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SCOUR MONITORING AROUND THE BREAKWATER HEAD AT MAILIAO HARBOR

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Breakwaters are usually placed on seabed to prevent a shore area or harbor from waves attack or current-induced erosion. However, scouring often occurs in the neighboring area of breakwaters, especially around a breakwater head or deflected points where contraction of flow or wave reflection and diffraction occurs, to induce breakwater failures. Severe souring occurs near the head of west breakwater III at Mailiao harbor located on the southwestern coast of Taiwan. Therefore, to study the head scour phenomena, the past field measurements including bed topography and sediment characteristics in the neighborhood of the breakwater head are collected. By assuming tidal current to be the main and the only force, results of velocity field in the neighborhood of the head simulated by DHI MIKE21 are presented as well. The equilibrium scour depth and time scale are discussed in this paper.

Key Words : *breakwater, field measurement, bed topography, Mailiao harbor, equilibrium scour depth*

1. INTRODUCTION

Most of coastal man-made structures are placed on seabed directly, usually exposed to waves and currents, and combined waves and currents. Since the presence of the structure often changes the flow field in its neighboring area, resulting in an increase of the sediment transport capacity in the vicinity of the structure. This therefore often leads to scour, and if the scour hole is too deep and the scour extent is too large, breakwater failures may occur.

Mailiao harbor, located on southwestern coast of Taiwan (figure 1), constructed in compliance with the necessities of the Sixth Naphtha Cracking Complex Project in Taiwan is of importance in transporting raw materials and processed products in the offshore Primary Industrial Zone in Yunlin, Taiwan. During construction of the west breakwater, it was paused for five to seven months every year due to the severe construction condition caused by the northeastern monsoon. Therefore, six scour locations had been observed, which are at caisson #17, #36, #50, #62, #80, #90 during the construction period.

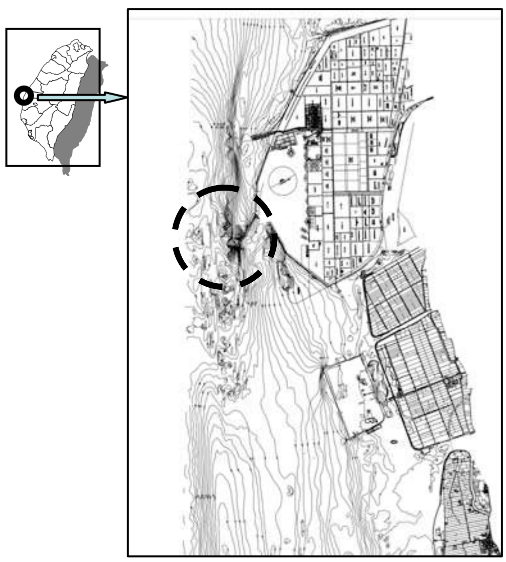

Figure 1 Mailiao harbor. Circle indicates the location of WB III head

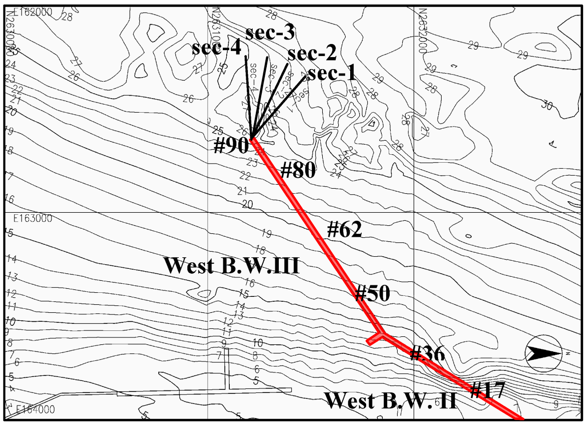

Figure 2 Seabed topography in May 1996 prior to WB III was built.

These temporary positions of scour hole were located at around 120m away from the end of the unfinished breakwater, 45° measured clockwise from the centerline of the breakwater. In addition, after the last caisson (#90) of the west breakwater III (referred to as WB III herein after) was placed in November 2000, the scour hole continues changing its depth and extent. In order to prevent the possible continuous scouring, WB III was extended by a submerged breakwater with 150m which was constructed from May 2004 to Jun. 2006. The long-term behavior of the scour hole near the head and whether the stability is reached are of great interest.

2. FIELD MEASUREMENTS

(1) Historical changes of bed topography

WB III was under construction from May 1996 to September 2000 and a submerged rubber-mount breakwater along the centerline of WB III was constructed from May 2004 to Jun. 2006. In order to study the behavior of the head scouring, past field measurements near the head of WB III dated in between 1996 to 2007 are collected, and the analyses of the bed topography are presented at four stages in respective with different construction period as follows.

a) Prior to construction of WB III (before March 1996)

Figure 2 displays the bed topography in the neighborhood of WB III in March 1996 when WB III has not been built yet. It can be seen that prior to the construction of the breakwater, the slope of seabed in the near shore region where the water depth is less than 25m is rather mild. The slope of seabed in the region where the bed level is between

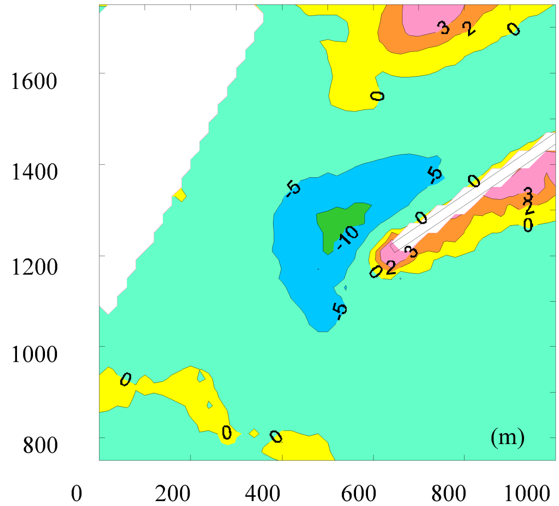

Figure 3 Accretion/Erosion near the head of WB III (May 2001-March.1996)

-5m~-15m is about 1:100 and where the bed level is between -15m~-25m is about 1:80. On the other hand, the bed topography with water depth greater than 25m is more complex and irregular, but the overall slope is milder. It seems that current might be the dominant force on the bed topography variation where the water depth is greater than 25m.

b) After the completion of WB III (from September 2000 to May 2004)

After the last caisson (#90) of WB III was placed in September 2000, a scour hole quickly formed. Two field measurements in May 2001 and April 2004, after the completion of WB III and prior to the construction of the submerged breakwater, are compared with the bed topography in March 1996, and the results of accretion/ erosion are shown in figure 3, and figure 4, respectively.

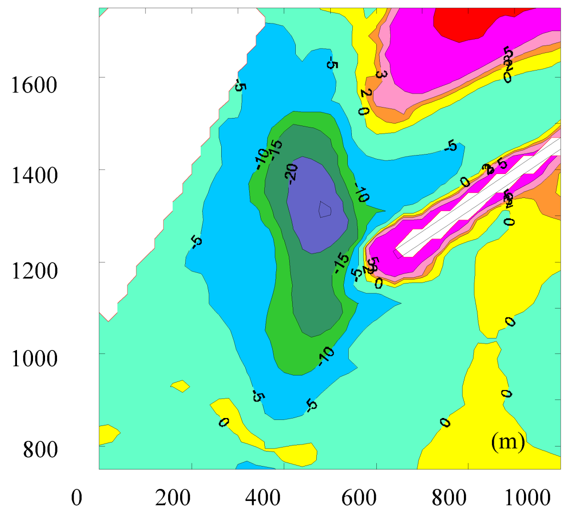

Figure 4 Accretion/Erosion near the head of WB III (April 2004 March.1996)

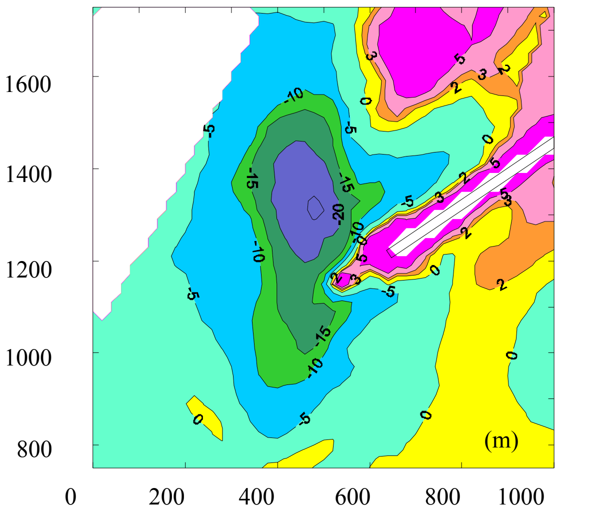

Figure 5 Accretion/Erosion near the head of WB III (April 2005-March.1996)

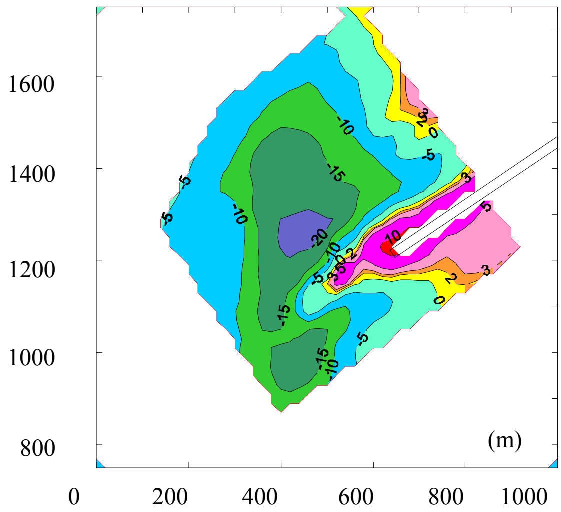

Figure 7 Accretion/Erosion near the head of WB III (March 2007-March.1996)

Figure 3 shows that in May 2001 just after the construction of WB III was completed a scour hole with maximum scour depth to 12m was formed at about 125m away from the head of the breakwater, 45° from the extended centerline of the breakwater when measured clockwise. Figure 4 shows that in April 2004 the scour extent enlarged both in the northern and southern direction with the maximum scour depth of 25m and the center of scour is about 215m away from the head, 75° from the centerline.

c) During construction of the submerged breakwater (from May 2004 to Jun 2006)

WB III was extended by a submerged breakwater with length of 150m and top design level of -24.1m, which was constructed from May 2004 to Jun. 2006. Figure 5 is the accretion/erosion in April 2005 compared with March 1996. It can be seen from figure 5 the appearance of the submerged breakwater. The reason why a boulder like topography appears at the location of the submerged breakwater is due to bad construction conditions. Figure 6 shows that in May 2006 the extent of the sour hole is reduced significantly. The maximum scour depth was reduced about 4m and the location was moved southward along the submerged breakwater.

d) After completion of the submerged breakwater (after June 2006)

Figure 7 and figure 8 show that in March 2007 and in August 2007, after the completion of submerged breakwater, the scour hole is gradually

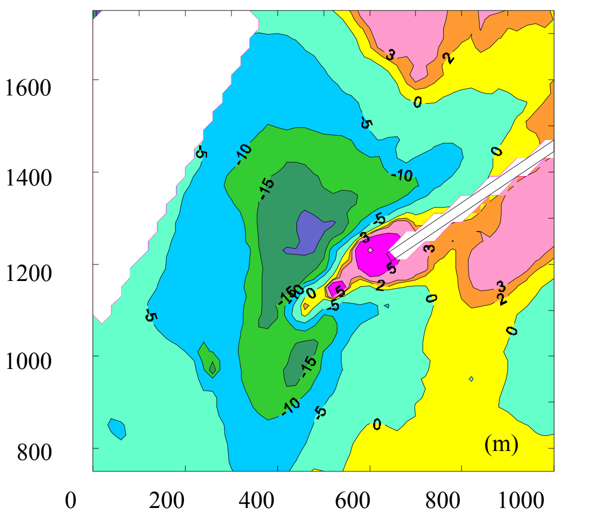

Figure 6 Accretion/Erosion near the head of WB III (May 2006-March.1996)

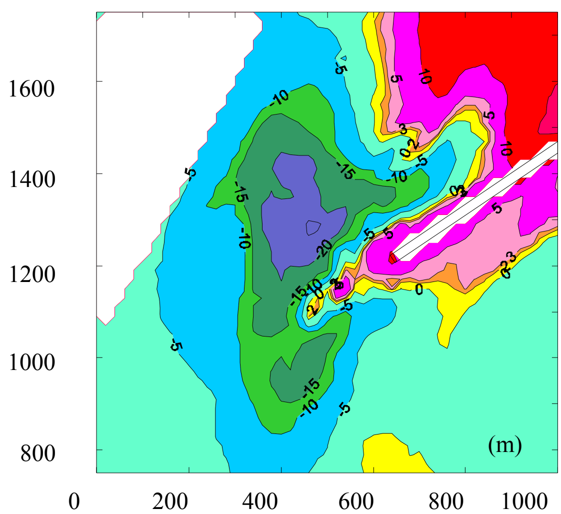

Figure 8 Accretion/Erosion near the head of WB III (August 2007-March.1996)

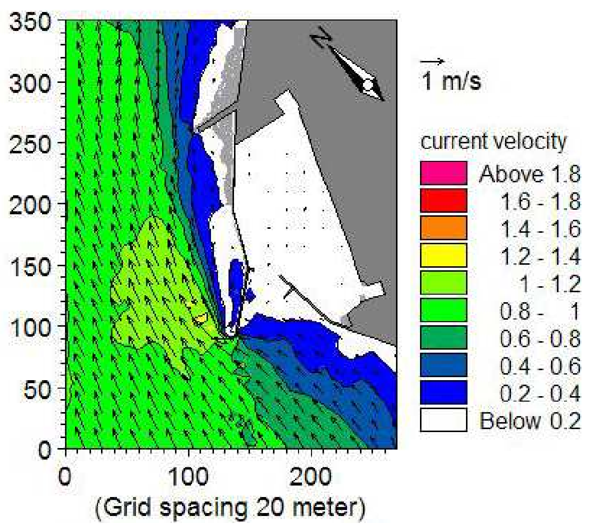

Figure 9 Flow field during flood tide

increasing its extent with the width of the region where scour depth is greater than 20m widened from about 100m to 250m, and maximum scour depth of 25m is approximately equal to the maximum scour depth in April 2004.

(2) Characteristics of bottom sediment near the project site

According to the survey reports between the year of 1996 and 1999, in which 4 surveys were performed, bottom sediment at project site is quartz sand grain with the density of quartz being 2.65 kg/m^3. The survey results also show that the average median diameter (D50) of each survey is ranged from 0.22mm~0.28mm. D90 is ranged from 0.37mm~0.46mm. The void ratio is 0.33~0.54. The fall velocity is about 2.5 cm/s for diameter of

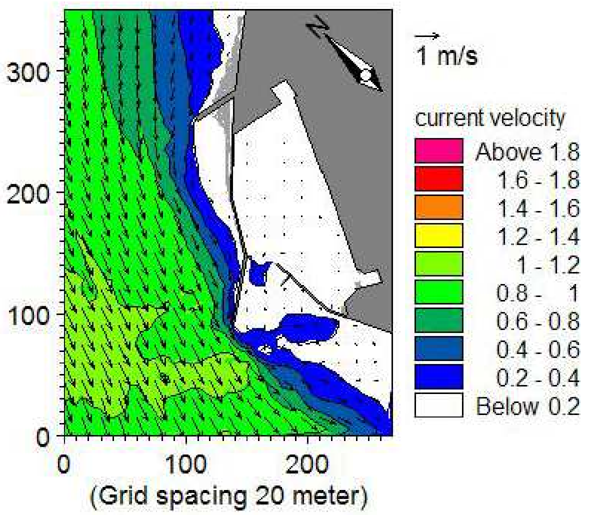

Figure 10 Flow field during ebb tide

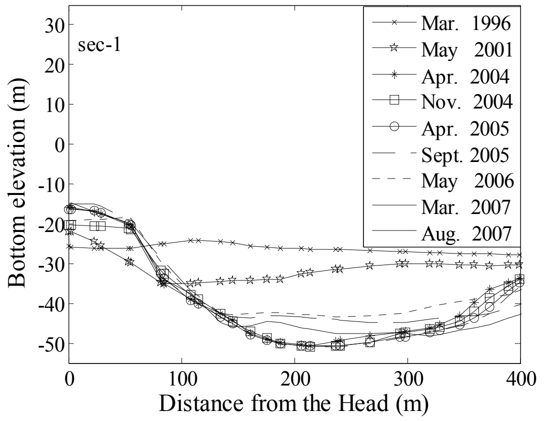

Figure 11 Measurements of seabed level along Sec-1

0.24mm at seawater temperature 20℃. The critical velocity of the bed materials transport with diameter of 0.24mm is 25cm/sec~40cm/sec by van Rijn[1)].

3. NUMERICAL SIMULATIONS OF FLOW FIELD

Flow field simulation is carried out by HD module of MIKE21. Simulation time is from 2001/08/07 00:00 ~ 2001/08/25 24:00 due to the availability of the water level measurements. Figure 13 and figure 14 are the results of flow field during flood and ebb tide, respectively. It shows that during flood tide the flow direction near the head of WB III is from south to north and a clockwise vortex occurs near the west breakwater at sea side. In addition, during ebb tide the flow direction near the head is opposite the flood tide and a counterclockwise vortex occurs near the east side of WB III. The simulated results are validated with a field measurement of current with a good agreement. The results also indicate that the current velocity near the head of WB III during flood tide is greater than the velocity during ebb tide, namely net mass transport is from south to north. Furthermore, the maximum current velocity near the head during simulation period is about 1.2 m/s.

4. DISCUSSIONS

The past surveys show that severe scouring occur in between 30° to 75° measured clockwise from the extended centerline of WB III. Hence, the historical changes of bed topography along profile sec-1 to sec-4 indicated in figure 2 is further investigated and the results of sec-1(75°), sec-2(60°), and sec-3(45°) are shown in figure 11, figure 12 ,and figure 13, respectively. The bed level and location of lowest point along each profile (sec-1 to sec-4) are

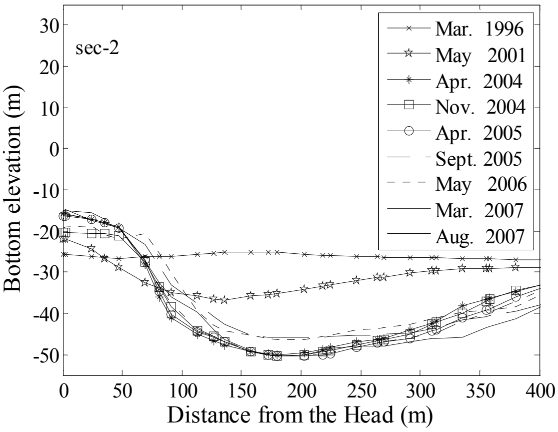

Figure 12 Measurements of seabed level along Sec-2

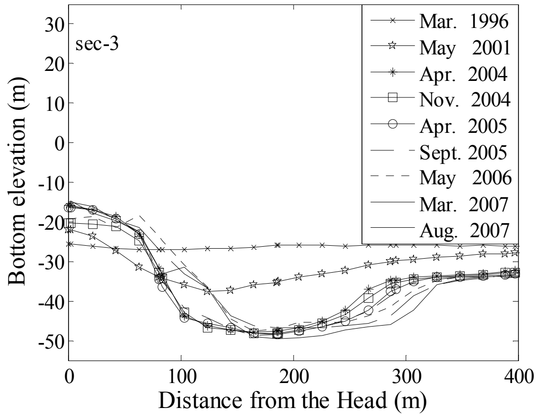

Figure 13 Measurements of seabed level along Sec-3

indicated in table 1. It can be seen that after the completion of WBIII, the bottom topography seems become stable with the maximum scour depth about 25 m. During the construction of the submerged breakwater, temporary deposition at the scour hole occurs. However, an evidence of the lowest point of sec-2 in August 2007 coincides with the one in May 2006 shows that after the completion of the submerged breakwater, the sea bed was eroded again. It seems that the submerged breakwater has little effect upon preventing the erosion near the head.

Time variation of scour depth can be approximately represented by the following equation, Sumer & Fredsøe[2)]

$$\frac{S_t}{S} = \left[1 - \exp\left(-\frac{t}{T}\right)\right] \qquad (1)$$

where S is the scour depth corresponding to the equilibrium stage and T is the time scale of the scour process. Figure 13 displays the time development of the scour hole in which Time=0 indicates March 1996. It can be seen from figure 13 that the equilibrium scour depth seems to be reached, and the time scale of the scour process is about 10 months. In addition, the simulation of current velocity near the head indicates that the net flow in a tidal period is in north direction, which shows the sour is more severe at the north side of the head of WB III. It seems so far the scouring has reached the equilibrium stage, however for the safety of the structure monitoring on a regular basis is suggested.

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Table 1 Maximum Scour along sec-1~ sec-4

Time	sec-1(75°)		sec-2 (60°)		sec-3 (45°)		sec-4 (30°)	
mon.yr	BL	D	BL	D	BL	D	BL	D
(a)no WBIII								
05.96	-24.2	115.0	-25.1	172.3	-25.7	0.0	-25.1	402.3
(b)after completion of WBIII								
05.01	-35.1	108.6	-36.8	135.7	-37.7	124.3	-37.3	142.4
04.04	-50.6	214.5	-50.2	180.2	-47.9	165.0	-46.3	182.5
(c)during construction of the submerged breakwater								
11.04	-50.9	214.5	-50.4	180.2	-48.3	165.0	-47.0	162.4
04.05	-50.7	214.5	-50.4	180.2	-48.4	185.4	-47.4	182.5
09.05	-50.9	240.9	-50.3	180.2	-48.6	165.0	-46.2	182.5
05.06	-43.6	240.9	-46.5	202.4	-47.7	165.0	-46.1	202.5
(d)after completion of the submerged breakwater								
05.07	-44.8	293.9	-45.9	202.4	-46.9	205.8	-46.2	222.6
08.07	-48.2	320.3	-50.3	180.2	-49.5	186.3	-47.2	202.5

* BL: bed level (m) , D: Distance(m)

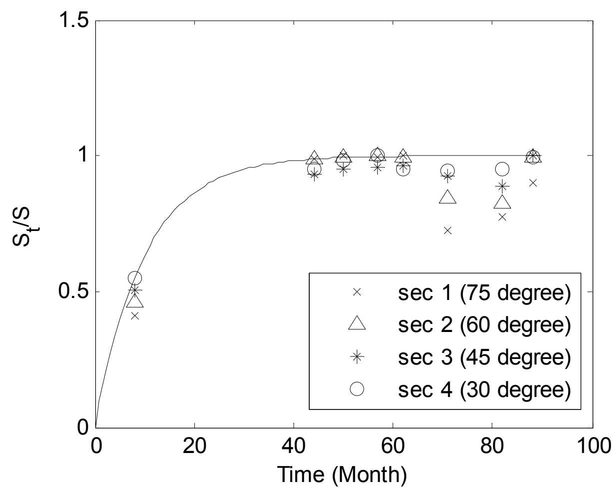

Figure 14 Time development of scour depth