5-10 cm under the ground surface in the inter-tidal zone. These samples were used for the thermo-luminescence (TL) test. This study measured TL intensity of the feldspar extracted from the sand samples. Consistency between the results of this method with the interpretations based on the analysis of land-sat images was achieved. Using the same samples, sand characteristics were further investigated. The grain size distribution; the median sand size, D50 was measured using the laser diffraction particle size distribution measuring apparatus. The color of sand grains was also identified by naked eyes and the mineral composition based on color was interpreted using the automated analysis of images captured by a digital microscope.

Last, shoreline change model was applied to reasonably explain physical procedures of the observed shoreline changes, accounting for sediment size distributions. The calibrated model is then used for predictions of the future shoreline changes accounting for different climate scenarios. The present model accounted for the quantitative characteristics of coastal structures and river mouth. The improved numerical model simulates the wave transformation, regional sediment transport, sediment size, and shoreline changes. The model composed of two parts, Energy Balance Equation model and One-line model. Due to the high curvature of the shoreline along the study site, the One-line model was formulated in terms of local coordinates normal to and tangential to the actual shoreline. Based on Kumada et al. (2002), alongshore distributions of the sediment grain sizes were also computed and compared with the observed results.

Approximately 46% of the Nile Delta Coast (NDC) experienced erosion while 52% undergo some accretion. The general features along the NDC are the erosion at the three headlands of Rosetta, Burullus and Damietta, and the accretion for the embayment, near the structures, and the sand spit (Eastward Damietta).

As a result of the TL test, it was found that the sand grains near the Rosetta and Damietta branches present a higher TL signal and TL intensity gradually decreases with increasing distance from the two river mouths, which indicates sediment alongshore transport features. The small difference of TL intensities between the sand grains near the river mouth and the ones on the natural coast indicates that the sediment supply from the river is limited. The estimated sediment transport directions based on the TL analysis are consistent with the interpretations based on the analysis of land-sat images around Rosetta promontory while these two estimations were contrary to each other on the west side of Damietta promontory. Observed inconsistency may be due to fluctuating errors of TL measurements

Through the analysis of sand characteristics, clear difference was noticed by the naked eyes in the sand color, and size between different areas. Around Rosetta promontory the sand color is light and average size is 0.28 mm, while in the middle part of the Delta the color is lighter and grain sizes are coarser with average size of 0.6mm, and from Damietta to Port Said the color is darker and average grain size is 0.23mm. The sediment comes from the river contains blackish sand with small size and other colors with bigger size. The dark sand is dominant in the sand dunes. The sand samples near the large traps i.e., Idku jetty, El Burullus jetty, and Damietta breakwater are characterized by dark color. This illuminates that the dark grains is smaller than other grains which moves easily and accumulated near the coastal structure.

The improved model was calibrated and validated against the data from Land-Sat images along the NDC in Egypt. The model successfully simulates the general features along the NDC. The model exhibits its ability in the prediction of the shoreline around Rosetta promontory before and after placing the countermeasure structures. The correlation between the numerical model simulation and the Land-Sat image data was more than 90%. The model was used to check the importance of placing the current coastal structures around Rosetta mouth by simulating the shoreline changes with and without structures. Severe erosion was estimated in the case if there are no structures around the Rosetta mouth. By comparing the grain size distribution around Rosetta mouth in 1988 with the size in 2012, it is noted that the grain size become coarser due to the erosion. The model succeeded to qualitatively simulate such change of the grain size around the Rosetta mouth.