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（河口周辺の海浜変形）
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論 文 内 容 要 旨

The natural river mouth seems have similar condition with perpendicular structure. The river water usually flow to the sea in perpendicular direction depending on the course of river mouth. The perpendicular of water flow may able also to obstruct the long-shore sediment transport like jetty or groin. The response of this obstruction usually in the form of sand spit development in the river mouth. The obstruction by river flow make the long-shore sediment is deposited and thus sand spit is developed from one side. On other side of river mouth, the sediment is eroded by river flow and transported further down side by waves. Then, the axis of river mouth will move from its original position. In some river, the other side might be can not eroded due to geologic structure or the weakness of river flow causing by low discharge. If the condition likes this, the river mouth can be closed by sand spit and there is no again the obstruction to the long-shore sediment transport. However, some river can maintain its flow and make equilibrium condition, which is shown by narrowest width of river mouth. This condition raises the possibility that the river mouth must able also to obstruct the long-shore sediment transport like jetty or groin. Considering the river flow is not rigid as same as barrier structure, so the influence may not so much apparent as same as structure.

The river mouth influence to the surrounding beach was investigated through examining the shoreline position around river mouth from aerial photograph. The 20 years span series of aerial photographs were analyzed to extract shoreline position. The long-term behavior can be detected with this time span of data as well as the short-term behavior. Then, the Statistical method, Even-Odd method and EOF method were employed to reveal the influence of river mouth. The Sediment Budget analysis, which many researcher perform the method in tidal inlet, was also applied to investigate the possibility of sediment bypass the river mouth as same as in tidal inlet. The numerical model of shoreline change around river mouth was performed with incorporated the reservoir model and river mouth model. Those both models represent the natural process which occurs in river mouth and to simulate the influence of river mouth

The aerial photograph data is very useful source for analyzing geomorphology especially in this study. The data can be collected frequently with fast and less effort, even it has considerable costs. However, the analysis of aerial photograph should be done with care. Many methods and technique are available for analyze the aerial photograph. Each method or technique has own superiority, shortage and different reliability results. Nevertheless, the inherent errors in aerial photograph still make un-correction error what ever the technique is used. The technique, which is used in this study, is relatively simple and still has some error in the results. However, the error is correlated with the size of measured object. The error can be tolerated if still smaller than concerning object. The 6 m shoreline measurement error in this study is still acceptable when is compared with the shoreline movement in the study area.

The study area (Nanakita River mouth) had experienced a great influence from Sendai Port breakwater since the beginning of construction in 1970 until around 1990. The time of data, which was used in this study, had been chosen by considering the achievement of new equilibrium condition in this area. Statistical analysis of shoreline data on the left and right side of river mouth reveal some influence of river mouth. Small cone shape of shoreline to the river mouth implies the role of river mouth as sediment supplier to the system. The different magnitude movement between left and right side show the possibility that river mouth as caused of that. It means the river mouth become difference border between left and right side by its flow. The statistical analysis of shoreline data shows also the long-term fluctuation, which may be correlated with river mouth influence, as well as the short-term fluctuation.

The statistical analysis has already shown the existence of short and long term shoreline change in the study area. The shoreline can be influenced by cross-shore process. The evident of cross-shore influence is shown by the same direction movement of shoreline on both sides of river mouth. The shoreline can also be influenced by long-shore process. The evident of long-shore influence is by different movement of both sides, one move advance and other move retreat, and this evidence direct to influence of river mouth as obstruction line. Therefore, the data need to be decomposed to separate cross-shore and long-shore influence. The Even-Odd method is capable to reveal the long-shore influence only in one time interval (1993~1996). The strong cross-shore influence appears almost in all time. However, the Even-Odd method is less reliable because only use two data, in beginning and end of time interval. Therefore, the Empirical Orthogonal Function (EOF) method is expected to give better results because utilizes all of data.

Initially, the EOF method is just matrix calculation which has no correlation with another meaning. The result of EOF method is used to explain the natural phenomena by trying to make correlation between them. The correlation of first mode EOF results with wave parameter gives good agreement, which makes the first mode is concluded has correlation with cross-shore process. The first mode also has biggest contribution than other mode. It is imply that in the study area, especially around the Nanakita River mouth, the cross-shore influence is dominant. The EOF results show the temporal eigen-function of first mode is agree with shoreline long term fluctuation.

The second mode of EOF results was correlated with long-shore wave energy flux. As same as first mode, the correlation was made indirectly. It was calculated the gradient of c_2 ($\Delta c_2/\Delta t$). The positive gradient value is accretion and negative is erosion condition. The wave parameter is expressed in long-shore wave energy flux. The accretion or erosion in two months (shoreline data interval) is considered due to the action of long-shore wave energy flux during that time. Therefore, the energy flux was also calculated the net in consecutive two months. The results show that it exist the relationship between the second mode of EOF result and the long-shore sediment transport. It is about 40% data (39 or 40 from 103 data) show that the positive net wave energy flux may induce positive c_2 gradient of right side / negative c_2 gradient of left side and vice versa. It is about 20% (19 from 103 data) have combination of accretion-erosion on both sides. The decreasing of acceptable data and low correlation value may be caused by the action of river mouth as sediment supplier. The simple wave transformation model was used in this calculation, whereas the hydrodynamic condition of left side area is complex due to the influence of Sendai Port breakwater. It may cause another reason that makes the correlation value of left side is lower than right side. Nevertheless, it may conclude that the second mode of EOF result reflect the long-shore process in the beach.

The second mode of EOF results shows the existence of accretion-erosion process on both sides of river mouth. It means the natural river mouth have influence as same as the jetty structure by obstructing the long-shore sediment transport. The influence range of river mouth was about 300 m to the left and right side, which was indicated by the second mode spatial eigen-function. However, the trend in long-term fluctuation of shoreline is depicted in the first mode of temporal function, which reflect the cross-shore process and does not have any correlation with river mouth condition.

The expectation of river mouth disturbs the long-shore sediment transport and cause long-term fluctuation of shoreline is proven in some extent in the EOF results. The second mode of EOF result has indicated the role of river mouth as disturbance for long-shore-sediment transport, even no strong correlation exist, and as sediment supplier to the surrounding beach. The magnitude of obstruction will influence the magnitude of sediment transport that can pass the river mouth. Moreover, the sediment bypassing will influence the beach condition around river mouth. The Sediment Budget method is employ in the study to identify the existence of sediment bypassing by using mass balance principle.

In the Sediment Budget method, the conceptual budget and mass balance equation was setup. The mass inside one cell should balance between the sediment transport in/out of cell and the volumetric sediment change inside cell. The known component of sediment transport was calculated such as wave induces long-shore sediment transport, river flux, volumetric shoreline change and sand spit development. The unknown component was estimated from mass balance equation such as offshore loss transport and sediment bypassing of river mouth. The results capable to reveal the sediment bypassing, however the sediment amount blocked by river mouth is small. It is about 10% of long-shore transport is blocked by river mouth in average estimation from 1991 until 2009. It may conclude that the obstruction to long-shore transport by river mouth exist but have small effect. The Sediment Budget results also show the strong role of river mouth as sediment supplier. The sediment transport to the left and right side shoreline during high river discharge with ratio influenced by the alignment of river mouth axis.

Even the previous result have show the small influence of river mouth in terms as obstruction to the long-shore transport on long-term scale, but the evidence from aerial photograph shows this strong influence especially during equilibrium condition. Seasonal variation of wave and river discharge strongly show interaction between those components which is correlated with shoreline response around river mouth in short-term scale. Therefore, the numerical analysis was performed to simulate the shoreline change around river mouth by incorporating the natural condition around river mouth in order to examine its influence to the shoreline change especially in terms of magnitude. The One-line model is applied due to simple and suitable to simulate the long term shoreline change. The Reservoir model was used to simulate the influence of river mouth. The Reservoir model simulates the development of sand terrace in front of river mouth during high river discharge. The wave condition also controlled the existence of sand terrace. The bigger sand terrace was developed, the smaller sediment can bypass the river mouth. Therefore, the ratio between instantaneous and equilibrium volume of sand terrace can be expressed as the Bypassing factor. The RMSE between calculated and measured shoreline suggest that by incorporating the river mouth influence in shoreline change model, the accuracy was increase better than without detail consideration. The simulation of river mouth influence by obstruction to long-shore transport has increased the quality of shoreline change model around river mouth. However, the simulation of river mouth influence as sediment supplier still needs improvement.

Some main conclusion can be defined from this study. First, the influence of river mouth to the surrounding beach morphology is apparent in form of sediment supplier and obstruction of long-shore transport. Second, the magnitude influence as obstruction is smaller than as sediment supplier that makes the river mouth is considered only as sediment source in the coastal system. Third, the frequency of strong influence is in the order of days or months correspond with seasonal variation of river discharge. This makes argue that the river mouth can influence the adjacent beach in long-term scale. It can become exception if the large change is also work in the river itself, such as: dam construction in upstream, maintenance dredging, etc., which makes long-term influence to the river.

論文審査結果の要旨

沿岸域における土砂収支評価に際して，河川は土砂の供給源として位置づけられる．しかし，その存在が，河口噴流・河口前面堆積地形を通じて沿岸漂砂の連続性を分断する効果を持つ．特に，沖側に張り出した河口テラスが強固に存在する場合には，たとえ導流堤が無くても沿岸漂砂を阻止する効果を有する．本研究においては，仙台海岸に注ぐ七北田川河口周辺を対象として，河口の存在が周辺海浜漂砂系に及ぼす影響について土砂収支の観点から評価を行っている．

第１章では，「序論」として本論文の目的と構成について述べている．

第２章においては，河口部での土砂移動現象及び海浜での土砂収支に関する既往の研究を紹介し，これまでの扱いの問題点を明らかにしている．

第３章においては，本論文で対象とする仙台海岸の海岸線位置の変化率を用いて，マクロな汀線変化を解析している．その結果，河口左右岸において変動幅に大きな差異があることが確認された．これらは興味深い成果である．

第４章においては，現地観測により得られた沿岸方向の汀線位置データを even-odd analysis 及び empirical eigen-function 法によって解析している．その結果，第一成分が岸沖漂砂による海岸地形の変化を表し，第二成分が沿岸漂砂による地形変化に対応することが確認された．これは実用上，重要な成果である．

第５章においては，第３章において得られた汀線変化速度，河川流出土砂，及び流入沿岸漂砂量を加味して，土砂収支を評価している．その結果，河口テラスによる沿岸漂砂の阻止効果などを評価することが出来た．これは工学上重要な結果である．

第６章においては，汀線変化予測モデルを用い，河口テラスによる沿岸漂砂阻止の有無により予測結果が異なることを示している．この結果は，漂砂系に流入する河川の役割として，単に漂砂源のみならず，漂砂の不連続性を生じさせることの重要性を示している．これは海岸工学上重要な成果である．

第７章は総括及び今後の課題を述べたものである．

以上要するに，現地における海浜地形実測データをもとに河口部が周辺の漂砂環境に及ぼす影響を定量的に評価し，さらに数値シミュレーションによりその効果を明らかにしており，海岸工学分野の発展に寄与するところが少なくない．

よって，本論文は博士(工学)の学位論文として合格と認める．