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CALCULATION AND ANALYSIS OF SEDIMENT DEPOSITION IN NANHAI PETROCHEMICALS DONGLIAN PORT AREA

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Abstract: Based on the simulated current fields under different layouts offered by numerical models, the Liu Formula Cao and Formula, which have been widely used in the sedimentation engineering, are adopted to calculate the volume of sediment deposition. The calculated results show that the depositing intensity and the amount of sediment deposition are not large. If the maintained water depth is –9 m, the dredging amount for keeping this depth is just 70,000 m^3 to 80,000 m^3; if the maintained water depth is –11 m, the dredging amount for keeping this depth is just 110,000 m^3 to 120,000 m^3.

Key words: Port area, Sediment deposition, Calculation and analysis

1. GEOGRAPHIC LOCATION

The proposed Donglian port area is planned to be located at the top of Days Bay, at the northwest of Huizhou port about 7.5km, near the Xiayong scenic spot at the east, facing the sea area of Daya Bay at the south, and linking the center area of Daya Bay at the west in Guangdong Province. The vegetation is very flourishing along this shore and its geographic location is excellent. The dock is planned to build around -4.0m contour line at the northeast of Ezhou Island (the Theory depth datum plane, the same below), and to adopt form of the trestle with mooring dolphins. Its berthing pocket and turning area are open and without protection. The dock is connected with sea shore through an approach pier which length is 1238m (in Fig. 1).

2. HYDRODYNAMIC CONDITIONS AND SEDIMENT CONDITIONS IN PROJECT AREA

2.1 TIDE

The type of tide in this sea area is a kind of semidiurnal mixed tide. T he time of diurnal tide is 8 to 10 days, and other time is the semidiurnal tide every month. The tidal waves have obvious distortion during spreading from the open ocean into Daya Bay, so the diurnal inequality of tide is very obvious. The annual average range of tide is 1.03m, the maximum is 2.68m and the average sea level is 1.20m in this project sea area. This sea area is a weak tide one.

2.2 TIDAL CURRENT

The average speed of tidal current is 0.07m/s to 0.24m/s in Daya Bay where belongs to a weak current bay. The value of tidal current speed is gradually reduced from the mouth of bay to the top of bay. The minimum speed happens at the berthing pocket and the approach channel near the shore. In such areas the average speed is 0.09m/s to 0.16m/s, and the maximum is less than 0.30m/s (in Table 1).

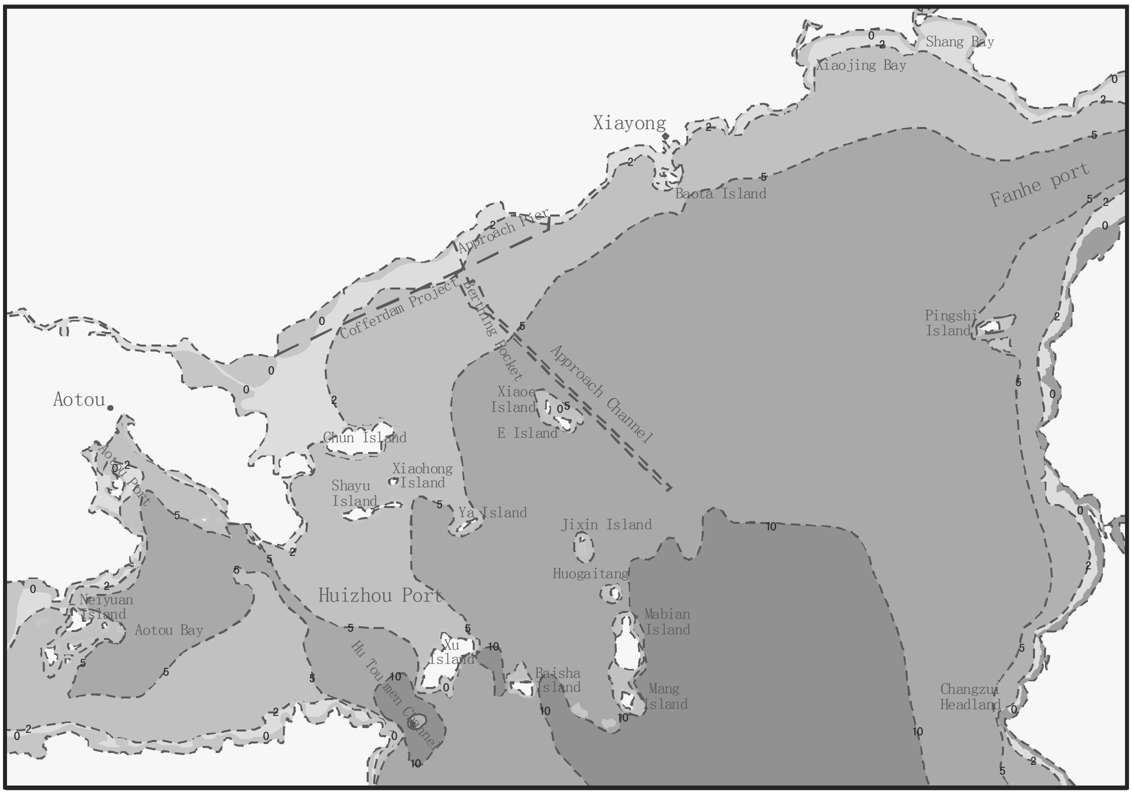

Fig. 1 Geographic Location of Nanhai Petrochemicals Donglian Port area

Table 1 Speed in Daya Bay Unit: M/S

Date	Mouth of the bay		Center of the bay		Project sea area			
					-9m		-4m	
	Ave	Max	Ave	Max	Ave	Max	Ave	Max
Jan 20～21 1992	-	-	0.20	0.39	0.16	0.29	0.09	0.17
July 02～03 1992	0.21	0.45	0.19	0.40	0.14	0.26	0.10	0.18

The tidal current is rather weak in the project sea area. In view of the measuring accuracy and for the speeds more than 0.1m/s, their average flood tide direction is the north and northwest (4^o and 306^o) and the ebb tide direction is the southeast (115^o).

2.3 SEDIMENT CONCENTRATION

There is not any great river a round t his sea a rea, t he hydrodynamic force is rather weak, the tideland is steady, and the sediment resource is not rich. So the sediment concentration is low and the sea water is clear except windstorm climate. According to the site data from some whole hydrologic surveys that they were taken in a flood tide and an ebb tide during normal climate without wind in this project sea area the average sediment concentration is 0.010kg/m^3, the maximum value is just 0.018kg/m^3.

2.4 WAVES

The factors including the typhoon, the freezing air and the landform environment affect the process that the waves grew up and lower, and the character that the waves spread. While passing the bay mouth the waves spread into the inside of the bay, because of the block action from a lot of islands and headlands, the wave energy is reduced rapidly. According t o t he site w ave data made b y Ezhou Measuring Wave Station from January 1992 to January 1993, the type of waves is mainly the mixed waves which dominant factor is the wind-generated wave in this sea area. The dominant wave direction is SSE with a frequency of 31.0%, the sub-dominant wave directions are SE and S with their frequencies of 11.5% and 11.1% respectively. The powerful wave direction is ESE to SSE. The average wave height is 0.2m, the maximum height is 3.1m and the annual average period is 3.9s (in Table 2).

Table 2 Monthly max wave heights and ave wave parameters from Ezhou Station

Wave parameters	1	2	3	4	5	6	7	8	9	10	11	12	Annual
H_{max}(m)	1.6	1.4	1.0	0.9	1.0	1.9	3.1	1.2	1.9	2.6	1.4	1.2	3.1
$H_{1/10}$(m)	0.4	0.4	0.3	0.3	0.3	0.4	0.7	0.4	0.4	0.4	0.4	0.3	0.4
$H_{1/3}$(m)	0.3	0.3	0.2	0.2	0.2	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.3
H_{mcan}(m)	0.2	0.2	0.1	0.1	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2
$T_{1/3}$(s)	5.4	4.8	3.7	3.7	4.1	5.0	6.1	5.5	5.8	5.8	6.2	5.6	5.2
T_{mcan}(s)	4.1	3.7	2.9	2.8	3.2	3.9	4.8	4.2	4.5	4.5	4.5	4.1	3.9

2.5 BED MATERIALS IN PROJECT SEA AREA

The Fig. 2 and Fig. 3 show the distributions about the types of bed materials and theft median size (Md Φ)in the center of Daya Bay. In both Figures it is clear that the bed materials are mainly the fine grain materials in above sea area; outside the contour line of -4m, are the clayey silt and the silty clay with the median size of 7 Φ to 8 Φ that is its d_{50} of 0.0156mm to 0.0039mm, and the average value is 0.0098mm. Generally these materials belong to a type of silt. In addition the sand and rather rough silt mainly distribute along tideland and around some islands.

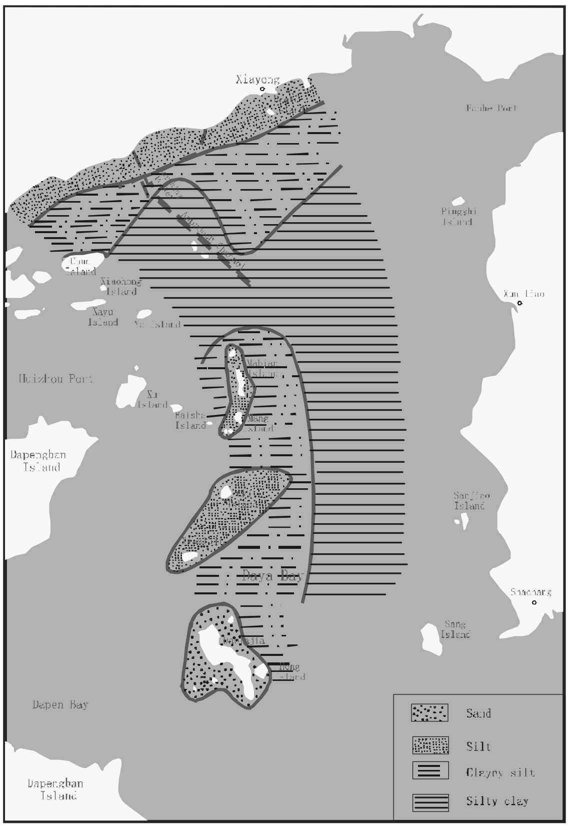

Fig. 2 Distribut on of bad materials at center of Daya Bay

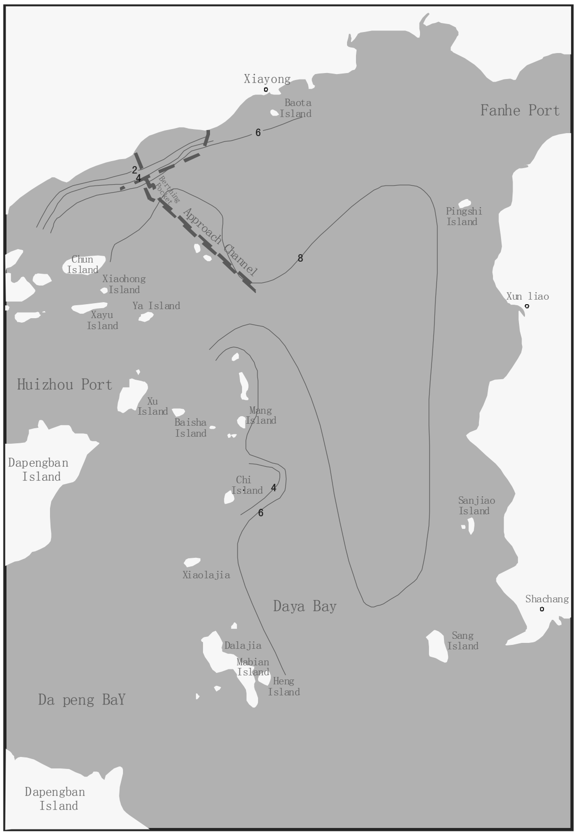

Fig. 3 Medina N size distributioin of bed materials at center of Daya Bay

3. CALCULATION ON SEDIMENT DEPOSITION FOR PORT AREA

3.1 PROJECT LAYOUT

The plan layout of Nanhai Petrochemicals Donglian Port area has two elementary types.

The first one:An approach pier extends to the contour line of-3m. For the approach pier the length is 1238m, the trend is 157^{o} to 337^{o}; along above direction the outside of the approach pier links a berthing jetty immediately. The designed depth in its approach channel and berthing pocket is -9m and -11m respectively (in Fig. 4).

The second one: The position and length are ditto, but both the jetty and its berthing pocket rotate towards the north 34^{o}. The designed depth in its approach channel and berthing pocket is still -9m and -11m respectively (in Fig. 5).

On the two elementary layouts, in view of other two plans whether the reclamation project is to be built upwards of the tideland at the end of the approach pier, the designed sizes for kinds of layouts can be showed in Table 3.

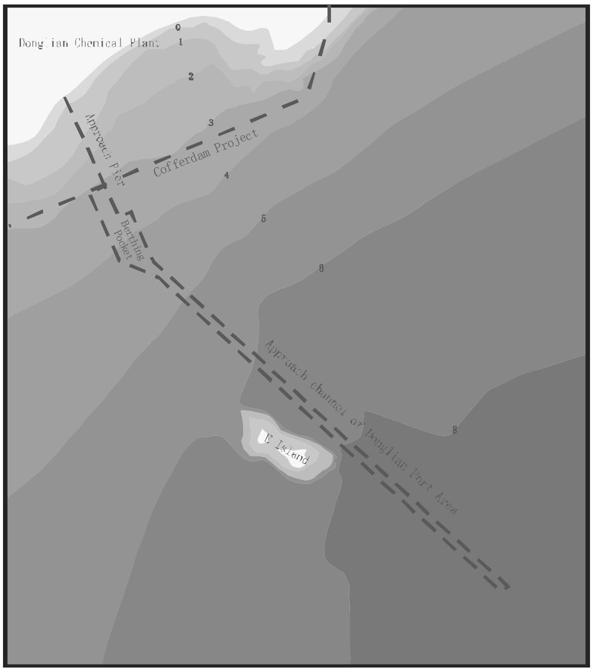

Fig. 4 Plan layout of Nanhai Petrochemicals Donglian port area (layout)

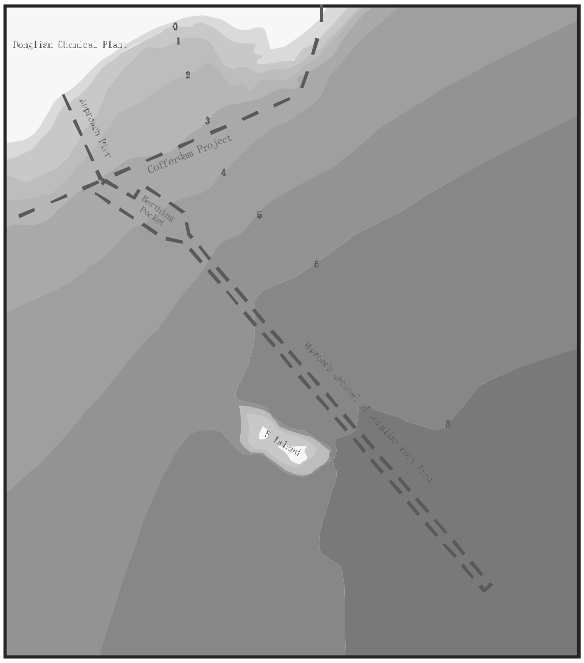

Fig. 5 Plan layour of Nanhai etorchemicals Donglian port area (layout)

3.2 CALCULATION ON SEDIMENT DEPOSITION FOR PORT AREA

3.2.1 The determination of formula

The bed materials are the silt, and the suspended sediment is the main factor to bring the sediment deposition, in addition its berthing pocket and approach channel are designed to be an open form without any protection. So the Formula 1 and Formula 2 bare adopted to calculate the volume of sediment deposition, which have been used in the sedimentation engineering widely

$$p = \frac{\omega s t}{\gamma_c}\left\{0.35\left[1-\left(\frac{h_1}{h_2}\right)^3\right]\sin\theta + 0.13\left[1-\frac{1}{2}\left(\frac{h_1}{h_2}+\frac{h_1^2}{h_2^2}\right)\right]\cos\theta\right\} \quad (1)$$

$$p=\frac{0.45\omega st}{\gamma_c}\left[1-\left(\frac{h_1}{h_2}\right)^{0.56}\cos^2\theta-\left(\frac{h_1}{h_2}\right)^3\sin^2\theta\right] \tag{2}$$

Where

P is the annual average depositing intensity (m);

ω is the setting speed of particles (m/s);

S is the annual average sediment concentration (kg/m^3);

t is the time of one year (s);

γ_c is the unit dry weight of sediment (kg/m^3);

h_1 is the water depth under the medial tidal level before dredging (m);

h_2 is the water depth under the medial tidal level alter dredging (m);

θ is the acute angle between berthing pocket and channel axes and streamline(°).

Table 3 Designed sizes for kinds of layouts in Donglian Port Area

Position	Items	-9m		-11m	
		Layout 1	Layout 2	Layout 1	Layout 2
Berthing pocket	Jetty trend	157° to 337°	123° to 303°	157° to 337°	123° to 303°
	Length of dock for work ship(m)	150	150	150	150
	Length of liquid rock oil dock (m)	420	420	510	510
	Turning area (Φ)	300	300	370	370
	Area of berthing pocket (10,000m^3)	26	26	33	33
Approach channel	Trend	133° to 313°	140° to 320°	133° to 313°	140° to 320°
	Bed width (m)	90	100	110	110
	Length (m)	5170	5250	10800	10800
	Sideslopes	1:10	1:10	1:10	1:10

3.2.2 Determining the related coefficients

(1) The annual average sediment concentration S

As a result of the lack of site sediment concentration, especially lack of some made during windy climates, so the annual average sediment concentration S has to be determined through Formula 3.

$$S=0.0273\gamma_s\frac{(\overrightarrow{V_{bt}}|+|\overrightarrow{W_w}|)^2}{gh} \tag{3}$$

Where

γ_s is the unit grain weight of sediment (kg/m^3);

$\overrightarrow{V_{bt}}$ is the vector sum of wind-generated current and tidal current (m/s);

$\overrightarrow{V_w}$ is the average speed of water particle in waves (m/s);

h is the water depth (m).

Through calculating the annual average sediment concentration can be determined to be0.029kg/m^3 in the berthing pocket, and 0.027kg/m^3 to0.017 kg/m^3 in the section of approach channel between -4.5m and -11m depth (in Table 4).

Table 4 Annual average sediment concentration indifferent positions

Contour line	-4	-5	-6	-7	-8	-9	-10	-11
Sediment concentration (kg/m^3)	0.029	0.026	0.024	0.023	0.022	0.022	0.019	0.017

(2) The unit dry weight of sediment γ_c

γ_c can be determined through the following Formula.

$$\gamma_c = 1750 d_{50}^{0.183}$$

The median particle size of suspended materials can be determined to be the average median particle size of bed materials, $\gamma_c = 750\,\text{kg/m}^3$.

(3) The setting speed of particles ω

According to the particle size of stirred bed materials, the current speed and the test results from the circuit rotating flume, the setting speed of particles is 0.00045m/s.

3.2.3 Calculated results

In Formula 1 and Formula 2, the simulated current fields offered by numerical models under different layouts and above coefficients are adopted to calculate the depositing intensity and volume of sediment deposition synchronistically. The difference of two results from Formula 1 and Formula 2 is less than 10%. The results from Formula 1 are more than them from Formula 2, and are filled in Table 5.These results are acknowledged as the predicted values of annual average depositing intensity and sediment deposition under different layouts.

Table 5 Calculated annual average depositng intensity and sediment deposition

Items	Berthing pocket				Approach channel					
		Water depth	-9m	-11m	-9m			-11m		
	Without reclamation	Bed Width	-	-	90m	100m	110m	90m	100m	110m
Depositing intensity (m)	Without reclamation	Layout 1 / Layout 2	0.15	0.16	0.06	0.06	0.06	0.05	0.05	0.05
	With reclamation	Layout 1 / Layout 2	0.18	0.19	0.06	0.06	0.06	0.05	0.05	0.05
Volume of sediment deposition (m^3)	Without reclamation	Layout 1 / Layout 2	39,000	53,000	28,000	31,000	35,000	49,000	54,000	59,000
	With reclamation	Layout 1 / Layout 2	47,000	63,000	28,000	31,000	35,000	49,000	54,000	59,000

The calculated results show:

(1) In general after the port to be completed, the values of the annual average depositing intensity and the sediment deposition under kinds of layouts should not be large. The depositing intensity is 0.15m to 0.19m and the volume of sediment deposition is 39,000m^3 to 63,000m^3 in the berthing pocket. The depositing intensity is 0.05m to 0.06m and the volume of sediment deposition is 28,000m^3 to 59,000m^3 in the approach channel.

(2) For the berthing pocket, if the reclamation project is not considered, then the annual average depositing intensity is 0.15m and 0.16m respectively, and the volume of sediment deposition is 39,000m^3 and 53,000m^3 respectively under two kinds of designed water depth; if the reclamation project is considered, as a result of the increased angle between the current along the approach pier and the berthing pocket then the depositing intensity is also increased, the annual average depositing intensity is 0.18m and 0.19m respectively, and the volume of sediment deposition is 47,000m^3 and 63,000m^3 respectively under two kinds of designed

water depth. By the way the reclamation project just makes the sediment deposition increased about 10,000m^3 annually.

(3) For the approach channel, the reclamation project affects the volume of sediment deposition in the approach channel hardly. Under the designed water depth of-9m and -11m, the annual average depositing intensity is 0.06m and 0.05m respectively. The volume of sediment deposition is related to the length and bed width of approach channel. Under -9m designed water depth, while the bed width is 90m, 100m and 110m, the volume of sediment deposition is 28,000m^3, 31,000m^3 and 35,000m^3 respectively; under -11m designed water depth, the volume of sediment deposition is 49,000m^3, 54,000m^3 and 59,000m^3 respectively. The distribution of depositing intensity along the approach chann23el is shown in Table 6.

Table 6 Distribution of depositing intensity along the approach channel under different water depth

Water depth (m)	-5.0	-6.0	-7.0	-8.0	-9.0	-10.0	-11.0	Ave
-9m	0.12	0.08	0.06	0.03	0.00	-	-	0.06
-11m	0.13	0.10	0.09	0.07	0.05	0.02	0.00	0.05

(4)The total volume of sediment deposition in the whole port area

If the reclamation project is not considered, under the designed water depth of -9m,while the bed width is 90m, 100m and 110m, the total volume of sediment deposition in the whole port area is 67,000m^3, 70,000m^3 and 74,000m^3 respectively; if reclamation project is considered the total volume of sediment deposition in the whole port area is 75,000m^3, 78,000m^3 and 82,000m^3 respectively.

If the reclamation project is not considered, under the designed water depth of-11m, while the bed width is 90m, 100m and 110m, the total volume of sediment deposition in the whole port area is 102,000m^3, 107,000m^3 and 112,000m^3 respectively; if reclamation project is considered the total volume of sediment deposition in the whole port area is 112,000m^3, 117,000m^3 and 122,000m^3 respectively.

In general if the maintained water depth is -9m, the dredging amount for keeping this depth is just 70,000m^3 to 80,000m^3; if the maintained water depth is -11m, the dredging amount for keeping this depth is just 110,000m^3 to 120,000m^3.

3.3 CALCULATION ON SUDDEN SEDIMENT DEPOSITION IN BERTHING POCKETS AND APPROACH CHANNEL

The signification of sudden sediment deposition is that during a short period the sediment deposition is brought in some weathers with strong wind and big waves. During the period of strong wind and big waves, the wave energy increased obviously makes the fine bed materials stirred and suspended very easily, then proceed to make the sediment concentration increased suddenly by leaps and bounds. Under such situation for the open berthing pocket and approach channel affected by waves directly, a lot of sediment deposition can be brought there in a short time.

For calculating the sudden sediment deposition, the wave with 10 year return period is adopted, which $H_{1/10}$ is 3.2m, wave period is 7.4s. The Formula is the same to above. Then the depositing intensity and sediment deposition in 24 hours could be calculated, and are shown in Table 7.

The calculated results show:

After the port project completed and under the big waves with a return period of 10 years, in the berthing pocket the 24 hour average depositing intensity is 2.8cm to 3.1cm, the 24 hour average sediment deposition is 7,000m^3 to 10,000m^3; in the approach channel the 24 hour average depositing intensity is 0.7cm to 0.9cm, the 24 hour average sediment deposition is

4,000m^3 to 9,000m^3. Generally, the sudden depositing intensity is not big, and can not threaten the normal shipping.

Table 7 Depositing intensity and sediment deposition at one time of windstorm

Items	Berthing pocket			Approach channel					
Depositing intensity (cm/d)	Water depth	-9m	-11m	-9m			-11m		
	Bed width	-	-	90m	100m	110m	90m	100m	110m
	Layout 1	2.8	3.0	0.9	0.9	0.9	0.8	0.8	0.8
	Layout 2	2.9	3.1	0.8	0.8	0.8	0.7	0.7	0.7
Volume of sediment deposition(m^3/d)	Layout 1	7,300	9,900	4,100	4,600	5,100	7,700	8,600	9,500
	Layout 2	7,500	10,200	3,800	4,200	4,600	6,800	7,600	8,400

4. INFLUENCE ON SEDIMENT DEPOSITION IN BERTHING POCKETS BROUGHT BY APPROACH PIER

For the sediment deposition after the project completed, the current along pier must be attached importance. According to lots of experiences from completed projects, the current along pier to be brought must possess some prerequisites. These prerequisites are shown as follows:

First, the b ulgy solid structure from s bore must be big enough. S econdly, the tidal current must be strong, and that the angle between the trend of solid structure and the direction of current must be large enough, accordingly makes the original direction of current changed in some local sea areas. Thirdly, the angle between the trend of solid structure and the direction of strong wind must be large enough, accordingly the obvious additional water level can be brought at its windward side of this structure, and then the water level at its leeside is lower than at windward side at some local sea area. The difference of water levels at two sides makes the water flow from windward side to its leeside; accordingly the current along pier can be brought.

In this project the approach pier can be thought to be a kind of bank head for both elementary layouts and its length is more than 1200m, but this is the only one of above conditions that is the first one. For the second one, the current is very weak, and according to the calculated results made by numerical models, the angle between the pier and current is about 30° , but the current speed is very low, the average speed is just 0.01m/s to 0.04m/s, and the maximum speed is just 0.03m/s to 0.11m/s at some local sea areas around the approach pier from the pier head to the shore. So the current along pier will be very low even though is in existence there. For the third one, on account of the v cry little angle between t he trend o f pier and direction o f tidal current, the difference of water levels at two sides of the approach pier can not be brought. After analyzing all the situations, it is clear that the current along pier can not be obvious, and the situation of sediment transport made by current along pier, and then depositing in the berthing pocket and approach channel can be ignored.

5. CONCLUSIONS

(1) There is no great river around the proposed port area, the tide dynamic force is rather weak and the tideland is steady. So the sediment resource is not rich.

(2) The type of bed materials are mainly the clayey silt and the silty clay with the median size of 0.0156mm to 0.0039mm, and belong to some kinds of fine grain materials in the proposed port sea area. So the suspended sediment is the main factor to bring the sediment deposition in this sea area.

(3) The sediment concentration of water body is low but the extreme weather with big waves. In general, the depositing intensity and sediment deposition are not large.

(4) Without the reclamation project, the approach pier can not bring obvious current along pier, and can hardly influence on the sediment deposition in its berthing pocket.

(5) With the reclamation project, it will just have a limited influence on the depositing intensity in its berthing pocket; but little influence on the approach channel.

(6) The two results of sediment deposition for above two elementary layouts are almost equal.

(7) The calculated results: While the designed depth is -9m, the annual dredging amount in the whole port sea area for keeping the maintained water depth is 70,000m^3 to 80,000m^3; while the depth is -11 m, it is 110,000m^3 to 120,000m^3.

(8) Under the big wave with a return period of 10 years, the 24 hour depositing intensity is about 3cm in the berthing pocket, and 0.8cm in the approach channel. Generally, the sudden depositing intensity is not big, and can not threaten the normal shipping.

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Appendix B: Natural Conditions of Donglian District, Tender Book for Port Area and Jetty of CSPC Nanhai Petrochemicals Project,

Report of Analysis on Hydrology and Sediment Character of Daya Bay (in English), Nanhai Ocean Institute Chinese Academy of Sciences

Two Dimension Tide Current Numerical Model for Donglian Project of CSPC Nanhai Petrochemicals Project, March 2002