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REMOTE SENSING IMAGE ANALYSIS ON CIRCULATION INDUCED BY THE BREAKWATERS IN THE HUANGHUA PORT

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Abstract: The Huanghua Port is a port newly constructed in North China. The phenomena of current along breakwater and circulation induced by the structures around the Huanghua Port are analyzed using the satellite remote sensing images. According to the hydrodynamic and meteorologic conditions, it can be concluded that the current along breakwater and circulation induced by the structures emerges generally under the conditions of ebb tide. Furthermore, the wind-driven current and the wave-generated longshore current may play important roles. From the point of view of sediment transport, the current along breakwater may result in high sediment concentration in local area. This will lead to severe siltation in the local area of the outer channel of the Huanghua Port.

Key words: Huanghua Port, Current along breakwater, Circulation, Siltation, Satellite remote sensing

1. INTRODUCTION

The Huanghua Port, sited on the southwest coast of Bohai Bay, is the largest newly-constructed coal-export port in north China. It belongs to typical man-made harbour on mild beach consisting of fine-grained sediments. During the first phase of the outer channel dredging of the Huanghua Port from the year 2000 to 2001, rather severe siltation occurred. Especially in the outer channel section of 3km−7km (3+0−7+0) seaward from the channel entrance, local siltation was quite obvious. To explore the mechanism of the channel siltation, multi-discipline researches are needed. In the present paper, the phenomena of current along breakwater or circulation induced by structure is analyzed through the collected satellite remote sensing images in the coastal area around the Huanghua Port. The effect of sediment transport caused by the current along breakwater on local siltation is discussed.

2. CURRENT ALONG BREAKWATER AND CIRCULATION PHENOMENA REVEALED BY REMOTE SENSING IMAGES

2.1 COLLECTION OF REMOTE SENSING IMAGES

Remote sensing data have the characteristics such as good periodicity and visualized images. Through synchronous calibration of field data, sediment concentration in the sea surface layer can be quantitatively determined. So the technique of satellite remote sensing are more and more wildly applied in coastal dynamics and sediment transport research (He Qing and Yun Caixing, 1999). In order to study local flow fields and sediment transport pattern in the vicinity of the Huanghua Port structures, 16 remote sensing images of LANDSAT (Landsat 5 and Landsat 7) around the Huanghua Port were collected, and 4

images with noticeable phenomena of current along breakwater or circulation are analyzed in the present paper. All images were provided by China Remote Sensing Satellite Ground Station.

2.2 CURRENT ALONG BREAKWATER AND CIRCULATION REVEALED BY REMOTE SENSING IMAGES

Fig. 1−4 are multi-temporal remote sensing images around the Huanghua Port. The images, which use the third band data of LANDSAT5 TM or LANDSAT7 ETM+, are obtained through image stretching and enhancing by utilizing the remote sensing analysis software of ENVI. It can be seen directly from the images that notable currents along both sides of breakwaters of the Huanghua Port occur. Because the formation mechanisms of current along breakwater may not be identical under different dynamical conditions, the width and length of the current along breakwater on both sides of the breakwaters are different. The pattern and scale of jet flow or circulation after the current along breakwater departing from channel entrance are also different. It should be pointed out that Fig. 1−4 are all images on ebb-tide phase and no current along breakwater appears on flood-tide phase in all collected 16 images.

2.3 EFFECTS OF CURRENT ALONG BREAKWATER AND CIRCULATION ON CHANNEL SILTATION

The gray-scale values at different points in Fig. 1−4 can approximately denote the magnitudes of sediment concentration. It can be simply summarized that the larger the gray-scale value (the lighter the color), the larger the sediment concentration is. It can be observed from the remote sensing images that currents along breakwater will carry large amounts of sediment moving to the offshore zone when the sediment concentration is large and high sediment concentration zone is wide in the nearshore area. The jet flow or large-scale circulation with high sediment concentration will build up when the current along breakwater extends seaward over the tips of the breakwaters. The length of jet flow or the diameter of circulation may reach more than 10km. Due to high sediment concentration carried, the jet flow or circulation may play significant roles on the local siltation of outer channel. Particularly it can be seen from the images that the current along breakwater will gradually decrease its velocity and deflect its direction to intersect with channel due to various influences of ambient flow fields. As a result, high concentration sediment carried by the current along breakwaters is likely to deposit directly in the channel with which the jet and circulation intersect. The intersecting positions of the current along breakwater and the outer channel are located at 3+0−10+0 along the outer channel, which coincides with the field observation of relatively severe local siltation. Thus it can be concluded that sediment transport by the current along breakwater is one of the most important factors for relatively severe local siltation in the outer channel of the Huanghua Port.

Fig. 1 TM Image around the Huanghua Port (End of ebb-tide for spring tide on Jun. 16, 1999)

Fig. 2 TM Image around the Huanghua Port (End of ebb-tide for meso-tide on Dec. 9, 1999)

Fig. 3 ETM+ Image around the Huanghua Port (End of ebb-tide for meso-tide on Mar. 9, 2001)

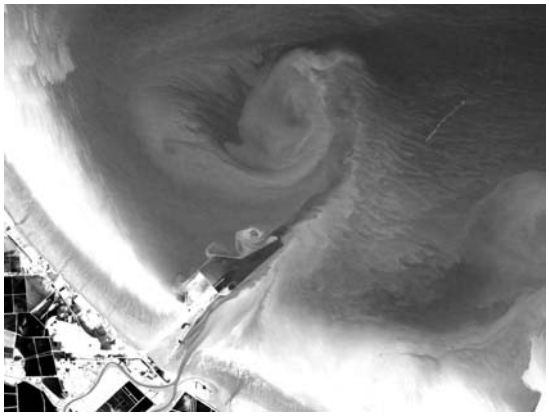

Fig. 4 ETM+ Image around the Huanghua Port (End of ebb-tide for meso-tide on Mar. 25, 2001)

3. ANALYSIS OF FORMATION REASONS OF CURRENT ALONG BREAKWATER AND CIRCULATION

The formation of current along breakwater and circulation may attribute to the following reasons. The first reason is that the longshore current, induced by the wave transformation within the surf-zone, will flow seaward along structures after being blocked off by the cross-shore structures. These phenomena have been widely observed on sandy coasts with steeper beaches (Baquerizo and Losada, 1998; Wind and Vreugdenhil, 1986). They may also occur on the coarse silt beach, such as Jingtang Port in China (Wang Chenghuan, 2000). But no observation has been reported on fine-particle sediment coast with finer silt and mud, as far as the authors have known. The second reason is that the tidal current in the coast area, being blocked off by the cross-shore structure, will generate circulation of which the current along breakwater is the important component. The third reason is the effect of strong winds. Wind-induced circulation can be generated in the shallow water of nearshore zone and can form the specific circulation configuration due to the presence of cross-shore structure. In this way, the current along structure is a part of wind-induced circulation. The above effects may occur simultaneously, and the complex circulation is formed. To explore the formation reasons of the current along the breakwater of the Huanghua Port, the four images shown in the Section 2 will be analyzed here by taking the hydrodynamic and meteorologic conditions into consideration.

Fig. 1 shows the image on Jun. 16, 1999. The wind situation was NE4 (which means that the wind direction was Northeast and the wind velocity was at the fourth wind scale), and the tidal situation was spring tide on the end of ebb. Wind of ENE7 occurred on Jun. 15, which caused high sediment concentration in the nearshore area. The current along the breakwaters, mainly induced by ebb tide, carried large amounts of sediment from the nearshore zone toward the open-sea when the satellite of Landsat5 was passing this area. Based on the image, it can be judged that the current velocity along the north side of the breakwaters is larger than that along the south side. Affected by wind-drift and ambient ebb current, the currents along both south and north side deviated to the southeast and intersect with the channel.

Fig. 2 shows the image on Dec. 9, 1999. The wind situation was SW3 and the tidal situation was meso-tide on the end of ebb tide. Currents along both sides of breakwaters can be clearly seen from the image. At the place about 4.4km away from the entrance, the jet shows the tendency of slight bend to south and the circulation is not obvious. According to the meteorology condition, it can be concluded that the currents along breakwaters in the image are mainly induced by ebb current.

Fig. 3 shows the image on Mar. 9, 2001. The wind situation was SW5 and the tidal situation was meso-tide on the end of ebb tide. Analyzing the image in detail, it can be concluded that the sea area outside the entrance is likely in the initial phase of flood tide, because the water with high sediment concentration just outside the entrance, caused by the current along the south breakwater during the ebb tide, begun to move toward the northwest on the effect of flood tide. As a result, "the clear water" formed by the ebbing current between the two breakwaters deviated to northwest. From the image, it can be estimated that seaward winds have an effect of increasing the current along breakwater induced by tide. The influencing area of the current along breakwater can attain 10km far from the entrance.

Fig. 4 shows the image on Mar. 25, 2001. The wind situation was ENE7−8 and the tidal situation was meso-tide on the end of ebb-tide. The image shows that the current along the south breakwater is more noticeable than that along the north breakwater, and the large-scale circulation appears seaward from the entrance. According to meteorologic condition, strong waves of ENE direction occur in the coastal area due to strong winds of ENE. All of the wave-induced set-up, longshore current together with the wind set-up and wind-induced drift may be large. All these factors may contribute to the current along the south breakwater and makes it deviate to north after it flows seaward over the breakwater tip, and consequently forms the large-scale circulation.

According to the collected satellite remote sensing images, the current along breakwater and its induced sediment transport phenomena only occurs at ebb tide. It can be concluded that the interaction between tidal flow field and the harbour structures is the dominant reason in the formation of the current along breakwater. The occurrence of different circulation pattern under the same tidal situation shows that wind-drift current, longshore current and wind-induced or wave-induced set-up in nearshore zone are supposed to play significant roles on the intensity of current along breakwater and the formation of circulation.

4. CONCLUSIONS

From the collected satellite remote sensing images, it can be seen that the current along breakwater mostly emerges on the end phase of ebb tide. It can be concluded that the ebb current is one of main factors in the formation process of the current along breakwater or circulation around the Huanghua Port. In addition, after the current along breakwater flow seaward off the structures, the scales of jet or circulation enlarge obviously in the situation of strong winds. Therefore, the formation of current along breakwater in nearshore zone is not only related to flood and ebb tide, but also significantly affected by wind-drift current and longshore current induced by wind waves. Comprehensive effects of the above factors are likely to produce complex circulation around the Huanghua Port. As for the sediment transport, the current along breakwater with velocity generally larger than the ambient waters, can carry large amounts of sediment from the nearshore zone and flow toward the offshore zone. When the current along breakwater departs from breakwater tips, affected by the ambient waters, bottom friction and wind-generated current, its velocity decreases gradually and its direction deflects to intersect with the channel at last. During the last motion period of the current along breakwater, some of the high concentration sediment in the current will most possibly deposit in the channel. Other sediment may deposit on the beach around the channel, and become the sources of channel siltation for the future. According to the satellite remote sensing images, the main location at which the current along breakwater intersects with the channel is around 3+0−10+0 in the outer channel of the Huanghua Port, which corresponds to relatively severe position of local siltation in the outer channel. Thus it can be concluded that sediment transport by the current along breakwater is one of the important factors causing relatively severe local siltation in the outer channel of the Huanghua Port.

In the present paper, the phenomena and formation reasons of the currents along the breakwaters and their impacts on local siltation in the Huanghua Port, are analyzed primarily. Because of the complexity of hydrodynamic factors and sediment movement, more work is to do on the formation process of the current along breakwater and quantitative influences of sediment transport by the current along breakwater on harbour siltation by means of numerical simulation.

REFERENCES

He Qing and Yun Caixing, 1999. Study of coastal stability in the Sanmen Bay based on the remote sensing data. *Acta Oceanologica Sinica*, Vol. 21, No. 5, pp. 87-94 (in Chinese)

Baquerizo A., and Losada M. A., 1998. Longitudinal current induced by oblique waves along coastal structures. *Coastal Eng.*, Vol. 35, pp. 211-230

Wind H. G. and Vreugdenhil C. B., 1986. Rip-current generation near structures. J. Fluid Mech., Vol. 171, pp. 459-476

Wang Chenghuan, 2000. The movement regulation and renovation measures for silty sediment close to Jintang Port. Port Engineering Technology, No. 1, pp. 5-10 (in Chinese)