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論 文 内 容 要 旨

In the field of coastal engineering, understanding the physical processes of sea bottom change is believed to be one of crucial works. The seaward limit of beach profile variability (called depth of closure) based on wave processes and sand characteristics is necessary to be examined for many research activities in sandy coast (Hallermeier, 1981; Kraus et al., 1998). In general, determination of depth of closure can be divided into two main approaches. The first one analyzes specific patterns and magnitude of profile changes from monitored data which in detail is the time series repetitive profile surveys, but in reality, it is difficult to obtain a complete and consecutive profile data collection, as well as the accuracy of the bathymetric surveys depending on the conducted survey methods (Birkemeier et al., 1981). Because beaches are extremely dynamic environments of changes in morphology and they are constantly influenced mainly by the impact of waves, several empirical equations exist for simulating this depth as the second approach. Normally, studies are firmly grounded on the idea that the depth of closure represents for a region would be the result of beach erosion generated by the highest waves, which would be the significant wave height occurred only 0.137% of the time (Hallermeier, 1981; Birkemeier, 1985). However, there are several remaining limitations in this idea that can be (i) the predicted deeper depth with increased observation duration (Nicholls et al., 1998), (ii) the existence of its longshore variation (Hinton and Nicholls, 1998; Francois et al., 2004), and (iii) its overestimation for periods of calm wave conditions. The evaluation of depth of closure with respect to seasonal changes has not been carried out in many studies. Although a more accurate empirical formula was improved by Birkemeier (1985) from Hallermeier (1981) equation based on higher quality field data, wave measurements and repetitive beach profile lines were generally surveyed in winter season. Therefore, the

only use of the 0.137% highest waves of the entire period to determine the depth of closure as proposed by Hallermeier's and Birkemeier's studies did not consider calmer wave conditions during summer season separately. In addition, a similar point of these studies above should be noticed that impacts of seasonal variation of wave characteristics were not obvious, i.e., seasonal longshore variation of coastal morphology in response to seasonal waves was not an important feature of their study sites. On the other hand, from profile lines surveyed by Birkemeier (1985), closure locations and depths varied monthly can be observed despite its slight variation. Therefore, a question that needs to be prompted whether it is really necessary to estimate the depth of closure for the periods of calm wave conditions and apply its result in engineering. For these reasons, instead of obtaining the single depth of closure for a region as in ordinary method, which may not be appropriate to apply to the beaches experiencing seasonal monsoon climate, this study proposes and clarifies the necessity in determining the seasonal or monthly depths of closure considering the influence of seasonal waves. At first, a study area, which has experienced by seasonal wave climate, should be taken into account. Therefore, Nha Trang Coast, located in South Central Vietnam and immensely influenced by tropical monsoon climate, is taken to be a case study and its morphological change has been analyzed. Interpretation of over 3.5-year time series of the fifteen-minute time-averaged images taken by a video-camera monitoring technique permits to distinguish the retreat and advance of shoreline which appear to be especially sensitive to the seasonal variation of wave characteristics. In the northeast monsoon season, the southward high waves resulting wider surf zone have caused the retreat of shoreline in the north and the southern deposition. Conversely, in the non-monsoon season, the northward waves are comparatively calm and the surf zone is thus narrow-width; therefore, the beach morphology tends to be recovered in the north area in response to the shoreline retreat in the south area. Then, results from the first EOF (Empirical Orthogonal Function) component (with 89% of contribution rate) reflect that the processes on Nha Trang Coast causing the seasonal evolution of morphology are alongshore dominated, and it corresponds to the changes of wave direction in each monsoon period. Moreover, most of the seasonal shoreline variability can be reasonably reproduced by the first EOF component. Due to the effect of seasonal waves, the significant wave height and the associated wave period according to each monsoon season have been investigated for identifying the relevant depth of closure. To be more specific, the 0.137% exceedance probability of significant wave height for the northeast monsoon season is slightly different to that in case without seasonal change. On the contrary, in case of the non-monsoon season, the distinct difference is there because the calm waves from east-southeast have been collected by removing the high northeast monsoon waves for investigation, and then a more accurate depth of closure for the calm wave period has been determined. Similar descriptions are for investigation of the monthly depth of closure to minimize the sudden change of the seasonal depths at the transition months. Additionally, the depth of closure for corresponded seasons might be expressed as a function of seasonal variation of the width of surf zone that can be extracted from the video-camera images. Because of the periodical shoreline response to seasonal waves, a considerable seasonal variability of longshore sand transport is obviously found on Nha Trang Coast, with beach erosion in relation to the southward sediment transport mainly during the period of strong northeast monsoon waves and deposition relating to the northward sediment movement occurring during the calmer weather in the non-monsoon period. The comparison for the rates of longshore sediment transport shows that its quantities in the non-monsoon period are overestimated by using a constant value of the depth of closure. The depth of closure varying seasonally and monthly are more effective variables for predicting the quantity and direction of net longshore sediment transport with deposited beach condition in the southern coast. In order to test the predictive capability of morphological change in each case of the depth of closure, a numerical modelling for investigating interaction between waves, sediment and structural variables in the trend of shoreline change is conducted. The calculated shoreline in the 4-year simulation is compared to the measured shoreline, which is extracted continuously based on a 40-month time series of camera image data. The calculated shorelines using seasonal and monthly depths of closure have good agreements with the measured shoreline. In which, the seasonal variation of shoreline position, especially the beach recovery process, is well reproduced. Based on the above results, the present study also leads to the following recommendations. Due to the continuous extracting shoreline data from the video-camera system, the relationship between morphological change, waves, winds and other factors can be described clearly. The applicability of the surf zone width for estimating the depth of closure is tested and can be useful to apply in other coastal areas. For coastal engineering application, an ordinary method to obtain the single depth of closure only based on the 0.137% largest waves of the entire period is merely appropriate if the fluctuations of wave characteristics in the entire period are not obviously with seasonal and monthly trends in every year. The proposed approach to determine the depth of closure corresponding to each monsoon wave condition could be easily applied in engineering. At least, this approach is obviously necessary to apply in the coastal areas, which have similar characteristics (e.g., the seasonal beach bounded by two groins or headlands). Furthermore, because information related to the river mouth (e.g., river discharge) in the present study area is missing, the scope of the present investigation did not allow for adding the feature of this river mouth in the calculation process. However, for further development, it is necessary to improve that by investigating the sediment transferred or bypassed around the coastal inlets and river mouths.

論文審査結果の要旨

漂砂移動限界水深は地形変化が生じる沖側限界での水深と定義され，汀線変化モデルによる予測や養浜効果の推定に際して使用される重要な物理量である．通常は沿岸域で一定値と扱われ，沖波条件・底質条件から定まるとされるが，波動場が顕著な季節変動を示す場合には一定値とはならない．この様な限界水深の時間的変化は汀線変化予測精度にも影響を与えるものであり，実務的にも重要性が高い．そこで，本研究では現地データ・数値シミュレーションをもとに，漂砂移動限界水深の季節変動と，それが漂砂移動に及ぼす影響について検討を行った．

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，漂砂現象，漂砂移動限界水深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，研究対象のベトナム・ニャチャン海岸の特徴，使用データ，研究手法について述べている．

第４章においては，ニャチャン海岸における長期・短期の汀線変動特性を示しており，北東モンスーンと南西モンスーンに応じて波浪条件が大きく変化し，それに伴う特徴的な汀線変動が生じることを明らかにしている．この結果は海岸工学上，きわめて重要な成果である．

第５章においては，ビデオ連続画像から移動限界水深の季節変動特性を論じ，南西モンスーン期に極端な減少が生じることを明らかにしている．これは，海浜予測にとって重要な知見である．

第６章においては，ビデオ連続画像から漂砂量の季節変動特性を推定しており，海岸管理の実務にとってきわめて重要な成果である．

第７章では季節的な波浪による移動限界水深の変化を加味したワンラインモデルによるシミュレーションを実施し，旧来計算手法による計算結果との相違を明らかにしている．これは海岸工学上，重要な成果である．

第８章では総括及び今後の課題を述べている．

以上要するに，現地資料および数値シミュレーションにより，モンスーン地域での漂砂移動限界および漂砂量の季節変動特性とその機構を明らかにしており，今後，汀線変化予測モデルの改良などにつながる実務的応用の可能性を有している．したがって，海岸・海洋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．